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Goddard Earth Sciences Data and Information Services Center (GES DISC)

README Document for LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree

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Revision History

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02/14/16	Some rewriting and editing from the original provided by Ming Pan	Bill Teng

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1.0 Introduction

This document provides basic information for using the LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set. This data set was generated with a focus on providing global-scale surface soil moisture estimates.

1.1 Data Set Description

The LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set was created as part of the "Developing Consistent Earth System Data Records for the Global Terrestrial Water Cycle" MEaSURES Project. Soil moisture is a key land surface state variable for regulating the energy and moisture fluxes between the atmosphere and the land surface. Better knowledge of soil moisture greatly contributes to our understanding of land surface processes (Entekhabi et al., 2010). Moreover, because the land surface serves as a boundary condition for weather and seasonal forecasting models, refining the soil moisture estimate that is used in the models' initialization should generally improve the accuracy of both short-term and seasonal forecasts.

The Land Surface Microwave Emission Model (LSMEM) is a physically-based, radiative transfer model that considers the emissions from the following sources: Ground surface, vegetation cover, atmosphere, and cosmic background (Fig. 1). Upward emissions from the ground surface, vegetation cover, and atmosphere travel through the media above them and reach the TOA (top-of-atmosphere). Downward emissions from the cosmos, atmosphere, and vegetation are first reflected by the ground surface and then reach the TOA. LSMEM calculates the brightness temperature of these emitting bodies and resolves the attenuations from these emissions passing through all the media. Because the ground surface is heterogeneous, LSMEM divides a computing pixel into three fractions: Vegetated surface, bare soil surface, and open water surface; it then performs a separate radiative transfer calculation for each individual surface type.

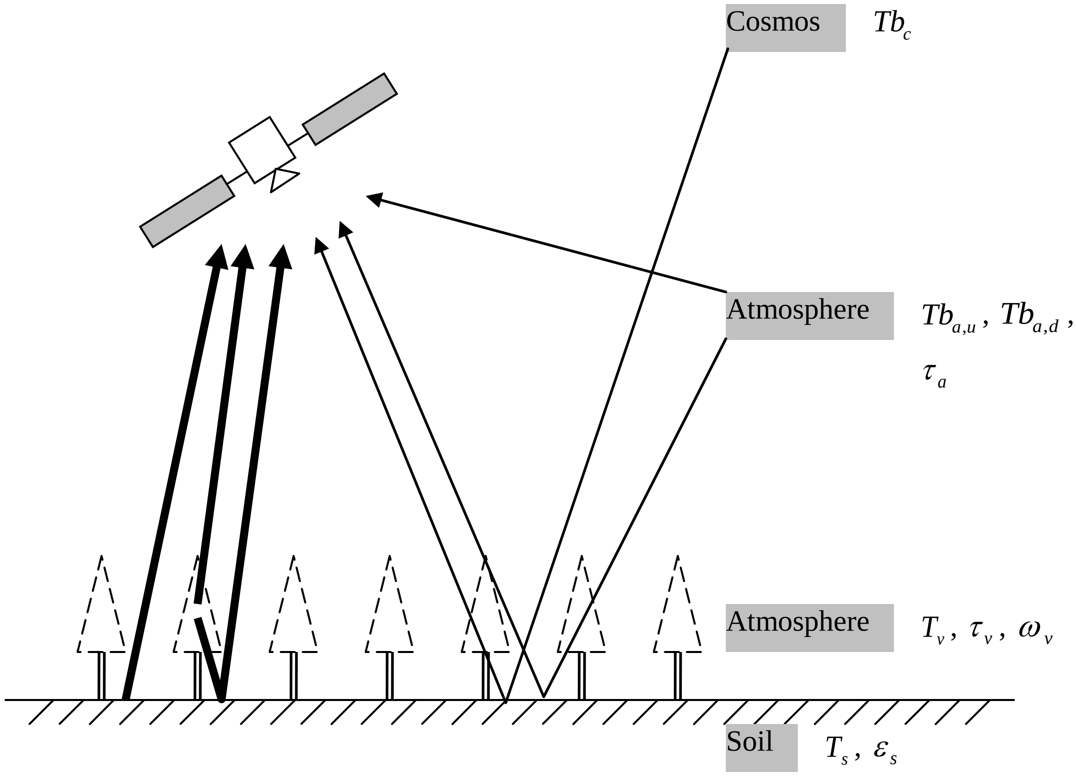

Figure 1. Radiative transfer over a vegetated surface in LSMEM.

LSMEM consists of four major modules: Soil, vegetation, snow, and atmosphere (Fig. 2). Each module calculates the emission properties of the target body, e.g., emissivity, reflectivity, albedo, optical depth, etc. Once all the necessary emission properties are computed, the radiative transfer routine combines all these emissions and calculates the final brightness temperature at TOA. The soil module has four sub-modules: Soil dielectric properties, effective temperature, smooth surface emissivity, and rough surface emissivity.

LSMEM is basically a collection of models (theoretical, semi-empirical, or empirical) that calculates the emission properties of different components. Because such models are developed for different ranges of frequencies, materials, and application conditions, LSMEM may implement more than one model for the calculation of the same variable. For example, the soil dielectric properties can be computed using either the model described in Dobson et al. (1985) or Wang and Schmugge (1980). This readme is not intended to serve as a complete documentation of LSMEM; thus, it only covers those models that were used in retrieving soil moisture in the project.

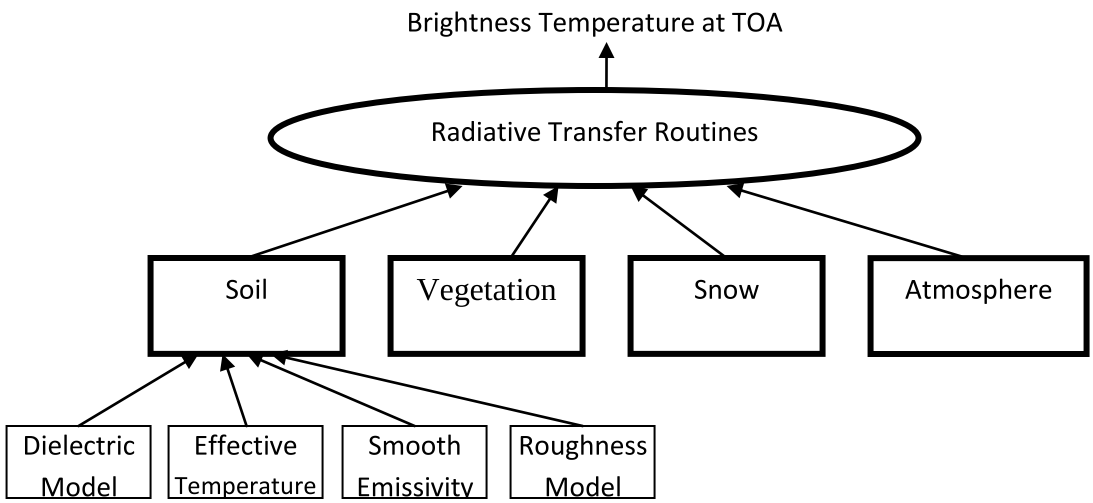

Figure 2. LSMEM schematic showing its four major modules of soil, vegetation, snow, and atmosphere; and the four sub-modules of the soil module.

This soil moisture data set does not include areas covered by snow; thus, the snow model is not described. Also, the atmosphere is assumed to have constant brightness temperatures; thus, the atmosphere model is also not described.

The main inputs to the soil moisture retrievals are the 10.65 GHz and 36.5 GHz brightness temperature measurements from the Advance Microwave Scanning Radiometer on board the EOS Aqua satellite (AMSR-E). The daily gridded brightness temperature data set from the National Snow and Ice Data Center (NSIDC), AMSR-E/Aqua Daily Global Quarter-Degree Gridded Brightness Temperatures (Knowles et al., 2006), is used. (Data and documentation are available at http://nsidc.org/data/docs/daac/nsidc0301_amsre_gridded_tb.gd.html.) The brightness temperatures in this data set are re-sampled to 0.25º. Where more than one swaths overlap during a day, only the last available swath is kept. Two separate brightness temperature maps are available for each of the AMSR-E channels: Ascending overpasses (equatorial crossing time 1:30 pm local time) and descending overpasses (equatorial crossing time 1:30 am local time).

All inputs to LSMEM are listed in Table 1 with their temporal and spatial variability classified to the following categories:

- Constant: invariant in both time and space
- Constant parameter: invariant in time but variant in space
- Seasonal parameter: changes slowly in time (weekly/monthly), variant in space
- Dynamic input: changes fast in time (sub-daily), variant in space

Table 1. Summary of LSMEM inputs.

	Symbol	Description	Details
Sensor	f	Channel frequency	Constant, $=10.65$ GHz for AMSR-E X-band
	φ	Sensor Earth incidence angle	Constant, $=55$ º for AMSR-E
Land cover	C_{veg}	Fractional coverage of vegetation	Seasonal parameter
	C_{soil}	Fractional coverage of bare soil	$=1-C_{veg}-C_{water}$, seasonal parameter
	C_{water}	Fractional coverage of water	Constant parameter
Atmosphere	Tb_c	Cosmic background temperature	Constant, $=2.725$ K
	τ_a	Optical depth of atmosphere	Constant, $=0.014$
	$Tb_{a,u}$	Upward atmospheric temperature	Constant, $=6.0$ K
	$Tb_{a,d}$	Downward atmospheric temperature	Constant, $=8.7$ K
Soil	ρ_s	Soil specific density	Constant parameter
	ρ_b	Soil bulk density	Constant parameter
	f_{clay}	Soil clay fraction	Constant parameter
	f_{sand}	Soil sand fraction	Constant parameter
	h_{rms}	Surface RMS roughness height	Constant, $=0.3$ cm
	S_{sw}	Soil water salinity	Constant, $=0.65$ ‰
	T_s	Surface temperature	Dynamic input
	T'_{sw}	Soil water temperature	$=T_s-273.15$, dynamic input
	θ	Soil moisture content (volumetric)	Dynamic input
Vegetation	S_{sw}	Vegetation water salinity	Constant, $=6.0$ ‰
	T'_{sw}	Vegetation water temperature	$=T_s-273.15$, dynamic input
	W_v	Vegetation water content	Seasonal parameter
	b	Vegetation structure parameter	Constant parameter
	ω_v	Vegetation single scattering albedo	Constant, $=0.07$

1.2 Algorithm Background

The algorithm that was used to produce this data set is documented in Pan et al. (2014). There have been two major revisions made to the LSMEM formulations and soil moisture retrieval algorithm: (1) Combining two vegetation parameters and one roughness parameter into one effective vegetation optical depth (VOD) value and (2) providing an additional model equation that estimates the effective VOD from both polarizations and an initial guess of soil moisture value.

1.3 Data Disclaimer

This data set comes with no warranty, explicit or implied, to the extent permitted by applicable law. If you use this data set, please cite the following publication:

Pan, M., A.K. Sahoo, and E.F. Wood, 2014. Improving soil moisture retrievals from a physically-based radiative transfer model, *Remote Sens. Environ., 140*, 130-140, doi: 10.1016/j.rse.2013.08.020.

For questions about the data set, please contact the data producer, Ming Pan, at email mpan@princeton.edu.

2.0 Data Organization

The LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set is packed into daily files, each containing the center latitude and longitude of 0.25° grid boxes and two 720 (lat) x 1440 (lon) arrays of surface soil moisture derived from, respectively, AMSR-E/Aqua descending and ascending overpass data.

2.1 File Naming Convention

File names are formatted as follows:

WC_LSMEM_SOILM_025_L3_V001_ YYYYMMDDT00Z.nc4

where

- WC_LSMEM_SOILM expands to **W**ater **C**ycle **L**and **S**urface **M**icrowave **E**mission **M**odel **SOIL** **M**oisture
- 025 indicates 0.25^{o} spatial resolution
- L3 indicates Level-3 gridded data
- V001 indicates version 1 of data product
- YYYYMMDD indicates date of data acquisition
- T00Z indicates starting time (hour) for data contained in the file
- .nc4 indicates netCDF4 file format

Filename example: WC_LSMEM_SOILM_025_L3_V001_20100601T00Z.nc4

2.2 File Format and Structure

LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data files are in netCDF4 (http://www.unidata.ucar.edu/software/netcdf/docs/), which facilitates the creation, access, and sharing of array-oriented data in a form that is self-describing and portable.

Each daily file contains geolocation information (latitude and longitude of grid box centers) and two data fields:

- surface soil moisture content estimates from ascending AMSR-E overpass

- surface soil moisture content estimates from descending AMSR-E overpass

There is also a set of global attributes defining the metadata for the data set. More details are provided in Section 3.0.

2.3 Key Science Data Fields

There is only one science data field: Satellite-derived volumetric soil moisture content at land surface derived from AMSR-E satellite brightness temperature measurements.

3.0 Data Contents

3.1 Dimensions

LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data are stored in 2-dimensional arrays with dimensions (lat, lon), where lat = 720, the number of grid boxes in the north-south direction; and lon = 1440, the number of grid boxes in the east-west direction.

3.2 Global Attributes

In addition to SDS (Scientific Data Sets) arrays containing variables and dimension scales, global metadata are also stored in the files. Some metadata are required by standard conventions; some are included to meet data provenance requirements; and others are provided as a convenience to users of the LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set. A summary of global attributes present in all files is shown in Table 2.

Table 2. Global metadata attributes associated with each SDS of the LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set.

Global Attribute	**Type**	**Description**
Title	String	Full data set title
ProcessingCenter	String	Location of data set production
ContactPersonName ContactPersonRole ContactPersonEmail ContactPersonAddress	String	Contact information for data set producers
Source	String	Algorithm basis for the data set
ProductReference	String	Citation information for reference on the data set
Identifier_product_doi	String	Digital object identifier of data set
Identifier_product_doi_authority	String	Digital object identifier host
ShortName	String	Product short name
ProcessingDate	String	Date of file creation, yyyy-mm-dd

VersionID	String	Product version number
Conventions	String	CF conventions followed
LocalGranuleID	String	File name
Format	String	File format
RangeBeginningDate	String	Start date of the data in the file
RangeBeginningTime	String	Time stamp of first temporal field
RangeEndingDate	String	End date of the data in the file
RangeEndingTime	String	Time stamp of final temporal field
NorthBoundingCoordinate	String	Center latitude of northernmost grid box
SouthBoundingCoordinate	String	Center latitude of southernmost grid box
EastBoundingCoordinate	String	Center longitude of easternmost grid box
WestBoundingCoordinate	String	Center longitude of westernmost grid box

A list of key metadata fields can be found in Table 3. Global attributes in a LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data file can be viewed with the *ncdump* software: ncdump –h -c <file>

Table 3. Key metadata fields

Name	**Type**	**Description**
FillValue	float32	Floating-point value used to denote missing data. Will normally be set to 1e15. Required by CF
long_name	String	Long descriptive variable name
standard_name	String	Standard description of the variable as defined in CF conventions
Units	String	Units of a variable. Must be a string that can be recognized by Unidata's UDUNITS package
Scale_factor	float32	If variable is packed as 16-bit integers, this is the scale_factor for expanding to floating-point.

3.3 Products/Parameters

This data set contains only one product: Volumetric soil moisture content at land surface estimated from the AMSR-E X-band measurements using the LSMEM algorithm.

4.0 Options for Reading the Data

The following are a few of the many command line and visualization tools available for reading netCDF4 format data, such as the LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data files. For more comprehensive lists of tools, please see the following:

https://www.unidata.ucar.edu/software/netcdf/docs/netcdf_tools.html

https://www.hdfgroup.org/products/hdf5_tools/

Most of the following tools (e.g., GrADS, NCO, CDO, NCL, IDL) can subset variables or subset data within specified temporal and/or spatial ranges. These tools can also calculate statistics like mean, standard deviation, maximum, minimum, etc. For further assistance on data use, please contact the data producer, Ming Pan, at email mpan@princeton.edu.

4.1 Command Line Utilities

4.1.1 ncdump (free)

The ncdump tool generates the CDL (Common Data Language) text (ASCII) representation of a netCDF or compatible file and writes to standard output. The tool can also be used as a simple browser for netCDF files, to display the dimension names and lengths; variable names, types, and shapes; attribute names and values; and, optionally, the values of data for all variables or selected variables. A common use of ncdump is with the –h option, with which only the header information is displayed. The ncdump tool comes with the netCDF library as distributed by Unidata.

http://www.unidata.ucar.edu/downloads/netcdf/

4.1.2 h5dump (free)

The h5dump tool enables users to examine the contents of an HDF5 file and dump those contents to an ASCII file or, optionally, as XML or binary outputs. It can display the contents of the entire HDF5 file or selected objects, which can be groups, data sets, a subset of a data set, links, attributes, or datatypes. The h5dump tool is included with the HDF5 distribution from The HDF Group.

https://www.hdfgroup.org/HDF5/release/obtain5.html

4.1.3 NCO (free)

The netCDF Operator (NCO) (http://nco.sourceforge.net/) toolkit manipulates and analyzes data stored in netCDF-accessible formats, including DAP, HDF4, and HDF5.

4.1.4 CDO (free)

CDO (Climate Data Operators) (https://code.zmaw.de/projects/cdo) is a collection of command line operators to manipulate and analyze Climate and Numerical Weather Prediction (NWP) model Data.

4.2 Visualization Tools

4.2.1 Ncview (free)

Ncview is a quick and easy way to visualize the contents of netCDF files.

http://meteora.ucsd.edu/~pierce/ncview_home_page.html

4.2.2 ncBrowse (free)

ncBrowse is a Java application that provides flexible, interactive graphical displays of data and attributes from a wide range of netCDF data file conventions.

http://www.epic.noaa.gov/java/ncBrowse/

4.2.3 Panoply (free)

Panoply is a Java application, developed by the NASA Goddard Institute for Space Studies (GISS), that plots geo-referenced and other arrays from netCDF, HDF, GRIB, and other data types. Among other capabilities, Panoply enables one to slice and plot geo-referenced latitude-longitude, latitude-vertical, longitude-vertical, time-latitude, or time-vertical arrays from larger multidimensional variables; combine two geo-referenced arrays in one plot by differencing, summing, or averaging; plot maps using various map projections; and access remote catalogs to retrieve data files.

http://www.giss.nasa.gov/tools/panoply/

4.2.4 HDFView (free)

HDFView is a Java-based visual tool created by The HDF Group for browsing and editing HDF4 and HDF5 files. It allows users to view all objects in an HDF file hierarchy, which is represented as a tree structure, and create, add, delete, and modify object contents and attributes.

https://www.hdfgroup.org/products/java/hdfview/

4.2.5 IDL netCDF tools (commercial)

Users familiar with the IDL programming language (http://www.exelisvis.com/ProductsServices/IDL.aspx) can use the netCDF functions available with the IDL software package to read and visualize the data.

4.2.6 GrADS netCDF tools (free)

Users familiar with the GrADS programming language (http://iges.org/grads/) can use the netCDF functions available with the GrADS software package to read and visualize the data.

4.2.7 NCL (free)

The NCAR Command Language (NCL) (http://www.ncl.ucar.edu/) is a free interpreted language designed specifically for scientific data processing and visualization.

5.0 Data Services

5.1 Mirador

Mirador is a GES DISC earth science data search and download tool. It provides a simple interface for users to make basic keyword, temporal, and spatial searches. More advanced, event-based searches are also possible. An interactive shopping cart offers various download options.

http://mirador.gsfc.nasa.gov/

The LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set can be keyword searched with "WC_LSMEM_SOILM_025" or accessed via Mirador's "Projects" view.

http://mirador.gsfc.nasa.gov/cgi-bin/mirador/collectionlist.pl?keyword=WC_LSMEM_SOILM_025

5.2 OPeNDAP

The Open-source Project for a Network Data Access Protocol (OPeNDAP) provides a means for requesting and accessing data across the internet, in a form usable by OPeNDAP clients, i.e., clients that can remotely access OPeNDAP-served data (e.g., Panoply, IDL, MATLAB, GrADS, IDV, McIDAS-V, Ferret). OPeNDAP provides the ability to retrieve subsets of files and to aggregate data from several files in one transfer operation.

The LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set is available from the GES DISC through OPeNDAP:

http://measures.gsfc.nasa.gov/opendap/TerrestrialWaterCycle/WC_LSMEM_SOILM_025.001/contents.html

6.0 More Information

Detailed documentation of the soil moisture retrieval algorithm can be found in the following publication:

Pan, M., A.K. Sahoo, and E.F. Wood, 2014. Improving soil moisture retrievals from a physically-based radiative transfer model, *Remote Sens. Environ.*, *140*, 130-140, doi: 10.1016/j.rse.2013.08.020.

6.1 Other Soil Moisture Resources

For other soil moisture and related data available at the GES DISC, please see http://disc.sci.gsfc.nasa.gov/hydrology

For other soil moisture and related data available elsewhere, please search NASA's Global Change Master Directory (GCMD) at

http://gcmd.nasa.gov/

6.2 Point of Contact

Name: GES DISC Help Desk
URL: http://disc.sci.gsfc.nasa.gov/
E-mail: gsfc-help-disc@lists.nasa.gov
Phone: 301-614-5224
Fax: 301-614-5268
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
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6.3 Acronyms

AMSR-E:	Advanced Microwave Scanning Radiometer - Earth Observing System
LSMEM:	Land Surface Microwave Emission Model
MEaSUREs:	Making Earth System Data Records for Use in Research Environments
TOA	Top of the Atmosphere
VOD:	Vegetation optical depth

7.0 Acknowledgments

The production of the LSMEM/AMSRE/Aqua Surface Soil Moisture Daily Level-3 0.25-degree data set and related research was supported by NASA's Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program and a separate NASA grant (NNX11AR24G) for "Advancing a Refined AMSR-E Soil Moisture Data Product."

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