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AirMOSS: L2/3 Volumetric Soil Moisture Profiles Derived From Radar, 2012-2015

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Summary

This dataset provides level 2/3 root zone soil moisture (RZSM) estimates at multiple depths at 90-m spatial resolution from the Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) radar instrument collected over ten sites across North America. AirMOSS produces estimates of RZSM with data from a P-band synthetic aperture radar (SAR) flown on a NASA Gulfstream-III aircraft. The resulting soil moisture estimates capture the effects of gradients of soil, topography, and vegetation heterogeneity over an area of approximately 100km x 25km at each of the study sites. AirMOSS flight campaigns took place at least biannually from 2012 to 2015 at each site.

This dataset includes 204 files in netCDF v4 (*.nc4) format. Each file represents the estimated L2/3 soil moisture for one AirMOSS flight campaign for a single site on a single day. The algorithm theoretical basis document (ATBD) for this data product is included as a companion file.

Walnut Gulch, AZ August 8, 2015

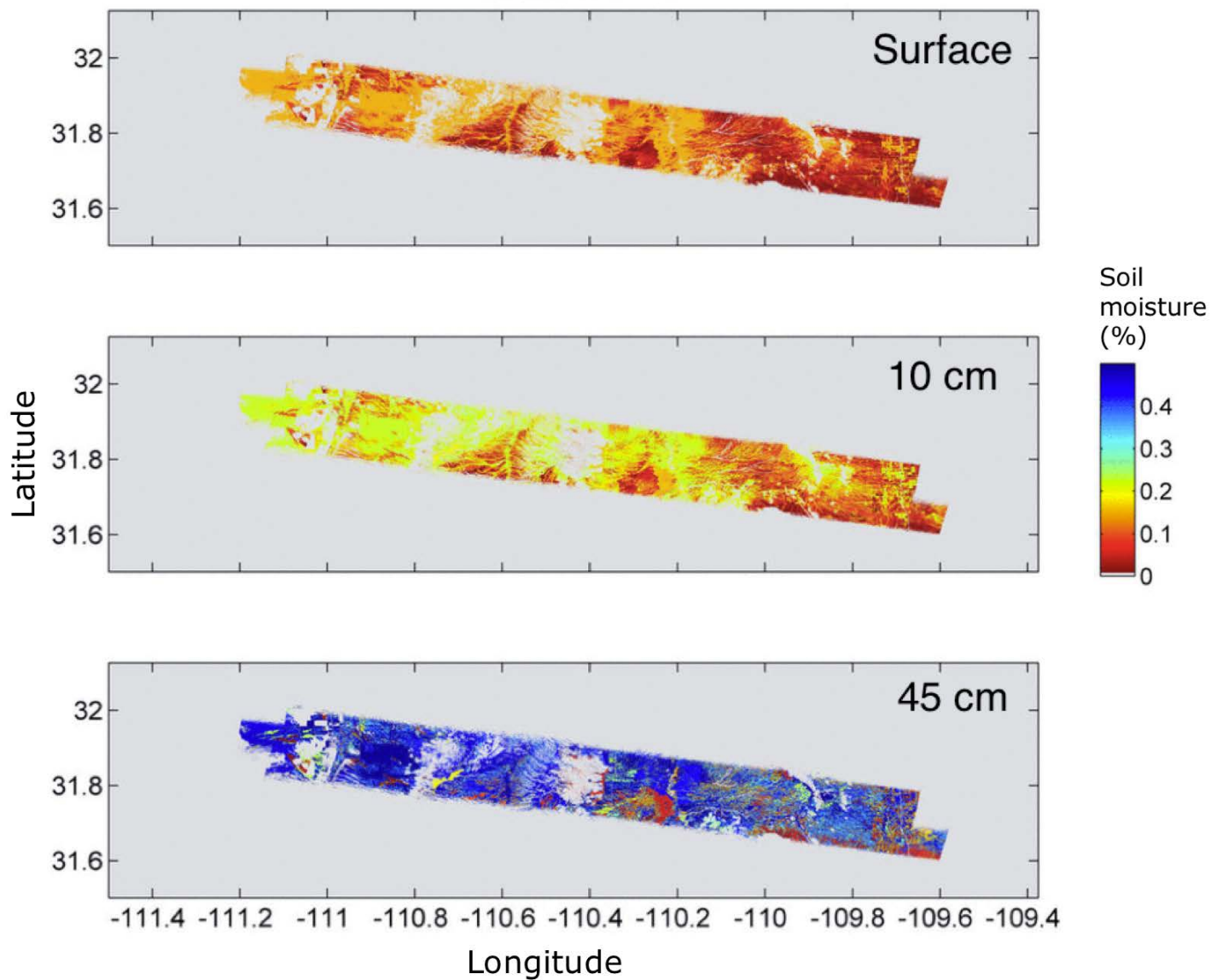


Figure 1: Soil moisture estimates at the Walnut Gulch site, Arizona, reveal a dry soil surface, but considerably more moisture at 45 cm depth.

Citation

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1. Data Set Overview

This dataset provides level 2/3 root zone soil moisture (RZSM) estimates at multiple depths at 90-m spatial resolution from the Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) radar instrument collected over ten sites across North America. AirMOSS produces estimates of RZSM with data from a P-band synthetic aperture radar (SAR) flown on a NASA Gulfstream-III aircraft. The resulting soil moisture estimates capture the effects of gradients of soil, topography, and vegetation heterogeneity over an area of approximately 100km x 25km at each of the study sites. AirMOSS flight campaigns took place at least biannually from 2012 to 2015 at each site.

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

The goal of NASA's Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) investigation is to provide high-resolution observations of root-zone soil moisture over regions representative of the major North American climatic habitats (biomes), quantify the impact of variations in soil moisture on the estimation of regional carbon fluxes, and extrapolate the reduced-uncertainty estimates of regional carbon fluxes to the continental scale of North America.

- The AirMOSS campaign used an airborne ultra-high frequency synthetic aperture radar flown on a Gulfstream-III aircraft to derive estimates of soil moisture down to approximately 1.2 meters.
- Extensive ground, tower, and aircraft in-situ measurements were collected to validate root-zone soil measurements and carbon flux model estimates.

The AirMOSS soil measurements can be used to better understand carbon fluxes and their associated uncertainties on a continental scale. Additionally, AirMOSS data provide a direct means for validating root-zone soil measurement algorithms from the Soil Moisture Active & Passive (SMAP) mission and assessing the impact of fine-scale heterogeneities in its coarse-resolution products.

Related Data:

A full list of AirMOSS data products is available at: <https://airmoss.ornl.gov/dataproducts.html>.

2. Data Characteristics

Spatial Coverage: Ten AirMOSS sites across North America (Table 1).

Spatial Resolution: 3.0 arcseconds (about 90 meters)

Temporal Coverage: 20120918 to 20150929

Temporal Resolution: Each flight campaign represents a single day. Most sites had at least three campaigns per year.

Study Area (coordinates in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
North America	-123.283	-68.3196	54.1254	9.87958

Table 1. AirMOSS sites

Site name	North latitude	South latitude	East longitude	West longitude	Fluxnet Site ID	Description
BermsP	54.125	53.501	-103.626	-107.125	CA-Ojp & CA-Oas	BERMS (Boreal Ecosystem Research and Monitoring Sites), Saskatchewan, Canada. Landcover: Mixed boreal forest. Elevation: 518m.
Chamel	20.326	19.316	-104.22	-105.29	MX-Cha	Chamela Biological Station, Jalisco, Mexico. Landcover: Seasonally dry tropical forest. Elevation: 58m.
DukeFr	36.368	35.437	-78.694	-79.849	US-Dk1, US-Dk2, US-Dk3	Duke Forest site, North Carolina, USA. Landcover: Mature oak-hickory dominated hardwood forest. Elevation: 169m.
Harvrd	43.376	42.293	-71.839	-72.389	US-Ha1 & US-Ha2	Harvard Forest site, Massachusetts, USA. Landcover: Temperate deciduous forest. Elevation: 353m.

Howlnd	45.778	44.669	-68.336	-69.086	US-Ho1, US-Ho2, US-Ho3	Howland Forest site, Maine, USA. Landcover: boreal - northern hardwood transitional forest. Elevation 72m.
LaSelv	10.878	9.92	-83.519	-84.57	CR-Lse	La Selva Biological Station, Costa Rica. Landcover: tropical rain forest. Elevation 93m.
Metoli	45.242	43.38	-120.363	-123.283	US-Me1 to US-Me6	Metolius site, Oregon, USA. Landcover: evergreen needleleaf forest. Elevation 1237m.
Moisst	36.880	35.775	-96.824	-98.996	US-ARM	The Marena, Oklahoma In Situ Sensor Testbed (MOISST) is located in Oklahoma, USA. Landcover: temperate grasslands, crops. Elevation: 312m.
TonziR	38.625	37.501	-120.001	-121.25	US-Ton	Tonzi Ranch site, California, USA. Landcover: oak savanna and grazed grassland. Elevation 170m.
Walnut	32.125	31.501	-109.376	-111.5	US-Wkg & US-Whs	Walnut Gulch site, Arizona, USA. Landcover: warm season C4 grassland with a few shrubs. Elevation 1524m.

Data File Information

This dataset includes 204 files in netCDF v4 (*.nc4) format. Each file represents the estimated L2/3 soil moisture for one AirMOSS flight campaign for a single site on a single day. The algorithm theoretical basis document (ATBD) for this data product is included as a companion file with this dataset as **L23RZSM-ATBD-V3.2.pdf**.

File naming convention

AirMOSS L2/3 RZSM data file names have the format:

L23RZSM_ssssss_FFFFF_YYYYMMDD_vv.nc4

where:

Name element	Description
ssssss	6-character sitename assigned to the site where data was acquired.
FFFFF	5-digit flight ID, where the first 2 digits are the last 2 digits of the year and the next 3 digits a numeric counter chosen to ensure uniqueness of the flight ID.
YYYYMMDD	UTC date at the start of the data take, with <i>YY</i> being the last two digits of the year, <i>MM</i> the month of the year (01-12), and <i>DD</i> the day of the month (01-31)
vv	2-digit product version number starting at 01. The version number is incremented by 1 when a product is reprocessed and redelivered.

Example file names:

L23RZSM_Chamel_14050_20140425_02.nc4

L23RZSM_Metoli_15120_20150824_01.nc4

Table 2. Data fields in the L2/3 RZSM data files.

Data Field	Units	Description
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lat	degrees North	Latitude of grid cell
lon	degrees East	Longitude of grid cell
BROWSE_RZSM_0CM	cm3/cm3	Volumetric soil moisture at 0 cm depth (surface).
BROWSE_RZSM_10CM	cm3/cm3	Volumetric soil moisture at 10 cm depth.
BROWSE_RZSM_30CM	cm3/cm3	Volumetric soil moisture at 30 cm depth (root zone).
COEFF1		Value of coefficient 1 (a). The volumetric soil moisture (mv) profile information is given in terms of second-order polynomial coefficient a, b, and c where $mv(z) = az^2 + bz + c$, where z is the depth in meters.
COEFF2		Value of coefficient 2 (b)
COEFF3		Value of coefficient 3 (c)

3. Application and Derivation

The AirMOSS data products and expected science results are tailored to meet the need to reduce uncertainty in estimates of net ecosystem exchange (NEE) through the development of methodologies to integrate remote sensing observations, in-ground soil sensors, and flux tower data into regional/continental flux models. Additionally, AirMOSS data provide a direct means for evaluating RZSM algorithms of the SMAP Decadal Survey mission and assessing the impact of fine-scale heterogeneities in its coarse-resolution products.

4. Quality Assessment

The baseline approach for assessing the retrieval errors of the L2/3-RZSM products is to compare them against the permanent in-situ soil moisture sensor profiles installed (or otherwise available) at the AirMOSS sites (data available at <http://dx.doi.org/10.3334/ORNLDAAAC/1416>). The error is calculated as a root mean square (RMS) measure, along with the calculation of a bias. The bias is removed for each biome on a yearly basis. The validation results showed accuracy ranging from 0.041 to 0.099 m³/m³ while confirming the intuitive notion that the accuracy decreases as depth increases (Tabatabaeenejad et al. 2015). Error in the retrieval results are associated with radar calibration errors, vegetation parameterization errors, surface roughness assumptions, and inaccuracies in the scattering and inversion models.

Validity Depth

The retrieval error generally increases when deeper points from installed probes are used in validation. This increase in error is expected as penetration depth of electromagnetic waves decreases with depth. We can therefore define a 'threshold depth' for each site as the depth up to which the retrieval is mathematically valid. The threshold depth depends on the number of modeled layers and their thickness in the forward model. The validity depth for each site is different because of its different vegetation, soil texture, and soil layers. However, it can be shown that the choice of 50 cm is reasonably accurate for all sites. All 2012 and 2013 RZSM products from BERMS, Metolius, MOISST, Tonzi Ranch, and Walnut Gulch (except for Tonzi Ranch 2013) are valid up to 95 cm. All 2014 and 2015 RZSM products from BERMS, Metolius, MOISST, Tonzi Ranch, and Walnut Gulch are valid up to 45 cm. Tonzi Ranch 2013 products are valid up to 55 cm.

5. Data Acquisition, Materials, and Methods

The goal of the Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) investigation is to provide high-resolution observations of root-zone soil moisture over regions representative of the major North American climatic habitats (biomes), quantify the impact of variations in soil moisture on the estimation of regional carbon fluxes, and extrapolate the reduced-uncertainty estimates of regional carbon fluxes to the continental scale of North America.

AirMOSS Flights

For AirMOSS, NASA's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) was flown on a Gulfstream-III aircraft, making frequent flights over ten sites (Table 1 and Figure 2) in 9 different biomes of North America over the course of four years (Chapin et al. 2012).

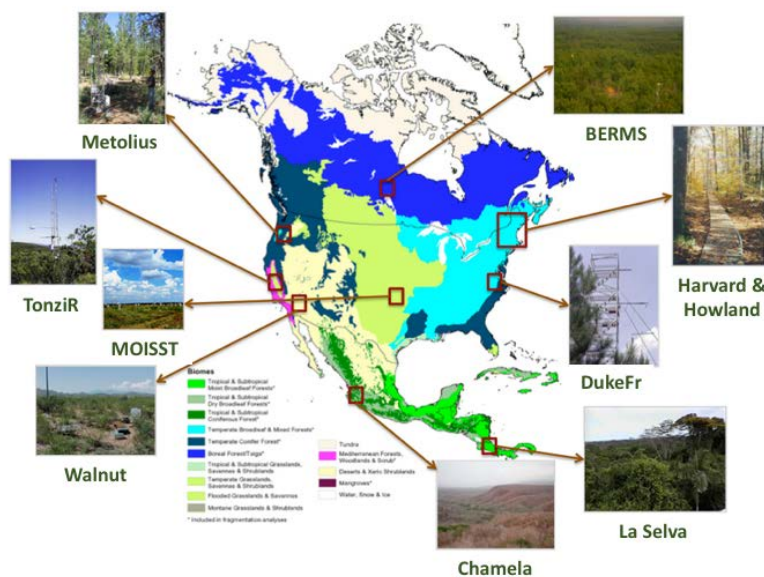


Figure 2. AirMOSS study sites were co-located with flux towers in nine different biomes across North America.

Beginning in September 2012, the AirMOSS instrument flew 215 flight campaigns. A summary of flight campaigns by year and site is found in Table 3. Typically, the aircraft made repeat visits to sites in the same region in a single week and then proceeded to another region. Most sites had at least three campaigns per year. The Harvard and Howland forest sites were flown together in a single day. In 2012, Chamela, La Selva, and Tonzir were not surveyed.

Table 3. Summary of AirMOSS flight campaigns.

	Site									
Year	BermsP	Chamel	DukeFr	Harvrd	Howlnd	LaSelv	Metoli	Oklaho	Tonzir	Walnut
2012	3	0	3	3	3	0	4	3	0	3
2013	6	3	9	9	9	6	7	8	5	6
2014	7	3	10	9	9	3	9	9	6	5
2015	9	2	5	5	5	3	9	6	5	6
Total	25	8	27	26	26	12	29	26	16	20

A complete list of AirMOSS flights can be found at: <https://airmoss.ornl.gov/flights.html>.

AirMOSS Level 2/3 Root Zone Soil Moisture Data Products

The AirMOSS aircraft carried an ultra-high frequency synthetic aperture radar that has the capability to penetrate through substantial vegetation canopies and soil to depths down to approximately 1.2 meters (see <https://airmoss.ornl.gov/documentation.html>).

The L2/3 RZSM product was produced using the 3 arcsec AirMOSS L1-S0 data and is reported on the same ground-projected grid. Due to the wide diversity of vegetation covers present in the AirMOSS study sites, the retrieval algorithms and the specifics of the parameter sets vary for different sites. In

general, sites were categorized into monospecies (including bare surfaces and grasslands) and mixed species. As such, the BERMS, Metolius, MOISST, Tonzi Ranch, and Walnut Gulch sites were classified in the monospecies category, and the remaining sites were treated as having mixed species. Although the soil moisture retrieval algorithms that produced L2/3-RZSM data were different, the end products are similar. Inputs to the retrieval algorithm are described in Table 4 below.

Table 4. Input data of AirMOSS L2/3 RZSM retrieval algorithm for monospecies vegetation.

Input data type	Data source
Radar backscatter (HH/VV)	AirMOSS L1-S0 (3 arcsec) *
Incidence angle	AirMOSS L1-S0 (3 arcsec) *
Terrain slope	AirMOSS L1-S0 (3 arcsec) *
Land cover class	NLCD 2011 (Homer et al. 2015), GlobCover 2009 (European Space Agency 2009)
Vegetation parameters	USDA FIA (2016), Allometrics, and field measurements
Soil texture	SSURGO (2016), HWSD (available from http://dx.doi.org/10.3334/ORNLDAAC/1247)
Soil temperature	in-situ measurements

* Available from <https://airmoss.ornl.gov/>

More detailed information about the retrieval algorithm can be found in the algorithm theoretical basis document for this data product, included with this dataset, **L23RZSM-ATBD-V3.2.pdf**.

6. Data Access

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

[AirMOSS: L2/3 Volumetric Soil Moisture Profiles Derived From Radar, 2012-2015](#)

Contact for Data Center Access Information:

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

7. References

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8. Data Set Revisions

Date	Release and Update History	Notes
2016-09-28	AirMOSS: L2/3 Volumetric Soil Moisture Profiles Derived From Radar, 2012-2015 (Version 1)	Initial data release
2018-03-05	AirMOSS: L2/3 Volumetric Soil Moisture Profiles Derived From Radar, 2012-2015 (Revision 1)	Incorporates updates to 54 data files.



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