Aquarius L3 Gridded 1-Degree Monthly Soil Moisture Climatology, Version 4

USER GUIDE

How to Cite These Data

As a condition of using these data, you must include a citation:

Bindlish, R. and T. Jackson. 2015. *Aquarius L3 Gridded 1-Degree Monthly Soil Moisture Climatology, Version 4*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/Aquarius/AQ3_MCSM.004. [Date Accessed].

FOR QUESTIONS ABOUT THESE DATA, CONTACT NSIDC@NSIDC.ORG

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/AQ3_MCSM

National Snow and Ice Data Center

TABLE OF CONTENTS

1 DETAILED DATA DESCRIPTION

1.1 Format

The data files are in Hierarchical Data Format 5 (HDF5). The values are stored as bytes, 2-byte integers, or 4-byte floats. Data are 32-bit float. The palette object is 8-bit unsigned integer. Each data file is paired with an associated XML file. XML files contain file level metadata and location, platform, and campaign information.

1.2 File and Directory Structure

Data are available on the HTTPS site in the `https://n5eil01u.ecs.nsidc.org/AQUARIUS/` directory. Data files are organized into directories by time period: Monthly and Seasonal:

```
/AQ3_MCSM.004/
/AQ3_SCSM.004/
```

Within each directory, folders are organized by date, for example:

```
/2011.08.25/
/2012.03.21/
```

Folders contain HDF5 and XML (.xml) files.

1.3 File Naming Convention

File names correspond to those of their parent Aquarius binned data products, indicating the binning periods as part of the names.

Files are named according to the following conventions and as described in Table 1:

```
Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg
```

```
QYYYYDDDyyyyddd.L3m_tttt_SOILM_vvvv_rad_sm_1deg
```

Where:

Table 1. File Naming Convention

Variable	Description
Q	Indicates Aquarius instrument
YYYY	Year climatology start
DDD	Day climatology start
yyyy	Year climatology end
ddd	Day climatology end
L3m	Processing level
tttt	Binning period length, where: MC = Monthly Climatology SCAU = Seasonal Climatology Autumn SCSP = Seasonal Climatology Spring SCSU = Seasonal Climatology Summer
SOILM	Geophysical parameter: SOILM = soil moisture
vvvv	Data version, example: V4.0
rad_sm_1deg	1-degree radiometer soil moisture

Each data file is paired with an XML file of the same name with .xml extension. The XML file contains metadata associated with the data file.

1.4 File Size

Data files are approximately 263 KB each.

XML files are approximately 3 KB each.

1.5 Volume

Data Volume for Aquarius L3 Monthly Soil Moisture Climatologies is approximately 4 MB.

Data Volume for Aquarius L3 Seasonal Soil Moisture Climatologies is approximately 2 MB.

1.6 Spatial Coverage

Spatial coverage is global.

1.6.1 Spatial Resolution

Spatial resolution of the L3 data is 1 degree.

1.6.2 Projection and Grid Description

The `l3m_data` object is a two-dimensional array (180 rows, 360 columns) of an Equidistant Cylindrical (also known as Plate Carrée) projection of the globe.

1.7 Temporal Coverage

AQ3_MCSM: 25 August 2011 to 31 May 2015

AQ3_SCSM: 25 August 2011 to 07 June 2015

Monthly climatology products contain the mean soil moisture values of composites for the mission.

- August 25, 2011 to August 31, 2014
- September 1, 2011 to September 30, 2014
- October 1, 2011 to October 31, 2014
- November 1, 2011 to November 30, 2014
- December 1, 2011 to December 31, 2014
- January 1, 2012 to January 31, 2015
- February 1, 2012 to February 28, 2015
- March 1, 2012 to March 31, 2015
- April 1, 2012 to April 30, 2015
- May 1, 2012 to May 31, 2015
- June 1, 2012 to June 30, 2014
- July 1, 2012 to July 31, 2014

Seasonal climatology products are defined between equinox and solstice. The file names contain the exact DOY for each season. For example: the file `Q20113552015079.L3m_SCWI_SOILM_V4.0_rad_sm_1deg` contains the data for Winter composites ranging from 2011 DOY 355 (21 December) to 2015 DOY 079 (20 March).

Seasonal climatology products contain the mean soil moisture values for the following composites for the mission:

- June 21, 2011 to September 20, 2014, includes mean value for Summer 2011, Summer 2012, Summer 2013, and Summer 2014.
- September 21, 2011 to December 20, 2014, includes mean value for Autumn 2011, Autumn 2012, Autumn 2013, Autumn 2014.
- December 21, 2011 to March 20 2015, includes mean value for Winter 2011, Winter 2012, Winter 2013, Winter 2014, and Winter 2015.
- March 21, 2012 to June 07, 2015, includes mean value for Spring 2012, Spring 2013, Spring 2014, and Spring 2015.

NOTE: Due to a power failure on the Satélite de Aplicaciones Científicas (SAC)-D spacecraft on 08 June 2015, data from NASA's Aquarius instrument were no longer being produced after 07 June 2015. Accordingly, the date range for the climatology Spring season ends on 07 June 2015, rather than extending through the full Spring season.

1.7.1 Temporal Resolution

Monthly, Seasonal

1.8 Parameter or Variable

The L3 products are representations of binned data products generated from Aquarius data. The data object, `l3m_data`, represents a mean Soil Moisture value of all composites for the mission at each grid point. The grid resolution is 1 degree.

1.8.1 Parameter Description

Each L3 soil moisture product contains the `l3m_data` object, with attributes described in Table 2.

Table 2. L3 Soil Moisture `l3m_data` Object Attributes

Name	Value
Scaling	linear
Scaling Equation	(Slope*l3m_data) + Intercept = Parameter value
Slope	1.0
Intercept	0
_FillValue	-32767.0
add_offset	0.0
scale_factor	1.0

The palette object included in the data file is the color palette used in graphics generated from the mapped files. The user can either use this palette or any palette of their choice.

Metadata are included as global attributes. Table 3 lists the global attribute names and the values from data file `Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg`. Values that vary from granule to granule are noted.

Table 3. L3 Soil Moisture Metadata General Attributes

Name	Value
Product Name	Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg
Sensor Name	Aquarius
Sensor	Aquarius
Title	Aquarius Level-3 Standard Mapped Image
Data Center	NASA/GSFC OBPG
Mission	SAC-D Aquarius
Mission Characteristics	Nominal orbit: inclination=98.0 (Sun-synchronous); node=6PM (ascending); eccentricity=<0.002; altitude=657 km; ground speed=6.825 km/sec
Sensor Characteristics	Number of beams=3; channels per receiver=4; frequency 1.413 GHz; bits per sample=16; instantaneous field of view=6.5 degrees; science data block period=1.44 sec
Product Type	MC
Processing Version	V4.0
Software Name	smigen
Software Version	5.04
Processing Time	2015166164053000 (varies)
Input Files	Q20112442014273.L3b_MC_SOILM_V4.0.main (varies)
Processing Control	smigen par=Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg.param (varies)
Input Parameters	ifile = Q20112442014273.L3b_MC_SOILM_V4.0.main|ofile = Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg|prod = rad_sm|palfile = /sdps/sdpsoper/Science/OCSSW/V2015.2/data/common/palette/sm.pal|processing version = V4.0|meas = 1|stype = 1|datamin = 0.000000|datamax = 0.400000|lonwest = -180.000000|loneast = 180.000000|latsouth = -90.000000|latnorth = 90.000000|resolution = 1deg|projection = RECT|gap_fill = 0|seam_lon = -180.000000|minobs = 0|deflate = 4|oformat = HDF5|precision = F|
L2 Flag Names	POINTING,NAV,LANDRED,ICERED,REFL_1STOKESMOONRED,REFL_1STOKESGAL,TFTADIFFRED, RFI_REGION,SAOVERFLOW,COLDWATERRED,WINDRED,TBCONS
Period Start Year	2011
Period Start Day	244 (varies)

Name	Value
Period End Year	2014 (varies)
Period End Day	274 (varies)
Start Time	2011244021854088 (varies)
End Time	2014274004423594 (varies)
Start Year	2011 (varies)
Start Day	244 (varies)
Start Millisec	8334088 (varies)
End Year	2014 (varies)
End Day	275 (varies)
End Millisec	2663594 (varies)
Start Orbit	1214
End Orbit	17781
Map Projection	Equidistant Cylindrical
Latitude Units	degrees North
Longitude Units	degrees East
Northernmost Latitude	90.0
Southernmost Latitude	-90.0
Westernmost Longitude	-180.0
Easternmost Longitude	180.0
Latitude Step	1.0
Longitude Step	1.0
SW Point Latitude	-89.5
SW Point Longitude	-179.5
Data Bins	11021
Number of Lines	180
Number of Columns	360
Parameter	Soil Moisture
Measure	Mean
Units	m^3/m^3
Scaling	linear
Scaling Equation	(Slope*l3m_data) + Intercept = Parameter value
Slope	1.0
Intercept	0.0
Data Minimum	0.02
Data Maximum	0.85605

Name	Value
Suggested Image Scaling Minimum	0.0
Suggested Image Scaling Maximum	0.4
Suggested Image Scaling Type	LINEAR
Suggested Image Scaling Applied	No
_lastModified	2015166164053000

1.8.2 Sample Data Record

Below is a sample of the l3m_data soil moisture climatology data array from the file: `Q20112442014273.L3m_MC_SOILM_V4.0_rad_sm_1deg`.

54	0.05489	0.05489	0.06213	0.0801	0.08629	0.0859	0.0859
55	0.04467	0.04467	0.04444	0.05324	0.06442	0.08355	0.10124
56	0.03256	0.03256	0.04029	0.04374	0.05017	0.08351	0.0937
57	0.03669	0.03669	0.0397	0.02986	0.05114	0.0481	0.04701
58	0.04616	0.04616	0.04752	0.04204	0.04013	0.05459	0.0454
59	0.04725	0.03238	0.03238	0.0399	0.04978	0.04559	0.04975
60	0.02869	0.04233	0.04233	0.04934	0.03821	0.03699	0.03707
61	0.02069	0.02631	0.02631	0.03816	0.02934	0.03536	0.03453
62	0.02024	0.02183	0.02183	0.03842	0.03257	0.03974	0.0279
63	0.0204	0.0205	0.02157	0.02157	0.02338	0.02836	0.02646
64	0.02096	0.02084	0.02083	0.02083	0.02455	0.02389	0.02307
65	0.02103	0.02392	0.02248	0.02734	0.02734	0.02594	0.02117
66	0.03425	0.02691	0.02465	0.03479	0.03479	0.02623	0.02464
67	0.04168	0.03642	0.02569	0.02757	0.02334	0.02334	0.0201
68	0.04033	0.05343	0.02551	0.03483	0.0259	0.0259	0.02318
69	0.04179	0.05976	0.04337	0.02483	0.04145	0.03007	0.03007
70	0.03175	0.04269	0.02891	0.03364	0.03634	0.03074	0.03251

2 SOFTWARE AND TOOLS

HDF-aware software must be used to read the Aquarius soil moisture files. The following external links provide access to software for reading and viewing HDF5 data files. Please be sure to review instructions on installing and running the programs.

HDFView: Visual tool for browsing and editing HDF4 and HDF5 files.

Panoply netCDF, HDF and GRIB Data Viewer: Cross-platform application. Plots geo-gridded arrays from netCDF, HDF and GRIB data sets.

For additional tools, see the HDF5 Tools and Software Web site.

3 DATA ACQUISITION AND PROCESSING

3.1 Theory of Measurements

The Aquarius SCA algorithm uses the L-band horizontally polarized (h-pol) brightness temperature observations due to the higher sensitivity of this channel to soil moisture. The Aquarius SCA approach is based on the simplified radiative transfer model developed under the assumption that the canopy and soil temperatures are the same (Jackson 1993). The SCA is applied to the individual Aquarius footprint Level-2 brightness temperature observations to produce a swath-based time-order product. (Bindlish and Jackson, 2013; Bindlish et al, 2013).

3.2 Data Acquisition Methods

Aquarius L3 Gridded 1-Degree Soil Moisture Climatology data are generated from measurements derived from the Aquarius Level-2 Soil Moisture product. Each climatology product contains data from one time period, monthly or seasonally. The best quality data are selected for each orbit during Level-0 to Level-1A data processing and are then used to create the Level-2 file that is input to the L3 science file.

3.3 Derivation Techniques and Algorithms

The Aquarius Level-3 gridding algorithm uses local polynomial fitting to grid the Level-2 soil moisture retrievals on a 1 degree grid (Fan and Gijbels, 1996; Lilly and Lagerloef, 2008). The Level-3 processing of Aquarius satellite data takes measurements at the boresight locations of the three radiometer beams, which have been already converted into physical units of soil moisture, and maps these onto a 1 degree grid.

This method fits a Pth-order polynomial at each grid point x_m. For data values g_n observed at locations x_n, n = 1, 2, … N, this corresponds to minimizing

$$\sum_{n=1}^{N} \left| g_n - \sum_{p=0}^{P} \widehat{\beta_p}(x)[x_n - x]^2 \right|^2 K_h(x_n - x)$$

(Equation 1)

at every grid point $x = x_m$, where

$$K_h(x) = K\left(\frac{x}{h}\right)/h$$

(Equation 2)

is a decaying weighting function which depends upon the bandwidth h, with K(x) being a probability distribution function.

The regression coefficients

$$\widehat{\beta_p(x)}$$ **(Equation 3)**

P = 1, 2, … P vary with spatial location, and are estimated at all grid point locations.

The function g(x) is estimated by the lowest order coefficient,

$$\hat{g}(x) = \widehat{\beta_o}(x)$$ **(Equation 4)**

while higher-order regression coefficients estimate the derivatives of the field through

$$g^{(p)}\widehat{(x)} = p!\,\widehat{\beta_{po}}(x)$$ **(Equation 5)**

The above discussion focuses on a 1-dimensional application, but can be extended to a 2-dimensional application. A complete description for the 2-dimensional problem is available in Fan and Gijbels (1996) and Lilly and Lagerloef (2008).

3.3.1 Processing Steps

Aquarius L3 Gridded 1-Degree Soil Moisture Climatology data are produced by NASA Goddard Space Flight Center's Ocean Data Processing System (ODPS).

Each product represents data binned over the period covered by the original Aquarius product. The mean for the observation period is used to obtain the values for the grid points from the binned data products. Each product contains one soil moisture image and is stored in one physical HDF file. The data are not filtered during the gridding process. The user is advised to refer to the flags in the Aquarius Level-2 Soil Moisture product.

Monthly Climatology products are the mean value of all monthly composites for the mission, for example:
(January 2012 + January 2013 + January 2014) / 3

Seasonal Climatology products are the mean value of all seasonal composites for the mission, for example:
(Spring 2012 + Spring 2013 + Spring 2014) / 3

3.4 Sensor or Instrument Description

Aquarius/SAC-D is a collaboration between NASA and Argentina's space agency, Comisión Nacional de Actividades Espaciales (CONAE), with participation from Brazil, Canada, France and Italy. The Aquarius instrument was built jointly by NASA's Jet Propulsion Laboratory and NASA's Goddard Space Flight Center.

The Aquarius instrument includes three radiometers and one scatterometer. The soil moisture data are collected by the radiometers. The radiometers measure brightness temperature at 1.414 GHz in the horizontal and vertical polarizations (T_H and T_V). The scatterometer is a microwave radar sensor that measures backscatter for surface roughness corrections. Table 4 summarizes instrument characteristics.

Table 4. Aquarius Instrument Characteristics

Instrument	Characteristics
3 radiometers in push-broom alignment	• Frequency: 1.413 GHz • Band width: less than or equal to 26 MHz • Swath Width: 390 km • Science data block period: 1.44 sec • Footprints for the beams are: 74 km along track x 94 km cross track, 84 x 120 km, and 96 x 156 km, yielding a total cross track of 390 km. • Beam incidence angles of 29.36, 38.49, and 46.29 degrees incident to the surface. Beams point away from the sun.
Scatterometer	• Frequency: 1.26 GHz • Band Width: 4 MHz • Swath Width: 390 km • Science data block period: 1.44 sec

SAC-D spacecraft Orbit Parameters:

- 98 minute sun-synchronous
- 6 PM ascending orbit, 6 AM descending orbit
- 657 km equatorial altitude (655 km minimum, 685 km maximum over the orbit)
- Ground-track repeat interval: Weekly, 103 orbits

4 REFERENCES AND RELATED PUBLICATIONS

Bindlish, Rajat, and Thomas J. Jackson. 2013. Aquarius Soil Moisture ATBD Users Guide, Version 2.0. Beltsville, Maryland USA: USDA Hydrology and Remote Sensing Lab. (https://nsidc.org/sites/nsidc.org/files/files/data/aquarius/Aquarius-VSM-ATBD-UsersGuide.pdf, 315 KB)

Bindlish, Rajat, Thomas Jackson, Michael Cosh, Tianjie Zhao and Peggy O'Neill. 2015. Global Soil Moisture from the Aquarius Satellite: Description and Initial Assessment. *IEEE Geosciences and Remote Sensing Letters* 12(5):923-927.

Fan, J. and I. Gijbels. 1996. *Local Polynomial Modelling and its Applications*, Chapman and Hall, 1996.

Jackson, T. J. 1993. Measuring Surface Soil Moisture Using Passive Microwave Remote Sensing. *Hydrological Processes* 7:139–152.

Lilly, Jonathan and Gary Lagerloef. 2008. *Aquarius Level 3 Processing Algorithm Theoretical Basis Document*. ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs/v2/AquariusLevel3_GriddingSmoothingPaper_Lilly&Lagerloef2008.pdf

Piepmeier, Jeffrey, Shannon Brown, Joel Gales, Liang Hong, Gary Lagerloef, David Le Vine, Paolo de Matthaeis, Thomas Meissner, Rajat Bindlish, and Thomas Jackson. 2013. *Aquarius Radiometer Post-Launch Calibration for Product Version 2.0*, Aquarius Project Document: AQ-014-PS-0015. ftp://podaac-ftp.jpl.nasa.gov/allData/aquarius/docs/v2/AQ-014-PS-0015_AquariusInstrumentCalibratrionDescriptionDocument.pdf.

4.1 Related Data Collections

AMSR-E/Aqua L2B Surface Soil Moisture, Ancillary Parms, & QC EASE-Grids, Version 2
SMAP Data Sets at NSIDC
AMSR-E/Aqua Daily L3 Surface Soil Moisture, Interpretive Parameters, & QC EASE-Grids, Version 2
AMSR-E Validation Soil Moisture Data
Aquarius Level-1 and Level-2 Sea Surface Salinity Data
Aquarius Level-2 Swath Single Orbit Soil Moisture Data
ESA Soil Moisture and Ocean Salinity (SMOS)
Soil Moisture Product Using Aquarius/SAC-D Observations

4.2 Related Websites

Aquarius L2 Soil Moisture Documentation
Aquarius Web site at NASA Goddard Space Flight Center
Aquarius Data Web Site at NSIDC
Aquarius Web Site at PODAAC
SMAP Web Site at NSIDC
SMOS Website at ESA

NASA Aquarius Gallery: Soil Moisture - monthly soil moisture map images

5 CONTACTS AND ACKNOWLEDGMENTS

Rajat Bindlish
NASA Goddard Space Flight Center
Hydrological Sciences Laboratory
Code 617, Bldg 33, G216
Greenbelt, MD 20771 USA

Thomas Jackson
United States Department of Agriculture
Agricultural Research Service
Hydrology and Remote Sensing Laboratory
Beltsville, MD 20705 USA

Acknowledgments:

This work was funded by NASA under the Interagency agreement NNH10AN10I. Tianjie Zhao helped with development of the soil moisture algorithm. The support provided by Michael Cosh, Peggy O'Neill, Thomas Holmes and Wade Crow is acknowledged. We acknowledge the support provided by Gary Lagerloef, David Le Vine, Gene Feldman and the Aquarius Data Processing Segment (ADPS) group in the implementation of the Aquarius Soil moisture algorithm.

6 DOCUMENT INFORMATION

6.1 Publication Date

01 October 2015

6.2 Date Last Updated

29 October 2020