SMEX04 Regional Soil Moisture Data: Arizona

Summary

This data set combines data for several parameters measured for the Soil Moisture Experiment 2004 (SMEX04). The parameters include gravimetric and volumetric soil moisture, bulk density, and soil temperature. Summary files containing field averages are provided for simplicity. SMEX04 was conducted during August 2004.

Data are provided in ASCII text files, and are available via FTP. The Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E) is a mission instrument launched aboard NASA's Aqua Satellite on 4 May 2002. AMSR-E validation studies linked to SMEX are designed to evaluate the accuracy of AMSR-E soil moisture data. Specific validation objectives include assessing and refining soil moisture algorithm performance, verifying soil moisture estimation accuracy, investigating the effects of vegetation, surface temperature, topography, and soil texture on soil moisture accuracy, and determining the regions that are useful for AMSR-E soil moisture measurements.

Citing These Data:

Jackson, T. J., M. H. Cosh, J. Famiglietti, and R. Bindlish. 2009. *SMEX04 Regional Soil Moisture Data: Arizona*. Boulder, Colorado USA: NASA DAAC at the National Snow and Ice Data Center.

Overview Table

Category	Description
Data format	ASCII tab-delimited text
Spatial coverage	32.1° N to 31.4° N, 109.7° W to 110.3° W
Temporal coverage	2 August 2004 to 26 August 2004

File naming convention	'AZ' designates the Arizona Regional site. 'RG' designates a Walnut Gulch Rain Gage Site. 'GVSM' is a soil moisture file. 'Raw' designates the full data set. 'Sum' designates a summary file.
File size	100 KB to 333 KB
Parameter(s)	Gravimetric soil moisture, bulk density, volumetric soil moisture, soil and surface temperature
Procedures for obtaining data	Data are available via FTP.

Table of Contents

1. Contacts and Acknowledgments:

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Acknowledgements:

Many graduate students and volunteers worked to collect the field data. We would like to thank the Soil Moisture Experiment 2004 Science Team, the Southwest Watershed Research Center for their assistance. We would also like to thank the National Aeronautics and Space Administration for their generous contributions to the study. This work was supported by the NASA Aqua AMSR, Terrestrial Hydrology and Global Water Cycle Programs.

2. Detailed Data Description:

Format:

ASCII tab-delimited text files.

File Naming Convention:

File names containing the letters AZ designate the SMEX04 Arizona Regional site. File names containing the letters RG designate the SMEX04 Walnut Gulch Watershed Rain Gage Site. Raw data files in each directory contain the word RAW; summary data files contain the word SUM.

File Size:

File sizes range from 105 KB to 164 KB.

Spatial Coverage:

Southernmost Latitude: 31.4° N
Northernmost Latitude: 32.1° N
Westernmost Longitude: 110.3° W
Easternmost Longitude: 109.7° W

Temporal Coverage:

3 August 2004 to 26 August 2004

Temporal Resolution:

Gravimetric, and soil and surface temperature data were collected daily.

Parameter or Variable:

Parameter Description:

Parameters in this data set include gravimetric soil moisture, bulk density, soil and surface temperature. The following table describes the units of measurement and sources of each parameter.

Parameter	Unit of Measurement	Sensor
Gravimetric soil moisture	grams of water per grams of dry soil*100%	manual soil collection
Volumetric soil moisture	grams of water per grams of dry soil*100%	manual soil collection
Bulk density	grams per cubic centimeter (g/cm^3)	manual soil collection
Surface and soil temperature	Degrees Celsius	OS643-LS Infrared Pyrometers And Temperature Probes
Soil Moisture	Water Fraction Volume (m^3/m^3)*100%	Theta Probes

Parameter Range:

The following tables detail the column headings for each data file in the categories of gravimetric sampling, bulk density, soil temperature, and theta probe data.

Gravimetric Sampling

"AZ_GVSM_Raw.txt" - Gravimetric Sampling Raw Data Columns

Column Heading	Description
Date month/	day/year
DOY	Day of Year
Site_ID Location	of Sampling
Lat	WGS84 Latitude in decimal degrees

Lon	WGS84 Longitude in decimal degrees
North_(m)	WGS84 Universal Transverse Mercator (UTM) Northing in meters, Zone 12
East_(m)	WGS84 Universal Transverse Mercator (UTM) Easting in meters, Zone 12
Time	Start Time of sampling in Mountain Standard Time
Temp_1cm	Temperature at 1 cm in C
Temp_5cm	Temperature at 5 cm in C
Temp_10cm	Temperature at 10 cm in C
TP_mV, A	Theta Probe millivolt reading in V, position A
TP_mV, B	Theta Probe millivolt reading in V, position B
TP_mV, C	Theta Probe millivolt reading in V, position C
TP_mV, D	Theta Probe millivolt reading in V, position D
TP_mV, E	Theta Probe millivolt reading in V, position E
TP_VSM_gc, A	Theta Probe VSM from general calibration in m^3/m^3, position A
TP_VSM_gc, B	Theta Probe VSM from general calibration in m^3/m^3, position B
TP_VSM_gc, C	Theta Probe VSM from general calibration in m^3/m^3, position C
TP_VSM_gc, D	Theta Probe VSM from general calibration in m^3/m^3, position D
TP_VSM_gc, E	Theta Probe VSM from general calibration in m^3/m^3, position E
TP_VSM_ssc, A	Theta Probe VSM from site specific calibration in m^3/m^3, position A
TP_VSM_ssc, B	Theta Probe VSM from site specific calibration in m^3/m^3, position B
TP_VSM_ssc, C	Theta Probe VSM from site specific calibration in m^3/m^3, position C
TP_VSM_ssc, D	Theta Probe VSM from site specific calibration in m^3/m^3, position D
TP_VSM_ssc, E	Theta Probe VSM from site specific calibration in m^3/m^3, position E
CanID_0-3 Can	identification number for 0-3 cm measure
Can_Wgt_0-3	Weight of Can for 0-3 cm measure

Wet_Wgt_0-3	Wet weight (g) for 0-3 cm measure
Dry_Wgt_0-3	Dry weight (g) for 0-3 cm measure
CanID_3-6 Can	identification number for 3-6 cm measure
Can_Wgt_3-6	Weight of Can for 3-6 cm measure
Wet_Wgt_3-6	Wet weight (g) for 3-6 cm measure
Dry_Wgt_3-6	Dry weight (g) for 3-6 cm measure
Samp_BD_0-6	Sample Bulk Density in kg/m/m/m in 0-6 cm
Soil_BD_0-6	Bulk Density of Soil in kg/m/m/m in 0-6 cm
Rock_Fraction_0-6	Volumetric Fraction of Rock (> 0.2 cm) in 0-6 cm
GSM_0-3	Gravimetric Soil Moisture in g/g for 0-3 cm
VSM_0-3	Volumetric Soil Moisture in m^3/m^3 for 0-3 cm
GSM_3-6	Gravimetric Soil Moisture in g/g for 3-6 cm
VSM_3-6	Volumetric Soil Moisture in m^3/m^3 for 3-6 cm
VSM_0-6	Volumetric Soil Moisture in m^3/m^3 for 0-6 cm
RFC	Rock Fraction Correction Coefficient
TP_gc_A_RFC	Theta Probe VSM from general calibration in m^3/m^3, position A with Rock Fraction Correction
TP_gc_B_RFC	Theta Probe VSM from general calibration in m^3/m^3, position B with Rock Fraction Correction
TP_gc_C_RFC	Theta Probe VSM from general calibration in m^3/m^3, position C with Rock Fraction Correction
TP_gc_D_RFC	Theta Probe VSM from general calibration in m^3/m^3, position D with Rock Fraction Correction
TP_gc_E_RFC	Theta Probe VSM from general calibration in m^3/m^3, position E with Rock Fraction Correction
TP_ssc_A_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position A with Rock Fraction Correction
TP_ssc_B_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position B with Rock Fraction Correction
TP_ssc_C_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position C with Rock Fraction Correction
TP_ssc_D_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position D with Rock Fraction Correction
TP_ssc_E_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position E with Rock Fraction Correction

VSM_0-6_RFC	Volumetric Soil Moisture in m^3/m^3 for 0-6 cm with Rock Fraction Correction

"AZ_GVSM_Sum.txt" - Gravimetric Soil Moisture Raw Data Columns

Date Month/	day/year
DOY	Day of Year
Site_ID	Site location identification number
Lat	Decimal Degree, WGS84
Lon Decimal	Degree, WGS84
North_(m)	WGS84, Zone 12, in meters
East_(m)	WGS84, Zone 12, in meters
Time	Starting time of sampling in MST (Most sampling is 5-10 minutes in duration if Stop Time is unavailable)
Temp_1cm	Temperature at 1 cm in C
Temp_5cm	Temperature at 5 cm in C
Temp_10cm	Temperature at 10 cm in C
VSM	Gravimetricallly based Volumetric Soil Moisture average for 0-6 cm.
Count	Number of Theta Probe readings taken
TP_mV_avg	Theta Probe millivolt reading average in V
TP_mV_stdev	Theta Probe millivolt reading standard deviation in V
TP_VSM_gc_avg	Theta Probe VSM average from general calibration in m^3/m^3
TP_VSM_gc_stdev	Theta Probe VSM standard deviation from general calibration in m^3/m^3
TP_VSM_ssc_avg	Theta Probe VSM average from site specific calibration in m^3/m^3
TP_VSM_ssc_stdev	Theta Probe VSM standard deviation from site specific calibration in m^3/m^3
VSM_RFC	Gravimetricallly based Volumetric Soil Moisture average for 0-6 cm with Rock Fraction Correction
TP_VSM_gc_avg_RFC	Theta Probe VSM average from general calibration in m^3/m^3 with Rock Fraction

	Correction
TP_VSM_gc_stdev_RFC	Theta Probe VSM standard deviation from general calibration in m^3/m^3 with Rock Fraction Correction
TP_VSM_ssc_avg_RFC	Theta Probe VSM average from site specific calibration in m^3/m^3 with Rock Fraction Correction
TP_VSM_ssc_stdev_RFC	Theta Probe VSM standard deviation from site specific calibration in m^3/m^3 with Rock Fraction Correction

Missing data are represented by –999

"WG_GVSM_Raw.txt" - Gravimetric Sampling Raw Data Columns

Column Heading	Description
Date month/	day/year
DOY	Day of Year
Site_ID Location	of Sampling
Lat	WGS84 Latitude in decimal degrees
Lon	WGS84 Longitude in decimal degrees
North_(m)	WGS84 Universal Transverse Mercator (UTM) Northing in meters, Zone 12
East_(m)	WGS84 Universal Transverse Mercator (UTM) Easting in meters, Zone 12
Time	Start Time of sampling in Mountain Standard Time
Temp_1cm	Temperature at 1 cm in C
Temp_5cm	Temperature at 5 cm in C
Temp_10cm	Temperature at 10 cm in C
TP_mV, A	Theta Probe millivolt reading in V, position A
TP_mV, B	Theta Probe millivolt reading in V, position B
TP_mV, C	Theta Probe millivolt reading in V, position C
TP_mV, D	Theta Probe millivolt reading in V, position D
TP_mV, E	Theta Probe millivolt reading in V, position E
TP_VSM_gc, A	Theta Probe VSM from general calibration in m^3/m^3, position A
TP_VSM_gc, B	Theta Probe VSM from general calibration in m^3/m^3,

	position B
TP_VSM_gc, C	Theta Probe VSM from general calibration in m^3/m^3, position C
TP_VSM_gc, D	Theta Probe VSM from general calibration in m^3/m^3, position D
TP_VSM_gc, E	Theta Probe VSM from general calibration in m^3/m^3, position E
TP_VSM_ssc, A	Theta Probe VSM from site specific calibration in m^3/m^3, position A
TP_VSM_ssc, B	Theta Probe VSM from site specific calibration in m^3/m^3, position B
TP_VSM_ssc, C	Theta Probe VSM from site specific calibration in m^3/m^3, position C
TP_VSM_ssc, D	Theta Probe VSM from site specific calibration in m^3/m^3, position D
TP_VSM_ssc, E	Theta Probe VSM from site specific calibration in m^3/m^3, position E
CanID_0-3 Can	identification number for 0-3 cm measure
Can_Wgt_0-3	Weight of Can for 0-3 cm measure
Wet_Wgt_0-3	Wet weight (g) for 0-3 cm measure
Dry_Wgt_0-3	Dry weight (g) for 0-3 cm measure
Dry_Wgt_3-6	Dry weight (g) for 3-6 cm measure
Samp_BD_0-6	Sample Bulk Density in kg/m/m/m in 0-6 cm
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Rock_Fraction_0-6	Volumetric Fraction of Rock (> 0.2 cm) in 0-6 cm
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TP_gc_B_RFC	Theta Probe VSM from general calibration in m^3/m^3, position B with Rock Fraction Correction
TP_gc_C_RFC	Theta Probe VSM from general calibration in m^3/m^3, position C with Rock Fraction Correction
TP_gc_D_RFC	Theta Probe VSM from general calibration in m^3/m^3, position D with Rock Fraction Correction

TP_gc_E_RFC	Theta Probe VSM from general calibration in m^3/m^3, position E with Rock Fraction Correction
TP_ssc_A_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position A with Rock Fraction Correction
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TP_ssc_C_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position C with Rock Fraction Correction
TP_ssc_D_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position D with Rock Fraction Correction
TP_ssc_E_RFC	Theta Probe VSM from site specific calibration in m^3/m^3, position E with Rock Fraction Correction
VSM_0-6_RFC	Volumetric Soil Moisture in m^3/m^3 for 0-6 cm with Rock Fraction Correction

"WG_GVSM_Sum.txt" - Gravimetric Soil Moisture Raw Data Columns

Date Month/	day/year
DOY	Day of Year
Site_ID	Site location identification number
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Temp_10cm	Temperature at 10 cm in C
VSM	Gravimetricallly based Volumetric Soil Moisture average for 0-6 cm.
Count	Number of Theta Probe readings taken
TP_mV_avg	Theta Probe millivolt reading average in V
TP_mV_stdev	Theta Probe millivolt reading standard deviation in V
TP_VSM_gc_avg Theta	Probe VSM average from general

	calibration in m^3/m^3
TP_VSM_gc_stdev	Theta Probe VSM standard deviation from general calibration in m^3/m^3
TP_VSM_ssc_avg	Theta Probe VSM average from site specific calibration in m^3/m^3
TP_VSM_ssc_stdev	Theta Probe VSM standard deviation from site specific calibration in m^3/m^3
VSM_RFC	Gravimetricallly based Volumetric Soil Moisture average for 0-6 cm with Rock Fraction Correction
TP_VSM_gc_avg_RFC	Theta Probe VSM average from general calibration in m^3/m^3 with Rock Fraction Correction
TP_VSM_gc_stdev_RFC	Theta Probe VSM standard deviation from general calibration in m^3/m^3 with Rock Fraction Correction
TP_VSM_ssc_avg_RFC	Theta Probe VSM average from site specific calibration in m^3/m^3 with Rock Fraction Correction
TP_VSM_ssc_stdev_RFC	Theta Probe VSM standard deviation from site specific calibration in m^3/m^3 with Rock Fraction Correction

Missing data are represented by -999

Error Sources:

Theta Probe

For various reasons, including extremely dry conditions, severe weather restrictions, and extreme rock fraction some sites were not sampled on particular days. Occasionally, a probe rod was broken because of very hard and dry soil conditions. When possible, the broken rod was replaced. When it was not possible to replace the rod, a new theta probe was used.

Bulk Density

A soil excavation method was used to estimate the bulk density of the sampling location for the top 6 cm. This was not done coincidently, therefore there is some error.

3. Data Access and Tools:

Data Access:

Data are available via FTP.

Software and Tools:

No special tools are required to view these data. A spreadsheet program, which recognizes tab-delimited text files, such as MS Excel is recommended. Also, a word-processing program or Web browser will also display the data.

4. Data Acquisition and Processing:

Theory of Measurements:

Sampling Technique

A scoop tool was used to retrieve approximately the top 6 cm of soil at the third Theta Probe sampling point for each site.

Computing Volumetric Soil Moisture and Bulk Density

Samplers used the following steps to compute volumetric soil moisture and bulk density:

Compute the gravimetric soil moisture (GSM) and dry mass. Compute volumetric soil moisture (VSM):
VSM=GSM*BD

Sensor or Instrument Description:

Gravimetric

Gravimetric samples were collected manually. In the laboratory they were weighed, dried, then weighed again.

Soil Moisture

Soil moisture samples were collected manually and taken to the laboratory, weighed, dried, and weighed again.

Theta Probes

Investigators used theta probes to measure surface volumetric soil moisture. The probes were Type ML2 manually-operated impedance instruments manufactured by Delta-T Devices, Ltd. The theta probes have 4 separate 6-cm stainless steel rods inserted vertically into the soil. Each instrument was connected to a handheld reader, which delivers the electrical pulse, detects the return signal, and converts the period to voltage between 0 V and about 1 V. Watershed surface soil moisture was sampled each afternoon (11:30AM-3:00PM) during the experiment.

The software provided by the probe manufacturer calibrates the theta probes by calculating an estimate of volumetric soil moisture according to the following equation:

$$Theta=(1.07+6.4*V-6.4*V2+4.7*V3-a_0)/a_1$$

where a_0 and a_1 are 1.6 and 8.4, respectively. These estimates are provided in the data files.

Researchers also performed site-specific calibration for each field of sampling. Theta probe voltage readings from a row sampling point were compared to the volumetric soil moisture measured at the same point. A regression relationship was developed and new volumetric soil moisture values were estimated.

Processing Steps:

Gravimetric Processing

Researchers weighed the wet soil obtained in the field, heated the soil in an oven to dry it, then weighed the dry soil.

Calibration and Rock Fraction Correction

As part of the Soil Moisture Experiment in 2004 (SMEX04), gravimetric and dielectric probe samples were taken daily throughout the WGEW to coincide with aircraft overflights. A gravimetric sample was taken at 64 sites within the watershed and 40 sites over the region. These were all co-located with in situ soil moisture sensors and rain gages. Five dielectric probe samples were also taken at each of the 64 sites. In a manner similar to Cosh et al. (2005), the dielectric probes were calibrated using the co-located gravimetric samples to create a site-specific calibration equation for volumetric soil moisture.

The first step in the process is the calculation of the Gravimetric Soil Moisture, GSM, as follows

$$\frac{WetWgt - DryWgt}{DryWgt - CanWgt} = GSM \qquad (1)$$

where WetWgt is the sample weight before drying, DryWgt is the sample weight after 24 hours of drying at 100 F, and CanWgt is the weight on an empty can and lid. From this Gravimetric Soil Moisture, in g/g, the (Gravimetrically-based) Volumetric Soil Moisture of the Sample ($GVSM_{SAMP}$) is calculated with

$$GSM * BD_{SAMP} = GVSM_{SAMP} \qquad (2)$$

where BD_{SAMP} is the bulk density of the sample volume. Field samples of bulk density and rock fraction, $RF_{SAMP,}$ were taken independently near the raingages and soil moisture sampling sites while making sure not to disturb the installations. One of the 5 dielectric samples was taken at the exact same location as the gravimetric sample. This is the dielectric measure used in the calibration. Using the following equation

$$\theta = \frac{\left[1.07 + 6.4V - 6.4V^2 + 4.7V^3\right] - a_0}{a_1} \qquad (3)$$

where V is the voltage reading from the probe, and a_0 and a_1 are calibration constants, the root mean square error between the $GVSM_{SAMP}$ and θ is minimized by changing a_0 and a_1. The overall root mean square error (RMSE) associated with the calibration for the dielectric probe sampling as compared to the gravimetric sampling was 0.024 m^3/m^3.

There is a degree of bias in the location of ground sampling, because there is a large amount of rock at the surface. People obtained samples at locations with fewer surface rocks. This sample represents the soil (plus small rocks) rock fraction. However, for remote sensing and grid based modeling, the volumetric moisture of the surface layer is required. A procedure was developed for converting the point observations, which is referred to as the Rock Fraction Correction.

The bulk density (and rock fraction) samples were approximately 300 cm^3 in volume, which is comparable to the ground sampling protocols for soil moisture (100 cm^3). This sample is a combination of rock and soil, however, it will be somewhat biased to a sample with more soil than if we were able to obtain a very large sample (>10,000 cm^3). There is a need to 'correct' this ground sample to a large-scale estimate, which would incorporate a more accurate rock fraction. The first step in this correction is to calculate the volumetric soil moisture

of the soil only, $GVSM_{SOIL}$. This is accomplished by using the rock fraction of the sample at the surface, RF_{SAMP}, with

$$GVSM_{SOIL} * (1 - RF_{SAMP}) = GVSM_{SAMP}. \quad (4)$$

In order to provide a more area representative estimate of rock fraction, we used the data provided in the NRCS. SSURGO (http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/) data base. These values are also available at coarser scales from using the VSM_{SOIL} and the rock fraction estimate from the SSURGO database, the rock fraction corrected volumetric soil moisture, VSM_{RFC}, is calculated by

$$GVSM_{SOIL} * (1 - RF_{SSURGO}) = GVSM_{RFC}. \quad (5)$$

More simply, this equation can be rewritten as

$$GVSM_{SAMP} * \left(\frac{1 - RF_{SSURGO}}{1 - RF_{SAMP}} \right) = GVSM_{RFC} \quad (6)$$

which clearly shows how the rock fraction correction is a scaling value, referred to as the Rock Fraction Correction. This correction should also be applied to the dielectric probe samples, because the dielectric probes are inserted in the ground with the same bias of sampling location (more soil than rock). The $GVSM_{SAMP}$ can be replaced with $\bar{\theta}$, which is the average volumetric soil moisture from the site specific calibrated dielectric probes. This is based on five sampling points compared to the single gravimetric sample.

$$\bar{\theta} * \left(\frac{1 - RF_{SSURGO}}{1 - RF_{SAMP}} \right) = \bar{\theta}_{RFC} \quad (7)$$

It is also necessary to apply a correction to the WGEW soil moisture sensor network (SMSN). Since the SMSN sensors were installed in the same soil (locally) that was sampled during SMEX04, it is logically to apply the same RFC to the sensor data per site, resulting in an $SMSN_{RFC}$ for each sensor.

5. References and Related Publications:

Please see the SMEX04 site for more information, and the NSIDC SMEX site to access data.

6. Document Information:

Glossary and Acronyms:

Please see the EOSDIS Glossary of Terms for a general list of terms.

List of Acronyms

The following acronyms are used in this document:
AMSR-E - Advanced Microwave Scanning Radiometer - Earth Observing System (AMSR-E)
AZ – Arizona Study Region
BD – Bulk Density
FTP – File transfer protocol.
gc – generalized calibration
GSM – Gravimetric Soil Moisture
GVSM – Gravimetrically-based Volumetric Based Soil Moisture
IRT – Infrared Thermometer
RG – Walnut Gulch Experimental Watershed Rain Gage
SMEX - Soil Moisture Experiment
ssc – site specific calibration
TP – Theta Probe
UTM - Universal Transverse Mercator
VSM – Volumetric Soil Moisture
WG – Walnut Gulch Experimental Watershed

Document Creation Date:

20 February 2005