National Aeronautics and Space Administration

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

README Document for LPRM Surface Soil Moisture Data Products

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Revision History

Revision Date	***Changes***	***Author***
11/06/2017	Edits of initial contents from Robert Parinussa; added contents related to data organization, etc.	Bill Teng
11/15/2017	Some edits and additional contents	Robert Parinussa
02/13/2018	(a) Added contents on data set summary (1.1), DOI and citation (1.4), Level-2 to Level-3 gridding process (2.0), and bit mask values (3.1, 3.2, 3.3) and (b) generalized readme to include all LPRM Level-3 products (AMSR-E, TMI, and AMSR2).	Bill Teng
02/14/2018	Reviewed and revised	Hualan Rui
02/15/2018	Final revisions	Bill Teng
05/02, 08/2018	Incorporated changes from Robert Parinussa and Robin van der Schalie	Bill Teng
11/21/2018	Added information on WindSat	Bill Teng
12/20/2021	Removed information on SSW tool; updated Help Desk email address; reviewed and revised	Carlee Loeser

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1.0 Introduction

This document provides basic information for using global soil moisture products from the Land Parameter Retrieval Model (LPRM). The LPRM is a multi-parameter retrieval algorithm generated with a focus on large-scale climate and hydrological studies. The LPRM is designed to retrieve surface soil moisture from passive microwave observations from various sensors. Space-borne observed brightness temperatures are converted, using LPRM, to soil moisture, vegetation optical depth (biomass-related), and land surface temperature. LPRM is based on a microwave radiative transfer model that links the surface geophysical variables to the observed brightness temperatures.

The LPRM was applied to various historical and current Earth-observing multi-frequency radiometers, spanning from the late 1970's to the present. Observations of the Earth's surface started with the Scanning Multi-channel Microwave Radiometer (SMMR) in 1978, and continued with several multi-frequency radiometers in the subsequent years. The Advanced Microwave Scanning Radiometer for EOS (AMSR-E; 2002-2011) and the TRMM Microwave Imager (TMI; 1997-2015) were important sensors for global soil moisture retrievals. Currently, sensors like the Advanced Microwave Scanning Radiometer 2 (AMSR2) and WindSat observe the Earth's surface in multi-frequencies.

1.1 Data Set Summary Characteristics

Table 1 provides a summary of some basic characteristics of the LPRM Surface Soil Moisture Data Products.

Table 1. Basic characteristics of the LPRM Surface Soil Moisture Data Products.

Contents	Outputs from LPRM with inputs from AMSR-E, WindSat, TMI, and AMSR2
Format	netCDF
Spatial extent	AMSR-E and AMSR2: -90º to 90º latitude, -180º to 180º longitude; WindSat: -64º to 83º latitude, -180º to 180º longitude TMI: -40º to 40º latitude, -180º to 180º longitude;
Spatial resolution	All: 0.25º; except AMSR2 downscaled: 0.1º
Temporal resolution	Daily
Temporal coverage	AMSR-E: June 19, 2002 – Oct 3, 2011; WindSat: Feb 1, 2003 – July 31, 2012; TMI: Dec 8, 1997 – Apr 8, 2015; AMSR2: July 3, 2012 – present, with 1-day latency
Dimension	All: 720 (lat) x 1400 (lon); except AMSR2 downscaled: 1800 (lat) x 3600 (lon)
Origin (1st grid center)	All: (89.875, -179.875); except AMSR2 downscaled: (89.95, -179.95)

1.2 Data Set Algorithm Description

Brightness temperatures can be derived from several passive microwave sensors with different radiometric characteristics. The observed brightness temperatures are converted to soil moisture values with the LPRM (Owe et al., 2008). LPRM is based on a microwave radiative transfer model that links soil moisture to the observed brightness temperatures. The different processing steps of LPRM are described below. Figure 1 shows a flowchart of the entire methodology.

Thermal radiation in the microwave region is emitted by all natural surfaces and is a function of both the land surface and the atmosphere. According to LPRM, the observed brightness temperature (T_b), as measured by a spaceborne radiometer, can be described as

$$T_{b,p} = \Gamma_a (T_{b\_s,p} + (1 - e_{r,p})(T_{b\_d} + T_{b\_extra}\Gamma_a)\Gamma_v^2) + T_{b\_u}$$

where Γ_a and Γ_v are the atmosphere and vegetation transmissivity, respectively; T_{b_s} is the surface brightness temperature; e_r is the rough surface emissivity; T_{b_extra} is the extraterrestrial brightness temperature; and T_{b_u} and T_{b_d} are the upwelling and downwelling atmospheric brightness temperatures, respectively. The subscript p denotes either horizontal (H) or vertical (V) polarization. The vegetation/atmosphere transmissivity is further defined in terms of the optical depth, $\tau_{v/a}$, and satellite incidence angle, u, such that

$$\Gamma_{v/a} = \exp(-\frac{\tau_{v/a}}{\cos u})$$

The radiation from a land surface (T_{bp}) is described according to a simple radiative transfer (Mo et al., 1982):

$$T_{b\_s,p} = T_s e_{r,p}\Gamma_v + (1-\omega)T_v(1-\Gamma_v) + (1-e_{r,p})(1-\omega)T_v(1-\Gamma_v)\Gamma_v$$

where T_s and T_v are the thermodynamic temperatures of the soil and the vegetation, respectively, and ω is the single scattering albedo. LPRM uses the model of Wang and Choudhury (1981) to describe the rough surface emissivity as

$$e_{r,p1} = 1 - \left(Q r_{s,p2} + (1-Q) r_{s,p1}\right) e^{-h\cos u}$$

where Q is the polarization mixing factor, h is the roughness height, r_s is the surface reflectivity, and *p1* and *p2* are the opposite polarization (horizontal or vertical). The surface reflectivity is calculated from the Fresnel equations:

$$r_{s,H} = \left| \frac{\cos u - \sqrt{\varepsilon - \sin^2 u}}{\cos u + \sqrt{\varepsilon - \sin^2 u}} \right|^2$$

$$r_{s,V} = \left| \frac{\varepsilon \cos u - \sqrt{\varepsilon - \sin^2 u}}{\varepsilon \cos u + \sqrt{\varepsilon - \sin^2 u}} \right|^2$$

where $r_{s,H}$ is the horizontal polarized reflectivity, $r_{s,V}$ is the vertical polarized reflectivity, and ε is the complex dielectric constant of the soil surface ($\varepsilon = \varepsilon' + \varepsilon'' i$). The dielectric constant is an electrical property of matter and is a measure of the response of a medium to an applied electric field. There is a large contrast in dielectric constant between water and dry soil, and several dielectric mixing models have been developed to describe the relationship between soil moisture and dielectric constant (Dobson et al., 1985; Wang and Schmugge 1980). LPRM uses the Wang and Schmugge model. A special characteristic of LPRM is the internal analytical approach to solve for the vegetation optical depth (Meesters et al., 2005). This unique feature reduces the required vegetation parameters to one, the single scattering albedo. LPRM makes use of the Microwave Polarization Difference Index (MPDI) to calculate τ_v,

$$MPDI = \frac{T_{b\_s,V} - T_{b\_s,H}}{T_{b\_s,V} + T_{b\_s,H}}$$

If one assumes that τ and ω have minimal polarization dependency at satellite scales, then the vegetation optical depth can be described as

$$\tau_v = \cos u \ln(ad + \sqrt{(ad)^2 + a + 1})$$

where

$$a = \frac{1}{2}\left[\frac{e_{r,V} - e_{r,H}}{MPDI} - e_{r,V} - e_{r,H} \right]$$

and

$$d = \frac{1}{2} \frac{\omega}{(1-\omega)}$$

By using these equations in combination with the dielectric mixing model, soil moisture could be solved in a forward fashion, together with a parameterization of the following parameters: atmosphere, soil and vegetation temperature (T_a, T_s, T_c), optical depth of the atmosphere (τ_a), roughness parameters Q and h, soil wilting point and porosity, and the single scattering albedo (ω). Temperatures were estimated using Ka-band (37 GHz) observations, according to the method of Holmes et al. (2009), and the soil wilting point and porosity derived from the Food and Agriculture Organization (www.fao.org) soil texture map.

Vegetation affects the microwave emission as well, and, under a sufficiently dense canopy, the emitted soil radiation would become completely masked. The simultaneously-derived vegetation optical depth can be used to detect areas with excessive vegetation, of which the boundary varies with observation frequency. Under frozen surface conditions, the dielectric properties of the water change dramatically. Therefore, all pixels where the surface temperature is observed to be at or below 273 K are assigned with an appropriate data flag, using the method of Holmes et al. (2009). Natural emission in several low frequency bands is affected by artificial sources, the so-called Radio Frequency Interference (RFI). As a diagnostic for possible errors, an RFI index is calculated according to Li et al. (2004). Most passive microwave sensors which are used for soil moisture retrieval have several frequencies. Therefore, the LPRM can switch to higher frequencies in areas affected by RFI.

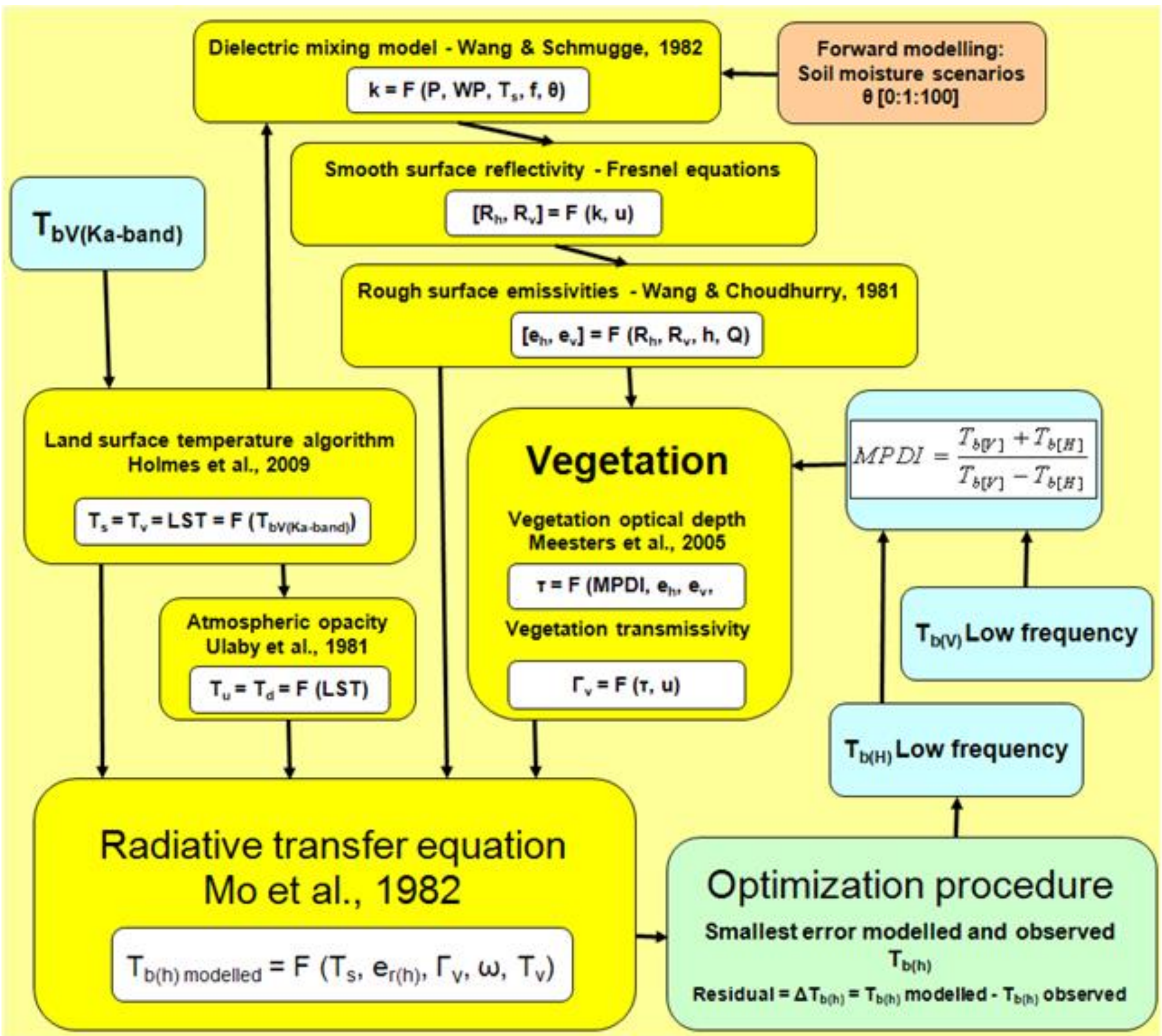

Figure 1. Flowchart of the main processes of the Land Parameter Retrieval Model (LPRM). Soil moisture is solved when the observed brightness temperature equals the modelled brightness temperature as derived by the radiative transfer.

1.3 Data Disclaimer

The LPRM Surface Soil Moisture Data Products are made available with no warranty, explicit or implied, to the extent permitted by applicable law.

1.4 Digital Object Identifier (DOI) and Citation

Users of LPRM Surface Soil Moisture Data Products should cite, in research papers, the data used, along with their associated Digital Object Identifiers (DOIs) (Table 2). A DOI is a unique alphanumeric string used to identify a digital object and provide a permanent link online. DOIs are often used in online publications in citations.

Table 2. DOIs for LPRM Surface Soil Moisture Data Products.

Product Short Name	Product Description	DOI
LPRM_AMSRE_A_SOILM3	AMSR-E/Aqua surface soil moisture (LPRM) L3 1 day 25 km x 25 km ascending V002	10.5067/X3K5V3NNLYAV
LPRM_AMSRE_D_SOILM3	AMSR-E/Aqua surface soil moisture (LPRM) L3 1 day 25 km x 25 km descending V002	10.5067/MXL0MFDHWP07
LPRM_TMI_DY_SOILM3	TMI/TRMM surface soil moisture (LPRM) L3 1 day 25 km x 25 km daytime V001	10.5067/8CHFMAWJQTCP
LPRM_TMI_NT_SOILM3	TMI/TRMM surface soil moisture (LPRM) L3 1 day 25 km x 25 km nighttime V001	10.5067/GWHRZEL8SA21
LPRM_WINDSAT_DY_SOILM3	WindSat/Coriolis surface soil moisture (LPRM) L3 1 day 25 km x 25 km daytime V001	10.5067/SZ5L2MRK43S2
LPRM_WINDSAT_NT_SOILM3	TMI/TRMM surface soil moisture (LPRM) L3 1 day 25 km x 25 km nighttime V001	10.5067/QSIHQIMUIM3G
LPRM_AMSR2_A_SOILM3	AMSR2/GCOM-W1 surface soil moisture (LPRM) L3 1 day 25 km x 25 km ascending V001	10.5067/M5DTR2QUYLS2
LPRM_AMSR2_D_SOILM3	AMSR2/GCOM-W1 surface soil moisture (LPRM) L3 1 day 25 km x 25 km descending V001	10.5067/CGDEOBASZ178
LPRM_AMSR2_DS_A_SOILM3	AMSR2/GCOM-W1 surface soil moisture (LPRM) L3 1 day 10 km x 10 km ascending V001	10.5067/B0GHODHJLDA8
LPRM_AMSR2_DS_D_SOILM3	AMSR2/GCOM-W1 surface soil moisture (LPRM) L3 1 day 10 km x 10 km descending V001	10.5067/SITUTTDUKYZE

Each "Product Short Name" in Table 2 is linked to its corresponding data product page. In the latter, the tab "Data Citation" provides the recommended citation for that product. If you use an LPRM data product(s) in your research or applications, please include the corresponding reference(s) in your publication(s). The following is an example citation (for LPRM_AMSR2_DS_D_SOILM3):

Vrije Universiteit Amsterdam (Richard de Jeu) and NASA GSFC (Manfred Owe) (2014), AMSR2/GCOM-W1 surface soil moisture (LPRM) L3 1 day 10 km x 10 km descending V001, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed **[***Data Access Date***]** doi:10.5067/SITUTTDUKYZE

Primary reference:

Owe, M., R. de Jeu, and T. Holmes, 2008. Multisensor historical climatology of satellite-derived global land surface moisture, *J. Geophys. Res.*, *113,* F01002, 17 pp., doi:10.1029/2007JF000769.

2.0 Data Organization

The LPRM Surface Soil Moisture Data Products (Table 2) are gridded, at 0.25- or 0.10-degree resolution, from their respective brightness temperature (Level-2 swath) products, as processed using LPRM. The first grid cell is centered at (latitude, longitude) of (89.875, -179.875) or (89.95, -179.95) in the northwest corner of the grid. The value of a given grid cell is the mean of the values of all Level-2 swath pixels, the centers of which fall within that grid cell, for a given day and either daytime/ascending or nighttime/descending. Typically, 1 or 2 values are averaged for a grid cell.

2.1 File Naming Convention

File names are formatted as follows and with <fields> described in Table 3:

LPRM-<microwave sensor>_L3_[DS]_[<orbitDirection>|<day/night>]_SOILM3_<product version>_<date of data acquisition>.nc

where

- LPRM is Land Parameter Retrieval Model
- L3 indicates Level-3 gridded data
- [DS] indicates "DS" (downscaled) if <microwave sensor> = "AMSR2"; else null
- [<orbitDirection>|<day/night>] indicates either <orbitDirection> or <day/night>
- SOILM3 is Soil Moisture Level 3
- .nc indicates netCDF file format

Table 3. Description of file name attributes.

Attribute	Description
<microwave sensor>	"AMSR_E" for Advanced Microwave Scanning Radiometer for EOS
	"WINDSAT" for WindSat
	"TMI" for Tropical Rainfall Measuring Mission's (TRMM) Microwave Imager
	"AMSR2" for Advanced Microwave Scanning Radiometer 2
<orbitDirection>	"A" for ascending or "D" for descending
<day/night>	"DY" for day; "NT" for night
<product version>	V002 for AMSR-E; V001 for WindSat and AMSR2; V001-<production date/time> for TMI
<date of data acquisition>	YYYYMMDD for AMSR_E and TMI; YYYYMMDDHHMMSS for WindSat and AMSR2

Filename examples:

LPRM-AMSR_E_L3_D_SOILM3_V002_20110101.nc – LPRM applied to input Level-2 swath brightness temperatures from AMSR_E, descending orbit, gridded to Level-3, version 002, for October 1, 2011

LPRM-WINDSAT_L3_DY_SOILM3_V001_20120101000050.nc – LPRM applied to input Level-2 swath brightness temperatures from WindSat, day orbit, gridded to Level-3, version 001, for January 1, 2012

LPRM-TMI_L3_NT_SOILM3_V001-20150105T134058Z_20150102.nc – LPRM applied to input Level-2 swath brightness temperatures from TMI, night orbit, gridded to Level-3, version 001, for January 2, 2015

LPRM-AMSR2_L3_DS_D_SOILM3_V001_20180201010321.nc4 – LPRM applied to input Level-2 swath brightness temperatures from AMSR2, descending orbit, downscaled, gridded to Level-3, version 001, for February 1, 2018, 01:03:21 GMT

2.2 File Format and Structure

The LPRM Surface Soil Moisture Data Products (Table 2) are in netCDF (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), a bit mask, and four to ten data fields (Sec. 3.0).

3.0 Data Contents

The following sections (3.1 – 3.4) and their corresponding tables provide descriptions of the LPRM data variables. The mask variable is expanded in each case to its bit values and their meaning. A bit mask value is a combination of all the bit conditions. Each Level-3 grid point may contain multiple bit conditions. For example, a value of 112 means bits 4, 5, and 6 are turned on, based on the inputs from the Level-2 data. A bit mask value captures all possible conditions existing for that grid point.

3.1 LPRM-AMSR_E Data Variables

Short Name	**Description**	**Unit**
soil_moisture_c	Volumetric soil moisture from C-band	%
soil_moisture_x	Volumetric soil moisture from X-band	%
sm_c_error	Uncertainty of soil moisture in C-band	%
sm_x_error	Uncertainty of soil moisture in X-band	%
opt_depth_c	Optical depth from C-band	
opt_depth_x	Optical depth from X-band	
ts	Skin temperature (2 mm)	K
mask	Bit mask	

* C-band – 6.9 GHz; X-band – 10.7 GHz

LPRM-AMSR_E bit mask values and their meaning are as follows:

Bits	**Meaning**
1	Negative optical depth in X
2	Negative optical depth in C
3	High optical depth value in X
4	High optical depth value in C
5	No valid data
6	Ice
7	Not processed

3.2 LPRM-WINDSAT Data Variables

Short Name	Description	Unit
soil_moisture_c	Volumetric soil moisture from C-band	%
soil_moisture_x	Volumetric soil moisture from X-band	%
sm_c_error	Uncertainty of soil moisture in C-band	%
sm_x_error	Uncertainty of soil moisture in X-band	%
opt_depth_c	Optical depth from C-band	
opt_depth_x	Optical depth from X-band	
ts	Skin temperature (2 mm)	K
mask	Bit mask	

* C-band – 6.8 GHz; X-band – 10.7 GHz

LPRM-WINDSAT bit mask values and their meaning are as follows:

Bits	Meaning
1	Negative optical depth in X
2	Negative optical depth in C
3	High optical depth value in X
4	High optical depth value in C
5	No valid data
6	Ice
7	Not processed

3.3 LPRM-TMI Data Variables

Short Name	Description	Unit
soil_moisture_x	Volumetric soil moisture from X-band	%
sm_x_error	Uncertainty of soil moisture in X-band	%
opt_depth_x	Optical depth from X-band	
ts	Skin temperature (2 mm)	K
mask	Bit mask	

* X-band – 10.7 GHz

LPRM-TMI bit mask values and their meaning are as follows:

Bits	Meaning
1	Negative optical depth in X
3	High optical depth value in X
5	No valid data
6	Ice
7	Not processed

3.4 LPRM-AMSR2 Data Variables

Short Name	Description	Unit
soil_moisture_c1	Volumetric soil moisture from 6.9 GHz	%
soil_moisture_c2	Volumetric soil moisture from 7.3 GHz	%
soil-moisture-x	Volumetric soil moisture from 10.7 GHz	%
soil_moisture_c1_error	Uncertainty of soil moisture in 6.9 GHz	%
soil_moisture_c2_error	Uncertainty of soil moisture in 7.3 GHz	%
soil_moisture_x_error	Uncertainty of soil moisture in 10.7 GHz	%
opt_depth_c1	Optical depth from 6.9 GHz	
opt_depth_c2	Optical depth from 7.3 GHz	
opt_depth_x	Optical depth from 10.7 GHz	
ts	Skin temperature (2 mm)	K
mask	Bit mask	

LPRM-AMSR2 bit mask values and their meaning are as follows:

Bits	Meaning
1	Negative optical depth in X
2	Negative optical depth in C2
3	Negative optical depth in C1
4	High optical depth value in X
5	High optical depth value in C2
6	High optical depth value in C1
7	No valid data
8	Ice
9	Not processed

4.0 Options for Reading the Data

The following are a few of the many command line and visualization tools available for reading netCDF format data, such as the LPRM Surface Soil Moisture Data Products. For more comprehensive lists of tools, please see the following:

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

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.

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. Please note h5dump may not work with older netCDF formats. 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/

The How-To's of NASA GES DISC provides a recipe for How to View Remote Data in OPeNDAP with 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 netCDFtools (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 netCDFtools (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

Access to GES DISC data requires all users to be registered with the **NASA Earthdata Login System** (as of August 1, 2016). Data continue to be free of charge and accessible via HTTPS. Access to data via FTP is no longer available (as of October 3, 2016). Detailed instructions on how to register and receive authorization to access GES DISC data are provided at https://disc.gsfc.nasa.gov/data-access.

GES DISC users who deploy scripting methods to list and download data in bulk via anonymous FTP are advised to review the How to Download Data Files from HTTP Service with wget recipe, which provides examples of GNU wget commands for listing and downloading data via HTTPS.

If you need assistance or wish to report a problem:

Email: gsfc-dl-help-disc@mail.nasa.gov

Voice: 301-614-5224

The following provides a list of the LPRM Surface Soil Moisture Data Products:
https://disc.gsfc.nasa.gov/datasets?page=1&keywords=LPRM

Each product is linked to its data product page that contains additional information.

5.1 HTTPS

For access to the online archive data via HTTP:

For LPRM-AMSR-E,
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSRE_A_SOILM3.002/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSRE_D_SOILM3.002/

For LPRM-WINDSAT,
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_WINDSAT_DY_SOILM3.001/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_WINDSAT_NT_SOILM3.001/

For LPRM-TMI,
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_TMI_DY_SOILM3.001/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_TMI_NT_SOILM3.001/

For LPRM-AMSR2,
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSR2_A_SOILM3.001/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSR2_D_SOILM3.001/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSR2_DS_A_SOILM3.001/
https://hydro1.gesdisc.eosdis.nasa.gov/data/WAOB/LPRM_AMSR2_DS_D_SOILM3.001/

5.2 Earthdata Search

Use the Earthdata Search portal to find and retrieve data sets archived at the GES DISC or across multiple data enters:

https://search.earthdata.nasa.gov/search?m=8.0859375!-15.328125!2!1!0!0%2C2&q=LPRM&ok=LPRM

5.3 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.

For LPRM-AMSR-E,
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSRE_A_SOILM3.002/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSRE_D_SOILM3.002/contents.html

For LPRM-WINDSAT,
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_WINDSAT_DY_SOILM3.001/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_WINDSAT_NT_SOILM3.001/contents.html

For LPRM-TMI,
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_TMI_DY_SOILM3.001/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_TMI_NT_SOILM3.001/contents.html

For LPRM-AMSR2,
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSR2_A_SOILM3.001/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSR2_D_SOILM3.001/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSR2_DS_A_SOILM3.001/contents.html
https://hydro1.gesdisc.eosdis.nasa.gov/opendap/LPRM_AMSR2_DS_D_SOILM3.001/contents.html

OPeNDAP subsetting services for each dataset are also available through each dataset landing page. Please see this guide for more information and instructions.

5.5 Giovanni

The NASA GES-DISC Interactive Online Visualization ANd aNalysis Interface (Giovanni) is a Web-based tool that allows users to interactively visualize and analyze data.

https://giovanni.gsfc.nasa.gov/giovanni/#service=TmAvMp&starttime=&endtime=&dataKeyword=LPRM

Figure 2 shows a sample map of LPRM-AMSR2 soil moisture generated by NASA Giovanni.

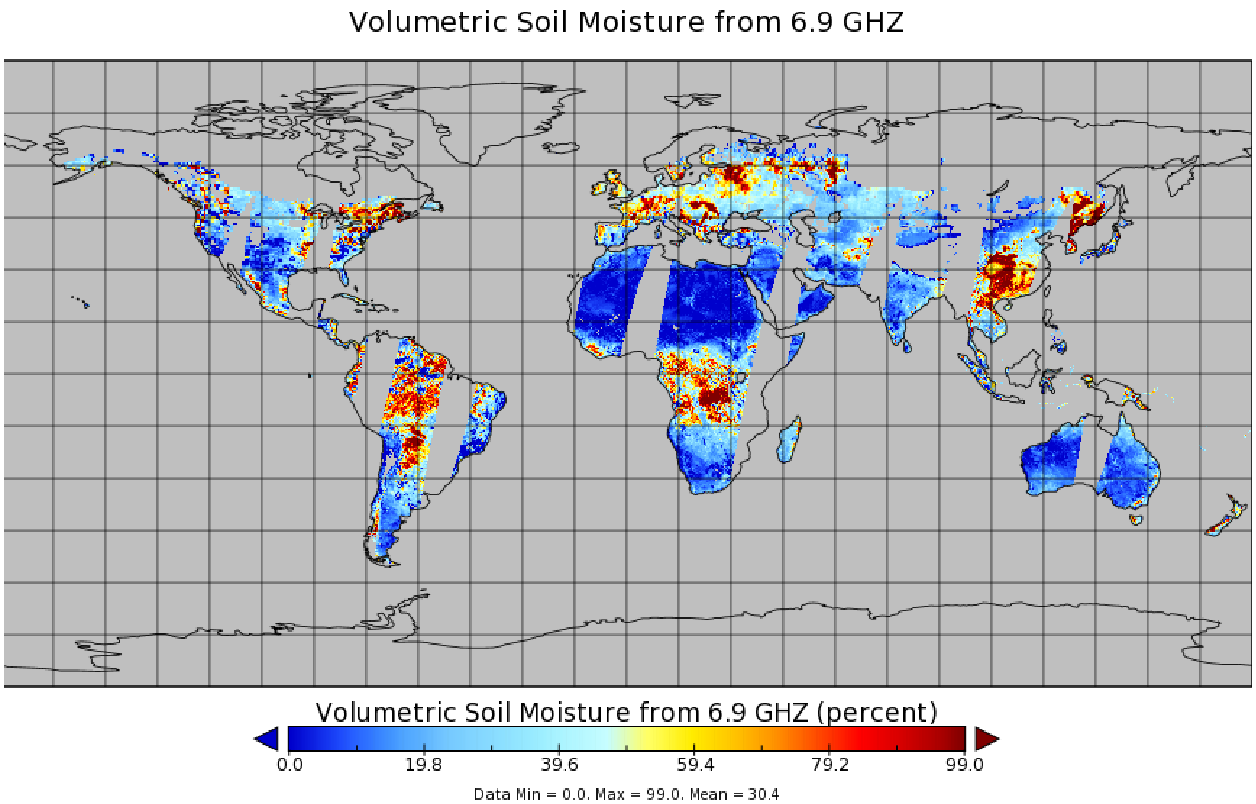

Figure 2. Surface soil moisture map (April 1, 2016; daily; 0.1^{o}) generated by LPRM applied to input brightness temperature data from AMSR2 6.9 GHz channel.

6.0 More Information

6.1 LPRM Algorithm*

Several algorithms to estimate surface soil moisture from passive microwave observations exist (e.g., Owe et al., 2008; de Jeu et al., 2008; Li et al., 2010; Pan et al., 2014). Results of these soil moisture algorithms have been validated on varying scales, using several types of observations and methods (e.g., Wagner et al., 2007; Draper et al., 2009; Jackson et al., 2010; Li et al., 2010).

These studies showed that LPRM soil moisture captures a high degree of the temporal variability (correlation coefficient) in spatially-averaged soil moisture estimates. This finding was confirmed by Crow et al. (2010) using a completely different approach and using soil moisture anomalies rather than absolute values. The skill to capture a high degree of temporal variability of soil moisture is arguably the most important indicator of utility, because the majority of the application and/or data assimilation techniques that use remotely sensed soil moisture often remove the climatology and scale the anomalies to match the models' climatology (Reichle and Koster, 2004; Liu, Q. et al., 2011; Crow et al., 2012). Liu, Y.Y. *et al.* (2011; 2012) showed that the combination of passive- and active-microwave-based soil moisture data sets has the potential to provide a higher quality soil moisture product, compared to single-sensor data sets. They also showed an exaggeration of the dynamics (amplitude) of the LPRM soil moisture product, when compared to true soil moisture. This exaggeration is related to estimated (unknown) values in the radiative transfer, and a scaling technique (CDF-matching) was proposed to match the dynamics of the LPRM soil moisture to the dynamics of a land surface model.

A time-efficient analytical solution to estimate the error of LPRM satellite surface soil moisture was presented in Parinussa et al., (2011). The error estimate is based on a basic error propagation equation, which uses the partial derivatives of the radiative transfer equation and estimated errors for each individual input parameter. Results similar to those of the Monte Carlo approach show that the developed time-efficient methodology could substitute for more computationally intensive methods. This error estimate is a welcomed solution for near-real-time data assimilation studies, where both the soil moisture product and error estimate are needed. The developed method was applied to the C-, X-, and Ku-bands of AMSR-E, to study differences in errors between frequencies.

** NB: The LPRM data products covered by this README Document were generated using the LPRM version 5 retrievals. The current version is LPRM version 6 (see Van der Schalie et al., 2016, 2017).*

6.2 Other Soil Moisture Resources

For other soil moisture and related data available at the GES DISC, please see

https://disc.gsfc.nasa.gov/datasets?page=1&keywords=soil%20moisture.

For other soil moisture and related data available elsewhere, please search NASA's Earthdata Search portal: https://search.earthdata.nasa.gov/.

6.3 Points of Contact

Name: GES DISC Help Desk
URL: https://disc.gsfc.nasa.gov/
E-mail: gsfc-dl-help-disc@mail.nasa.gov
Phone: 301-614-5224
Fax: 301-614-5268
Address: Goddard Earth Sciences Data and Information Services Center
Attn: Help Desk
Code 610.2
NASA Goddard Space Flight Center
Greenbelt, MD 20771
USA

For specific questions about the LPRM algorithm, please contact the data producer, Richard de Jeu (rdejeu@vandersat.com).

6.4 Acronyms

AMSR2:	Advanced Microwave Scanning Radiometer 2
AMSR-E:	Advanced Microwave Scanning Radiometer for EOS
DOI:	Digital Object Identifier
LPRM:	Land Parameter Retrieval Model
RFI:	Radio Frequency Interference
SMMR:	Scanning Multi-channel Microwave Radiometer
TMI:	TRMM Microwave Imager

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