Aquarius L3 Gridded 1-Degree Seasonal Soil Moisture, 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 Seasonal Soil Moisture, 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_SNSM.004. [Date Accessed].

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

FOR CURRENT INFORMATION, VISIT https://nsidc.org/data/AQ3_SNSM

National Snow and Ice Data Center

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1   DETAILED DATA DESCRIPTION

The Aquarius L3 Gridded 1-Degree Soil Moisture Data are produced by NASA Goddard Space Flight Center's Aquarius Data Processing Segment (ADPS).

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_ANSM.004/
/AQ3_DYSM.004/
/AQ3_MOSM.004/
/AQ3_SNSM.004/
/AQ3_WKSM.004/
```

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

```
/2013.09.03/
/2013.09.10/
/2013.09.17/
/2013.09.24/
```

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_MO_SOILM_V4.0_rad_sm_1deg
```

`QYYYYDDDyyyyddd.L3m_ttt_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
`ttt`	Binning period length, where: DAY = daily 7D = weekly MO = monthly SNSP = seasonal spring SNSU = seasonal summer SNAU = seasonal autumn SNWI = seasonal winter YR = yearly (annual)
`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 262 KB each.

XML files are approximately 3 KB each.

1.5 Volume

Data Volume for Aquarius L3 Daily Soil Moisture is approximately 476 MB.

Data Volume for Aquarius L3 Weekly Soil Moisture is approximately 70 MB.

Data Volume for Aquarius L3 Monthly Soil Moisture is approximately 17 MB.

Data Volume for Aquarius L3 Seasonal Soil Moisture is approximately 5.6 MB.

Data Volume for Aquarius L3 Annual Soil Moisture is approximately 1.8 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

25 August 2011 to 07 June 2015.

Due to a power failure on the Satélite de Aplicaciones Científicas (SAC)-D spacecraft on 08 June 2015, data from NASA's Aquarius instrument are no longer being produced. For more information on this event, please refer to the official NASA announcement. The NASA National Snow and Ice Data Center Distributed Active Archive Center (NSIDC DAAC) will continue to distribute Aquarius soil moisture and polar-gridded data sets for the full duration of the mission, 25 August 2011 to 07 June 2015.

The weekly data start from August 20, 2011 in 7 day intervals until the present, yeilding a weekly data file every 7 days. The first weekly data have a time period of August 20 to August 26, 2011. The file name specifies the start date and end dates for Aquarius coverage. For example, the weekly file named: Q20142392014245.L3m_7D_SOILM_V4.0_rad_sm_1deg contains data from Day Of Year (DOY) 239, 2014 to DOY 245, 2014.

The month data for August 2011 is a partial coverage only, comprised of observations from August 25 to August 31, 2011.

Similarly, the yearly data for 2011 has observations after August 25, 2011 only.

The seasons are defined between equinox and solstice. The file names contain the exact DOY for each season (Autumn: March 21 to June 21; Summer: June 22 to September 22; Fall: September

23 to December 21; and Winter: December 21 to March 20). For example: the file
Q20141722014263.L3m_SNSU_SOILM_V4.0_rad_sm_1deg contains the data for summer 2014
ranging from DOY 172 (June 21, 2014) to DOY 263 (September 20, 2014).

1.7.1   Temporal Resolution

Daily, Weekly, Monthly, Seasonal, and Annual

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 Level-3 soil moisture product contains the l3m_data object, with attributes described in Table
2.

Table 2. Level-3 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_MO_SOILM_V4.0_rad_sm_1deg. Values that vary from
granule to granule are noted.

Table 3. Level-3 Soil Moisture Metadata General Attributes

Name	Value
Product Name	Q20112442011273.L3m_MO_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; instatntaneous field of view=6.5 degrees; science data block period=1.44 sec
Product Type	MO
Processing Version	V4.0
Software Name	smigen
Software Version	5.04
Processing Time	2015166163059000 (varies)
Input Files	Q20112442011273.L3b_MO_SOILM_V4.0.main (varies)
Processing Control	smigen par=Q20112442011273.L3m_MO_SOILM_V4.0_rad_sm_1deg.param (varies)
Input Parameters	ifile = Q20112442011273.L3b_MO_SOILM_V4.0.main|ofile = Q20112442011273.L3m_MO_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

Name	Value
Period Start Year	2011
Period Start Day	244 (varies)
Period End Year	2011 (varies)
Period End Day	274 (varies)
Start Time	201124021854088 (varies)
End Time	201127002912490 (varies)
Start Year	2011 (varies)
Start Day	244 (varies)
Start Millisec	1752490 (varies)
End Year	2011 (varies)
End Day	274 (varies)
End Millisec	1752490 (varies)
Start Orbit	1214
End Orbit	1654
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	10875
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

Name	Value
Data Minimum	0.02
Data Maximum	0.85605
Suggested Image Scaling Minimum	0.0
Suggested Image Scaling Maximum	0.4
Suggested Image Scaling Type	LINEAR
Suggested Image Scaling Applied	No

1.8.2   Sample Data Record

Below is a sample of the l3m_data soil moisture climatology data array from the
file: Q20112442014273.L3m_MO_SOILM_V4.0_rad_sm_1deg.

0.16071	0.22976	0.22976	0.19657	0.15777	0.15777
0.1274	0.1274	0.1871	0.18483	0.16693	0.16693
0.06534	0.08972	0.15427	0.16872	0.16872	0.14687
0.05917	0.10082	0.13872	0.13872	0.13424	0.22034
0.06101	0.13039	0.15026	0.15026	0.18505	0.27296
0.04777	0.10618	0.10618	0.14647	0.17485	0.24603
0.04941	0.08218	0.08218	0.07871	0.12846	0.21371
0.03597	0.0628	0.0628	0.08638	0.12645	0.21622
0.03718	0.07301	0.07301	0.08993	0.1224	0.13274
0.03734	0.03734	0.05301	0.07994	0.10778	0.16494
0.03393	0.03393	0.04718	0.07038	0.10538	0.30449
0.02855	0.029	0.029	0.04431	0.15404	0.04838
0.03738	0.02706	0.02706	0.04746	0.08408	0.06758
0.04488	0.03459	0.04777	0.04777	0.04901	0.21728

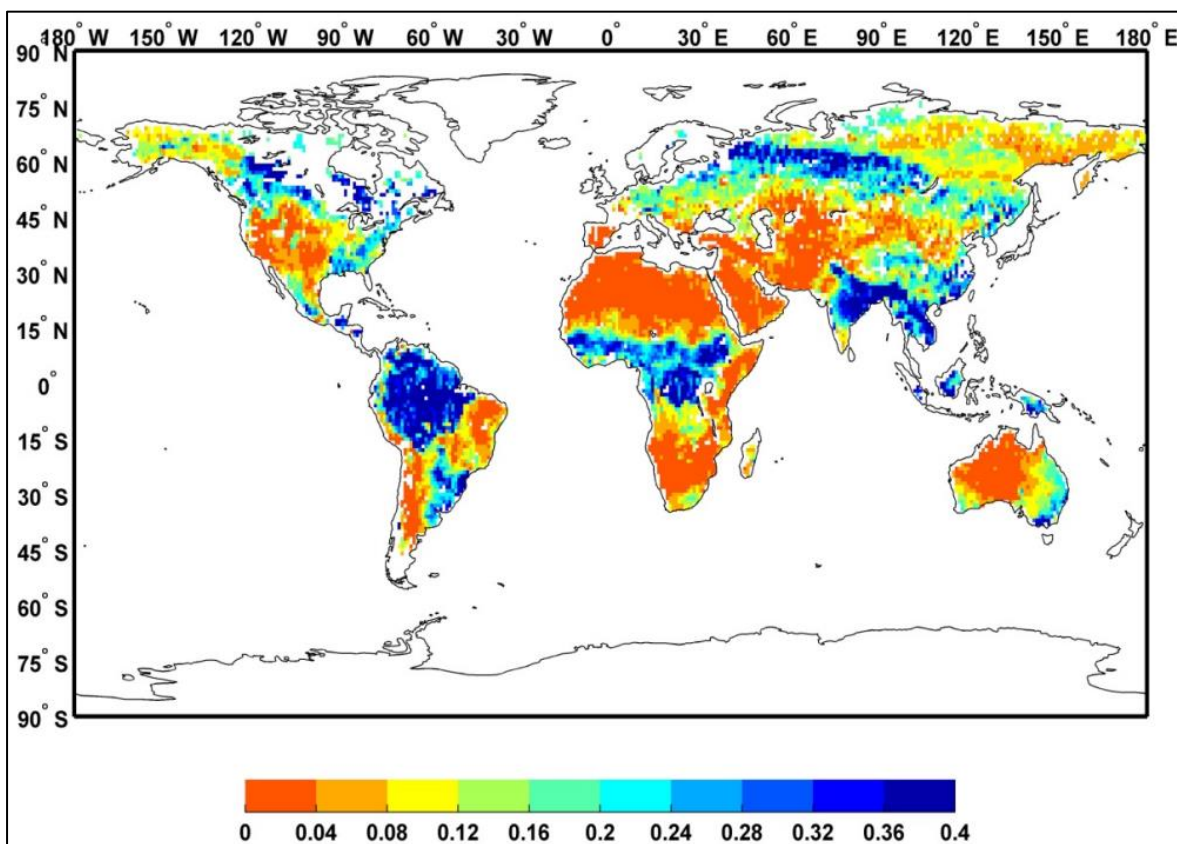Figure 1 shows the average soil moisture estimates for the month of July 2012.

Figure 1. Aquarius soil moisture estimates using all three beams for the month of July 2012.

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 NASA Aquarius Level-2 Sea Surface Salinity & Wind Speed Data V4.0 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, $n = 1, 2, \ldots N$, 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

$$\overline{\beta_p}(x) \quad \text{(Equation 3)}$$

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,

$$\hat{g}(x) = \overline{\beta_o}(x) \quad \text{(Equation 4)}$$

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

$$g^{(p)}\overline{(x)} = p!\,\overline{\beta_{po}}(x) \quad \text{(Equation 5)}$$

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

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.

3.3.2 Version History

Changes in the Version 4 Aquarius L3 Gridded 1-Degree Soil Moisture Data data include: use of the most recent version (Version 4) of Aquarius Brightness Temperatures as input.

The Aquarius L3 Gridded 1-Degree Soil Moisture Data, Version 3 are processed from the Aquarius L2 Swath Single Orbit Soil Moisture Data, Version 3. Changes in the Aquarius L2 Swath Single Orbit Soil Moisture Data, Version 3 data included: use of the most recent version (Version 3) of Aquarius Brightness Temperatures as input; Aquarius Brightness Temperatures are no longer re-calibrated before soil moisture retrievals as was done for Version 2 data; soil moisture observations are valid over a wider range of brightness temperatures compared to Version 2 data; updates to the soil moisture model parameters (b and ω).

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

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6 DOCUMENT INFORMATION

6.1 Publication Date

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6.2 Date Last Updated

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