AMSR-E/Aqua Monthly L3 5x5 deg Rainfall Accumulations, Version 2

USER GUIDE

How to Cite These Data

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

Adler, R., T. Wilheit, Jr., C. Kummerow, and R. Ferraro. 2004. *AMSR-E/Aqua Monthly L3 5x5 deg Rainfall Accumulations, Version 2*. [Indicate subset used]. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/AMSR-E/AE_RNGD.002. [Date Accessed].

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

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

National Snow and Ice Data Center

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1 DATA DESCRIPTION

1.1 Parameters

Rainfall Accumulation (mm) Over Ocean

Rainfall Accumulation (mm) Over Land

1.2 File Information

1.2.1 Format

Data are stored in Hierarchical Data Format - Earth Observing System (HDF-EOS) format. Files contain core metadata, product-specific attributes, and the following data fields:

Table 1. Data Fields

Field Name	Data Type	Description	Not Calculated
TbOceanRain	32-bit floating-point	Monthly ocean rainfall accumulation (mm)	-1
RrLandRain	32-bit floating-point	Monthly land rainfall accumulation (mm)	-1

1.2.2 File Contents

Each monthly granule is approximately 88 KB.

1.2.3 Naming Convention

This section explains the file naming convention used for this product with an example.

Example file name: `AMSR_E_L3_RainGrid_B05_200707.hdf`

`AMSR_E_L3_RainGrid_X##_yyyymm.hdf`

Refer to Table 2 for the values of the file name variables listed above.

Table 2. Values for the File Name Variables

Variable	Description
X	Product Maturity Code (Refer to Table 3 for valid values.)
##	file version number

Variable	Description
yyyy	four-digit year
mm	two-digit month
hdf	Hierarchical Data Format (HDF)

Table 3. Product Maturity Code Variables

Variable	Description
P	Preliminary - refers to non-standard, near-real-time data available from NSIDC. These data are only available for a limited time until the corresponding standard product is ingested at NSIDC.
B	Beta - indicates a developing algorithm with updates anticipated.
T	Transitional - period between beta and validated where the product is past the beta stage, but not quite ready for validation. This is where the algorithm matures and stabilizes.
V	Validated - products are upgraded to Validated once the algorithm is verified by the algorithm team and validated by the validation teams. Validated products have an associated validation stage.

Table 4. Validation Stages

Validation Stage	Description
Stage 1	Product accuracy is estimated using a small number of independent measurements obtained from selected locations, time periods, and ground-truth/field program efforts.
Stage 2	Product accuracy is assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts.
Stage 3	Product accuracy is assessed, and the uncertainties in the product are well-established via independent measurements made in a systematic and statistically robust way that represents global conditions.

Table 5 provides examples of file name extensions for related files that further describe or supplement data files.

Table 5. Related File Extensions and Descriptions

Extensions for Related Files	Description
`.jpg`	Browse data
`.qa`	Quality assurance information
`.ph`	Product history data
`.xml`	Metadata files

1.3 Spatial Information

1.3.1 Coverage

This data set offers coverage of all ice-free and snow-free land and ocean between 70°N and 70°S.

1.3.2 Resolution

Data are 5 degree by 5 degree resolution.

1.3.3 Grid Description

This data set contains two 5 degree by 5 degree grids with 28 rows by 72 columns: one for monthly rainfall accumulation over ocean and another over land.

1.4 Temporal Information

1.4.1 Coverage

Temporal coverage is from 19 June 2002 to 1 October 2011. See AMSR-E Data Versions for a summary of temporal coverage for different AMSR-E products and algorithms.

1.4.2 Resolution

Rainfall accumulation is averaged monthly.

2 DATA ACQUISITION AND PROCESSING

2.1 Processing

2.1.1 Theory of Measurements

Satellite-based estimates of rain rate and rain type rely primarily on cloud temperatures and information about vertical profiles. Atmospheric transmittance windows below 20 GHz, between 30 GHz and 40 GHz, and at 90 GHz are used for rainfall monitoring. Below 20 GHz, rainfall absorption and emission are predominant, and ocean surfaces are warmer than the background radiation. Thus, areas of the ocean where rainfall is occurring have higher brightness temperatures than the colder clear sky ocean backgrounds. Above 60 GHz, evidence of rainfall is primarily from scattering, where areas of heavy rainfall are colder than their backgrounds. Between 20 GHz and 60 GHz, a combination of absorption and scattering is present.

A radiative transfer equation that includes absorption and scattering coefficients is the basis for deriving rain rate from brightness temperatures in this data set. The absorption and scattering coefficients, which are summarized in more detail in Wilheit, Kummerow, and Ferraro (1999) and Wilheit, Kummerow, and Ferraro (2007) are expressed as an integral over the range of rain drop sizes. Excluding updrafts and downdrafts, the rain rate is expressed as:

$$R = V(D)(\pi D3 / 6)N(D)dD$$

(Equation 1)

Where:

$V(D)$ = fall speed of the drops as a function of diameter, D

$N(D)$ = number density of drops with diameters between D and D+dD

$\pi D3 / 6$ = volume of a drop of diameter, D

The large size of rain drops, compared with other water droplets within clouds, increases their absorption per unit mass and causes enough scattering that it must be considered in the retrieval. The introduction of ice above the freezing level greatly increases the importance of scattering. For wavelengths of a few mm or less, very low brightness temperatures result from scattering by ice particles with densities and sizes characteristic of rain (Wilheit, Kummerow, and Ferraro 1999).

At all channels, brightness temperatures increase toward a maximum and then drop off as rainfall rates increase further. The main difference between channels is the range of rainfall rates for which the curve increases in the emission region and decreases in the scattering region (Wilheit, Kummerow, and Ferraro 1999). The brightness temperatures at low frequencies are primarily a function of absorption and emission. The rain rate follows from the absorption coefficient implied by the measurements. As the rain rate increases, the absorption coefficient also increases causing warmer brightness temperatures. Ice and snow are efficient scatterers of microwave radiation compared with rain. Since land background has a high emissivity, rainfall rate over land must be inferred from the ice-scattering signature instead of relying on the emission signal from rain drops.

2.1.2 Derivation Techniques and Algorithms

Over oceans, the algorithm is not a simple average of the retrievals from the Level-2B rainfall product. On monthly scales, the details of the cloud structure and emission characteristics are not required as much as they are for instantaneous rainfall. A simplified emission algorithm is used to relate increases in 18.7 and 23.8 brightness temperatures to rainfall. This algorithm is illustrated in Figure 1 (Wilheit, Kummerow, and Ferraro 2003).

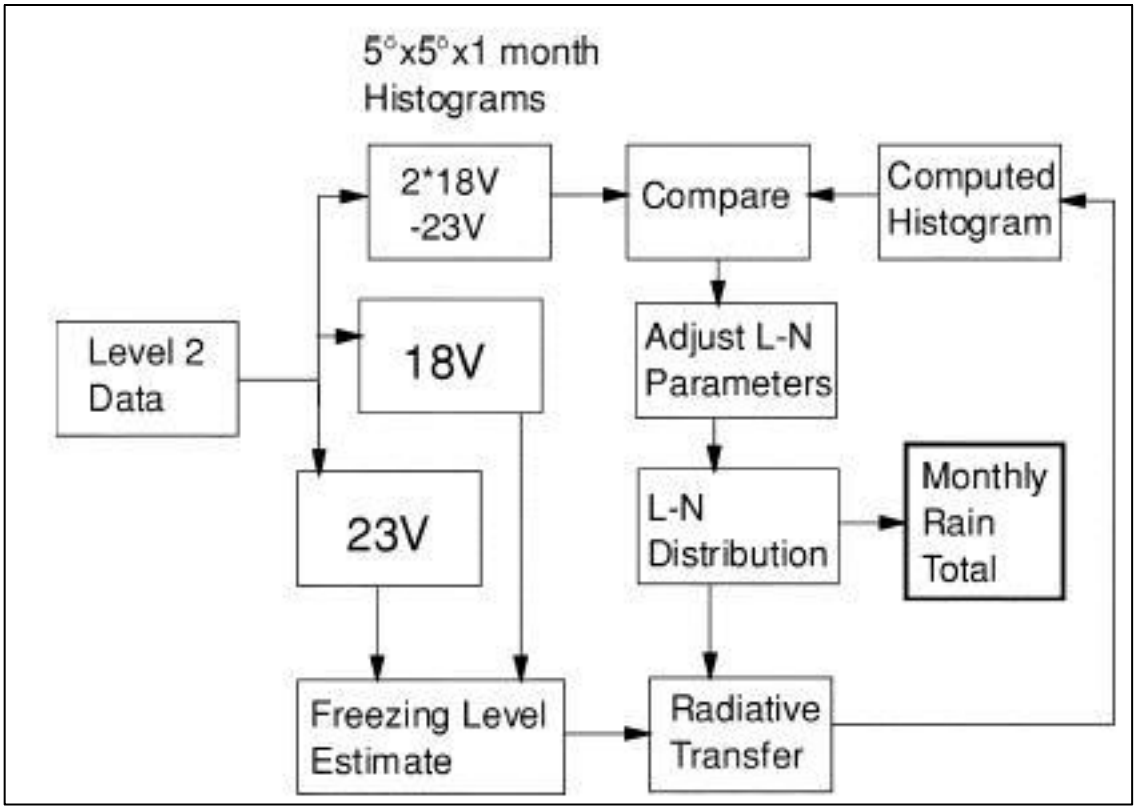

Figure 1. Flowchart for the AMSR-E Level-3 Oceanic Rainfall Algorithm

The algorithm accumulates three histograms of brightness temperatures for each 5 degree by 5 degree grid box for a month. The histogram consists of the 18.7 GHz brightness temperatures, the 23.8 GHz brightness temperatures, and the linear combination of these two frequencies 2*(18V-23V). These histograms are converted into monthly total rain rates on the basis of an assumed form of the Probability Distribution Function (PDF).

Per Kedam et al. (1990), rain rates are assumed to be distributed as a Mixed Log-Normal (MLN) over each 5 degree by 5 degree grid box, as shown in the following equation:

$$N(r) = (1-P_r)\delta(r)+P_r(2\pi^{)-1/2}r^{-1}\exp(-0.5*(\ln(r/r_0)/\sigma lr)^2)$$

(Equation 2)

Where:

Variable	Description
$N(r)$	the probability of a given rain rate
P_r	the probability that it is raining at all
$\delta(r)$	a delta function
r_0	the logarithmic mean rain rate when it is raining
σlr	the standard deviation of the logarithm of the rain rate when it is raining

The time/area average rain rate, R, is determined using the following equation:

$$R = r_0 P_r \exp(\sigma lr^2/2)$$

(Equation 3)

Each rain rate, r, is converted into a Brightness Temperature (T_b) using an analytic approximation to radiative transfer calculations using the following equation:

$$T_b = T_0 + (285K - T_0)(1 - \exp(-r/rc)) – a(r)^{0.5}$$

(Equation 4)

Where:

Variable	**Description**
T_0	the non-raining brightness temperature
r_c	the characteristic rain rate determined by the following equation: r_c = 28.04(mm/h)/(FL(km))1.13 Where: FL = freezing level
a	is 5.02 $K(mm/h)^{-0.5}$
r	rain rate

These parameters are computed by fitting this form to radiative transfer calculations for freezing levels ranging from 0.1 to 6 km. The value of T_0 can also be expressed this way; however, in this case, the fitting program solves for T_0 to absorb calibration and modeling errors. However, the fitted form of T_0 is used in the solution for the freezing level.

The freezing level for a given box at a given month is determined by calculating the 99th percentile brightness temperatures from the 18.7 GHZ and 23.8 GHz observed histogram. This brightness temperature pair is then used to select the single freezing level height. The freezing level height is then used to select the computed brightness temperature histogram from the radiative transfer calculations. The computed histogram is then compared to the observed histogram.

The algorithm adjusts the P_r and r_0 parameters of the MLN distribution of rain rate as well as T_0 and NEΔT (the instrumental noise) of a computed histogram to match characteristics of the observed histogram. The algorithm fits the mean, variance, and third moment as well as the point on the low brightness temperature end where the histogram value falls to 1/10 of the peak value. Normally, the value of σlr is left at one unless the fitting routine requires unphysical values of P_r. When satisfactory convergence is obtained, the average rain rate (R) is computed per the equation above. For output purposes, it is converted to units of mm/day and corrected for rainfall inhomogeneity.

Over land, Level-3 products are generated directly from the Level-2B rainfall products using the McCollum and Ferraro (2003) algorithm. Level-3 land products are created by simply summing rainfall rates into 5 degree by 5 degree monthly-averaged rainfall accumulations.

If the area within a grid box is more than 50 percent ocean, that grid box is considered to be an ocean grid box. More rain retrieval details can be found in Wilheit, Kummerow, and Ferraro (1999) and Wilheit, Kummerow, and Ferraro (2003).

2.2 Quality, Errors, and Limitations

2.2.1 Quality Assessment

Each HDF-EOS file contains core metadata with Quality Assessment (QA) metadata flags that are set by the Science Investigator-led Processing System (SIPS) at the Global Hydrology and Climate Center (GHCC) prior to delivery to NSIDC. A separate metadata file in XML format is also delivered to NSIDC with the HDF-EOS file; it contains the same information as the core metadata. Three levels of QA are conducted with the AMSR-E Level 2 and 3 products: automatic, operational, and science QA. If a product does not fail QA, it is ready to be used for higher-level processing, browse generation, active science QA, archive, and distribution. If a granule fails QA, SIPS does not send the granule to NSIDC until it is reprocessed. Level-3 products that fail QA are never delivered to NSIDC (Conway 2002).

2.2.2 Automatic QA

The investigators perform QA through visual examination of rainfall products on various temporal and spatial scales to ensure that rainfall maps are consistent with climate records, and that there are no gross errors. They also compare their rainfall estimates with those from satellite missions and ground-based radar.

2.2.3 Operational QA

AMSR-E Level-2A data arriving at GHCC are subject to operational QA prior to processing higher-level products. Operational QA varies by product, but it typically checks for the following criteria in a given file (Conway 2002):

- File is correctly named and sized
- File contains all expected elements
- File is in the expected format

- Required EOS fields of Time, Latitude, and Longitude are present and populated
- Structural metadata is correct and complete
- The file is not a duplicate
- The HDF-EOS version number is provided in the global attributes
- The correct number of input files were available and processed

2.2.4 Science QA

AMSR-E Level-2A data arriving at GHCC are also subject to science QA prior to processing higher-level products. If less than 50 percent of a granule's data is good, the science Q/A flag is marked suspect when the granule is delivered to NSIDC. In the SIPS environment, the science QA includes checking the maximum and minimum variable values and percent of missing data and out-of-bounds data per variable value. At the Science Computing Facility (SCF), also at GHCC, science QA involves reviewing the operational QA files, generating browse images, and performing the following additional automated QA procedures (Conway 2002):

- Historical data comparisons
- Detection of errors in geolocation
- Verification of calibration data
- Trends in calibration data
- Detection of large scatter among data points that should be consistent

Geolocation errors are corrected during Level-2A processing to prevent processing anomalies such as extended execution times and large percentages of out-of-bounds data in the products derived from Level-2A data.

The Team Lead SIPS (TLSIPS) developed tools for use at SIPS and SCF for inspecting the data granules. These tools generate a QA browse image in Portable Network Graphics (PNG) format and a QA summary report in text format for each data granule. Each browse file shows Level-2A and Level-2B data. These are forwarded from RSS to GHCC along with associated granule information, where they are converted to HDF raster images prior to delivery to NSIDC.

Please refer to AMSR-E Validation Data for information about data used to check the accuracy and precision of AMSR-E observations.

2.2.5 Error Sources

Quantifying errors in this data set is complicated because it involves understanding the nature of precipitation. Uncertainties arise when the rain layer thickness is not well understood, or when inhomogeneous rainfall occurs below the resolution of the satellite. Another potential source of error is the non-precipitating component of clouds, which contribute to brightness temperatures. Scattering-based retrievals over land also present many uncertainties, most notably the lack of a consistent relationship between frozen water aloft and liquid at lower altitudes. Quantifying the scattering by ice is especially problematic. Ambiguities occur in the data because microwave radiation is scattered not only by rainfall and associated ice, but by snow cover and dry land (Wilheit, Kummerow, and Ferraro 1999) and (Wilheit, Kummerow, and Ferraro 2007).

2.3 Instrumentation

2.3.1 Description

See the AMSR-E Instrument Description document.

3 SOFTWARE AND TOOLS

For tools that work with AMSR-E data, see the AMSR-E web page.

4 VERSION HISTORY

See AMSR-E Data Versions for a summary of algorithm changes since the start of mission.

5 REFERENCES

Conway, D. 2002. Advanced Microwave Scanning Radiometer - EOS Quality Assurance Plan. Huntsville, AL: Global Hydrology and Climate Center.

Kedam, B., L. Chiu, and G. North. 1990. Estimation of Mean Rain Rates: Applications to Satellite Observations. *J. Geophys Res*. 95: 1965-1972

Marshall, T. S. and W. M. Palmer. 1948. The Distribution of Raindrops with Size. *J. Meteorol* 5: 165-166.

Mie, G. 1908. Beiträge zur Optik Trüber Medien, speziell kolloidaler Metalösungen. *Ann. Phys*. 26: 597-614.

McCollum, J., and R. Ferraro. 2003. Next generation of NOAA/NESDIS TMI, SSM/I, and AMSR-E microwave land rainfall algorithms. *Journal of Geophysical Research* - Atmospheres 108(D8): art. no. 8382.

Tesmer, J. R., and T. T. Wilheit. 1997. An Improved Microwave Radiative Transfer Model for Tropical Oceanic Precipitation. *Journal of Atmospheric Science* 55:1674-1688.

Wang, S. A. 1995. *Modeling the Beam Filling Correction for Microwave Retrieval of Oceanic Rainfall*. PhD dissertation. Dept of Meteorology; Texas A&M University

Wilheit, Thomas, C. Kummerow, and R. Ferraro. 2007. [Supplement] AMSR-E Monthly Level-3 Rainfall Accumulations: Algorithm Theoretical Basis Document. College Park, Texas USA: Texas A&M University. (PDF file, 243 KB)

Wilheit, T., C. Kummerow, and R. Ferraro. 2003. Rainfall algorithms for AMSR-E. *IEEE Transactions on Geosciences and Remote Sensing* 41(2): 204-214.

Wilheit, T., C. Kummerow, and R. Ferraro. 1999. EOS/AMSR Rainfall: Algorithm Theoretical Basis Document. College Park, Texas USA: Texas A&M University. (PDF file, 867 KB)

Wilheit, T. T., A. T .C. Chang, and L. S. Chiu. 1991. Retrieval of monthly rainfall indices from microwave radiometric measurement using probability distribution functions. *Journal of Atmospheric Oceanic Technology* 8: 118-136.

For more information regarding related publications, see the Research Using AMSR-E Data web page.

6 DOCUMENT INFORMATION

6.1 Publication Date

March 2004

6.2 Date Last Updated

02 April 2021