Soil Moisture Profiles and Temperature Data from SoilSCAPE Sites, USA

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Documentation Revision Date: 2016-11-21

Data Set Version: V1

Summary

This data set contains in-situ soil moisture profile and soil temperature data collected at 20-minute intervals at SoilSCAPE (Soil moisture Sensing Controller and oPtimal Estimator) project sites in four states (California, Arizona, Oklahoma, and Michigan) in the United States. SoilSCAPE used wireless sensor technology to acquire high temporal resolution soil moisture and temperature data at up to 12 sites over varying durations since August 2011. At its maximum, the network consisted of over 200 wireless sensor installations (nodes), with a range of 6 to 27 nodes per site. The soil moisture sensors (EC-5 and 5-TM from Decagon Devices) were installed at three to four depths, nominally at 5, 20, and 50 cm below the surface. Soil conditions (e.g., hard soil or rocks) may have limited sensor placement. Temperature sensors were installed at 5 cm depth at six of the sites. Data collection started in August 2011 and continues at eight sites through late 2016. The data enables estimation of local-scale soil moisture at high temporal resolution and validation of remote sensing estimates of soil moisture at regional (airborne, e.g. NASA's Airborne Microwave Observation of Subcanopy and Subsurface Mission - AirMOSS) and national (spaceborne, e.g. NASA's Soil Moisture Active Passive - SMAP) scales.

This data set includes 249 files in NetCDF v4 (*.nc) format; 231 node-level 20-min soil moisture data files, 12 site-level files containing the daily average soil moisture, and six soil temperature data files. There are also companion files, consisting of 116 photos of the sensor nodes in the field, and ten maps providing soil and site characteristics for each SoilSCAPE site.

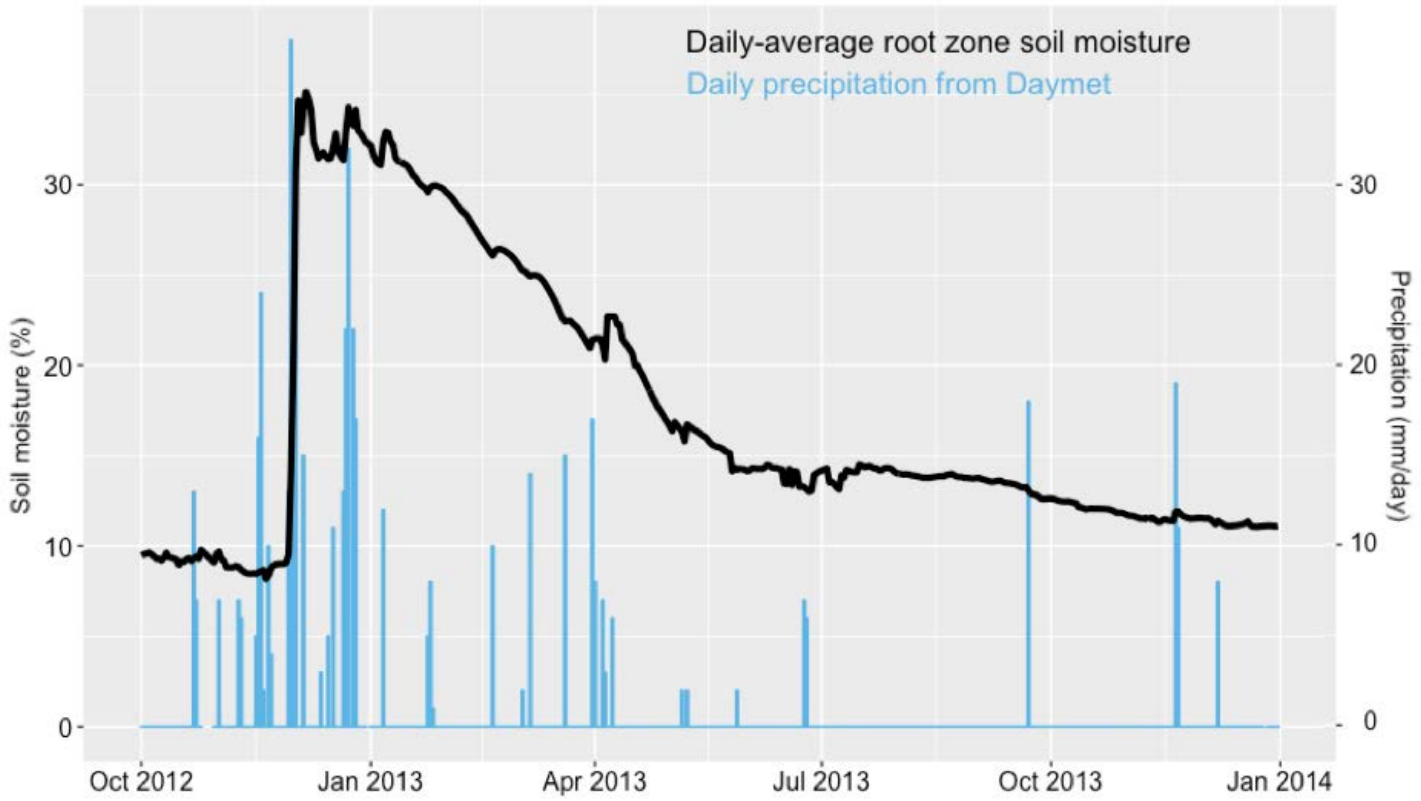

Figure 1. Site-average daily root zone soil moisture for Tonzi Ranch, CA site. Daily precipitation data is shown for comparison (from Daymet, 2016).

Citation

Moghaddam, M., A.R. Silva, D. Clewley, R. Akbar, S.A. Hussaini, J. Whitcomb, R. Devarakonda, R. Shrestha, R.B. Cook, G. Prakash, S.K. Santhana Vannan, and A.G. Boyer. 2016. Soil Moisture Profiles and Temperature Data from SoilSCAPE Sites, USA. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1339

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1. Data Set Overview

This data set contains in-situ soil moisture profile and soil temperature data collected at 20-minute intervals at SoilSCAPE (Soil moisture Sensing Controller and oPtimal Estimator) project sites in four states (California, Arizona, Oklahoma, and Michigan) in the United States. SoilSCAPE used wireless sensor technology to acquire high temporal resolution soil moisture and temperature data at up to 13 sites over varying durations since August 2011. At its maximum, the network consisted of over 200 wireless sensor installations (nodes), with a range of 6 to 27 nodes per site. The soil moisture sensors (EC-5 and 5-TM from Decagon Devices) were installed at three to four depths, nominally at 5, 20, and 50 cm below the surface. Soil conditions (e.g., hard soil or rocks) may have limited sensor placement. Temperature sensors were installed at 5 cm depth at six of the sites. Data collection started in August 2011 and continues at eight sites through late 2016.

The data enables estimation of local-scale soil moisture at high temporal resolution and validation of remote sensing estimates of soil moisture at regional (airborne, e.g. NASA's Airborne Microwave Observation of Subcanopy and Subsurface Mission - AirMOSS) and national (spaceborne, e.g. NASA's Soil Moisture Active Passive - SMAP) scales.

Related Data Sets:

The SoilSCAPE data can be used for validation of soil moisture estimates derived by the AirMOSS project. Access AirMOSS data at ORNL DAAC.

Acknowledgements:

Funding for the SoilSCAPE project came from NASA's Earth Science Technology Office, Advanced Information Systems Technology program.

2. Data Characteristics

Spatial Coverage: Continental USA

Spatial Resolution: Point locations

Temporal Coverage: The data covers the period 2011-08-03 to 2016-11-14. Sampling is continuing at active sites, and data will be updated periodically.

Temporal Resolution: 20 minutes

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

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Continental USA	-120.99	-83.663	42.299	31.735

Table 1. SoilSCAPE Sites. * Inactive sites.

Site	Number of nodes	Temperature Measured	Start Date	End Date	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Kendall, AZ	10	No	2015-08-16	2016-11-14	-109.946	-109.940	31.737	31.735
Lucky Hills, AZ	7	No	2015-08-17	2016-11-14	-110.052	-110.052	31.744	31.742
BLM Land 1 (S Tonzi), CA	17	No	2013-07-05	2016-11-14	-120.906	-120.904	38.393	38.390
BLM Land 2 (S Tonzi), CA	16	No	2013-07-08	2016-11-14	-120.906	-120.904	38.389	38.386
*BLM Land 3 (N Tonzi), CA	6	No	2015-11-02	2016-04-26	-120.994	-120.994	38.471	38.470
New Hogan Lake South, CA	18	Yes	2012-12-13	2016-11-14	-120.789	-120.785	38.150	38.145

New Hogan Lake North, CA	14	Yes	2012-10-18	2016-11-14	-120.806	-120.806	38.173	38.171
*Terra d' Oro, CA	27	Yes	2013-04-06	2015-10-26	-120.799	-120.794	38.507	38.503
Terra d' Oro, CA	24	No	2016-01-13	2016-11-14	-120.797	-120.796	38.507	38.504
Tonzi Ranch, CA	19	Yes	2012-08-17	2016-11-14	-120.968	-120.964	38.433	38.430
*Vaira, CA	24	No	2012-09-08	2012-10-19	-120.955	-120.947	38.417	38.412
*Matthaei Gardens, MI	27	No	2011-08-03	2014-06-14	-83.666	-83.663	42.299	42.297
*Canton, OK	21	Yes	2011-08-26	2016-06-11	-98.632	-98.628	36.002	36.000

Figure 2. SoilSCAPE site locations.

Data File Information

This data set includes 237 files in NetCDF format for 20-min interval data, 231 for soil moisture and 6 for soil temperature. There are 12 site-specific files for the daily averages of soil moisture. The locations of the sites are provided in Table 1.

Table 2. File Naming Convention

File Name	Description
soil_moist_20min_aaa_XX_nNNN.nc	20 min interval soil moisture data (node level files)
soil_temp_20min_aaa_XX_nNNN.nc	20 min interval soil temperature data (node level files)
soil_moist_daily_aaa_XX.nc	Daily average soil moisture data for each node (site level files)
aaa = Name of site (each site contains multiple nodes) XX = State (e.g. OK, AZ, CA, MI) NNN = Node ID (physicalid)	

Table 3. Data fields in the 20 min interval soil moisture files (e.g. *soil_moist_20min_aaa_XX_nNNN.nc*)

Data Field	Units	Description
time	minutes since 2011-01-01	Date and time of the data collection
physicalid		Physical identifier of the node
lat	decimal degrees	Latitude of the node
lon	decimal degrees	Longitude of the node
soil_moisture	%	Volumetric soil moisture. Soil moisture values expressed as percentage volumetric water content. To convert to m^3/m^3 divide by 100.
moisture_flag		Soil moisture flag. For each sensor there is a numeric flag. The flags are intended to mirror the CEOP Data Flags used by the International Soil Moisture Network. 0 - (G) Good (Standard for all data) 1 - (D) Dubious (Automatically flagged, spikes etc.,) 2 - (I) Interpolated / Estimated 3 - (B) Bad (Manually flagged) 4 - (M) Missing 5 - (C) Exceeds field size (Negative SM values, fixed at 0.1 percent). Spikes are detected if |sm[i] - med(sm[i-1:i+1])| > 10 percent. Spikes are set to -9999.0 and flagged using flag 1. Soil moisture values less than 0.1 percent are fixed at 0.1 percent and flagged (5), negative values sometimes occur due to the current calibration. Values over 60 percent are flagged (5) and set to -9999.0.

depth	cm	Depth at which the soil moisture sensors are placed
sensor		Type of the soil moisture sensor. This can be either Decagon's 'EC-5' or '5TM' sensor. 'NA' means sensor information is not available.

Table 4. Data fields in the 20 min interval soil temperature files (e.g. *soil_temp_20min_aaa_XX_nNNN.nc*)

Data Field	Units	Description
time	minutes since 2011-01-01	Date and time of the data collection
physicalid		Physical identifier of the node
lat	decimal degrees	Latitude of the node
lon	decimal degrees	Longitude of the node
soil_temperature	degrees Celsius (C)	Soil temperature. Soil temperature measured with a custom-made probe placed at 5 cm below the soil surface. Accuracy is +/- 0.5 degrees for temperatures in the range 5 - 30 degrees and +/- 1.5 degrees outside this range.
temp_flag		Soil temperature flag. Soil temperature outside the range of -30 to 80 degrees C were flagged (5) and the soil temperature values set to -9999.0f.

Table 5. Data fields in the daily average soil moisture files (e.g. *soil_moist_daily_aaa_XX.nc*)

Data Field	Units	Description
time	days since 2011-01-01	Date of the data collection
physicalid		Physical identifier of the node
lat	decimal degrees	Latitude of the node
lon	decimal degrees	Longitude of the node

soil_moisture	%	Daily average volumetric soil moisture for a node. Soil moisture values expressed as percentage volumetric water content, to convert to m^3/m^3 divide by 100. Soil moisture values with moisture flag values of 0 (Good) and 2 (Interpolated/Estimated) were used to compute the daily average.
depth	cm	Depths at which the soil moisture sensors were placed

Companion Files:

Companion files with this data set include 116 photos of the sensor nodes in the field (compressed within the “NodePhotos” directory), and ten *.pdf maps providing soil and site characteristics for each SoilSCAPE site.

3. Application and Derivation

This data set can be used for:

(1) Generation of local scale estimates of soil moisture at high temporal resolution. The point measurements from the sensor are scaled up to regional level hydrological models to produce local estimates of soil moisture.

(2) Validation of remote sensing based estimates of soil moisture. Currently, the dataset is being used as part of validation dataset for two NASA missions – Airborne Microwave Observation of Subcanopy and Subsurface Mission (AirMOSS) and spaceborne Soil Moisture Active Passive (SMAP).

4. Quality Assessment

Uncertainty in the data was not quantified. The data was calibrated using site specific calibration equations and Decagon mineral soil calibration. The standard calibration equation from Decagon used for converting the raw data (voltage * 1024/1200) to volumetric soil moisture (VSM %) is:

VSM = -40.1 + 0.1279569 * raw

For some sites in California, additional soil samples were collected to update the calibration (Table 6). These calibrations had RMSE of 1.5 % compared to the field-collected samples.

Measurement spikes were removed by comparing to the immediately previous and following measurements for the node. The minimum soil moisture is fixed at 0.1 percent. The sensors with very noisy measurements (based on manual checking) were set to -9999.0. The flag values are included in the data file for each sensor.

For temperature (T) calibrations, the raw value is converted to degrees C as:

T = ((1.075268 * raw) - 500) / 10) + 1.8

Table 6. Site-specific equations applied to calibrate raw data to volumetric soil moisture (VSM)

Site	**Calibration**
Kendall, AZ	VSM = -40.1 + 0.1279569 * raw
Lucky Hills, AZ	VSM = -40.1 + 0.1279569 * raw
BLM Land 1 (S Tonzi), CA	VSM = -34.79 + 0.1111 * raw
BLM Land 2 (S Tonzi), CA	VSM = -34.79 + 0.1111 * raw
BLM Land 3 (N Tonzi), CA	VSM = -40.1 + 0.1279569 * raw
New Hogan Lake North, CA	VSM = 9.92249 - 0.133828 * raw + 0.000358248 * raw^2

New Hogan Lake South, CA	VSM = 9.92249 - 0.133828 * raw + 0.000358248 * raw^2
*Terra d' Oro, CA (2013-2015)	VSM = 9.92249 - 0.133828 * raw + 0.000358248 * raw^2
Terra d' Oro, CA (2016-)	VSM = -40.1 + 0.1279569 * raw
Tonzi Ranch, CA	VSM = -33.8015 + 0.1131 * raw
Vaira, CA	VSM = -40.1 + 0.1279569 * raw
*Matthaei Gardens, MI	VSM = -40.1 + 0.1279569 * raw
*Canton, OK	VSM = -40.1 + 0.1279569 * raw

Inactive sites are marked with an asterisk (*)

5. Data Acquisition, Materials, and Methods

The soil moisture sensors (EC-5 and 5-TM from Decagon Devices) were installed at different depths (usually 3-4 depths up to 90 cm) below the soil surface. For newer installations, the sensors were placed at 5cm, 20cm and 50cm depths below the surface. However, when it was not possible to drill down deep enough due to hard soil and rocks, the sensors were installed as deep as possible (up to 30cm or 40cm depth). The sensor was held in place by fastening it to a t-post (Figure 3). A barbed wire fence was also installed around the sensor at some locations to prevent damage from cattle grazing.

Figure 3. View of sensor node 401 at Tonzi Ranch, CA.

The sensors communicated with a local coordinator which wirelessly sent the data to the data server located at the University of Southern California (Figure 4). The optimal placement of the sensors in time and space is achieved using the steady-state soil moisture statistics and surface state distribution of soil moisture in the area of interest weighed against the cost of communication associated with the sensor placement. The system uses the wireless sensor architecture called Ripple (Silva et al., 2012), which has undergone a number of improvement over the years. The current iteration is Ripple 2D+.

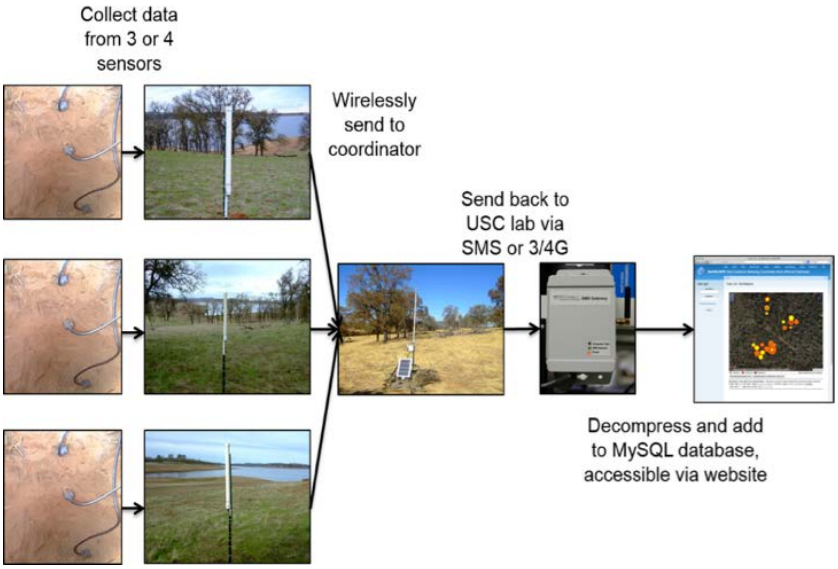

Figure 4. The wireless architecture of the SoilSCAPE network.

6. Data Access

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

Soil Moisture Profiles and Temperature Data from SoilSCAPE Sites, USA

Contact for Data Center Access Information:

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7. References

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8. Data Set Revisions

Version	Description	Published
	The SoilSCAPE data were originally published in September 2016. This initial data release contained data from all sites from 2011-08-03 to 2016-07-14.	2016-09-06
R1	The SoilSCAPE data were updated to include measurements through 2016-11-14.	2016-11-22