National Aeronautics and Space Administration Goddard Earth Science Data Information and Services Center (GES DISC)

README Document for Global Precipitation Climatology Project Version 3.2 Monthly Precipitation Data

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Revision History

Revision Date	*Changes*	*Author*
March 14, 2019	Original	George Huffman
July 29, 2020	Version 3.1	George Huffman
December 10, 2020	Update MCTG Reference	George Huffman
June 9, 2021	Update GES DISC contact email, explicitly mention “monthly”	George Huffman
February 1, 2022	Version 3.2	George Huffman

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1.0 Introduction

Precipitation observations are critical to research and many applications, including drought monitoring, flash floods, crop forecasting, disease prediction, and ocean salinity studies. Rain gauges are the primary source of direct precipitation observations. Unfortunately, rain gauges are point measurements and much of the globe is sparsely covered, especially in underdeveloped countries and areas of low population density. Furthermore, with the exception of a few buoy arrays, there are no precipitation gauge observations over the open ocean. Satellites seek to mitigate the limitations of rain gauge observations by estimating precipitation over land and ocean for most, or all, of the entire globe. When converted to gridded precipitation estimates, the satellite observations facilitate a multitude of studies, including those on the larger space-time scales that gauge analyses typically cannot provide. To augment the satellite-based precipitation estimates, uniformly processed gauge analyses are incorporated to improve the land-based estimates.

The Global Precipitation Climatology Project (GPCP) is a community-based activity of the Global Water and Energy Exchange (GEWEX) project in the World Climate Research Programme (WCRP), focused on creating a global, long-term homogeneous record of gridded precipitation estimates and ancillary information for use in climate studies and other applications. GPCP Version 3 is being developed as the successor to the highly successful GPCPV2 data set. This document introduces the GPCPV3.2 Monthly products; the Daily has been released, and the 3-hourly product is being developed.

This latest release, labeled V3.2, replaces V3.1 and V3.0, and is considered stable but has known limitations. Specifically, the TOVS/AIRS record is not as homogeneous as we expect for a CDR, and the IR input has some noticeable seams. The team continues to work toward improving these issues in a future release.

1.1 Dataset/Mission Instrument Description

The GPCP V3.2 Monthly data set provides a gridded (Level 3) homogeneously processed record of global precipitation estimates at 0.5° spatial and monthly temporal resolution. The current data span is 1983-2020 with the potential to extend this record in the future. The current monthly product provides the following data fields:

(1) merged satellite-gauge precipitation estimate,
(2) merged satellite-gauge precipitation random error estimate,
(3) satellite-only precipitation estimate,
(4) satellite source field,

(5) gauge analysis precipitation,
(6) probability of liquid phase,
(7) gauge relative weighting, and
(8) quality index.

1.1.1 GPCPV3.2

The GPCPV3.2 Monthly estimates rely on a relatively homogeneous record of satellite precipitation estimates and gauge analyses as input. Passive microwave (PMW) radiometer estimates are computed from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSMI) that flew on the F11 and F13 spacecraft, and Special Sensor Microwave Imager/Sounder (SSMIS) that is flying on the F17 spacecraft, all using the Goddard Profiling Algorithm Version 2010 Version 2 (GPROF2010v2) produced by Colorado State University (see *http://rain.atmos.colostate.edu/RAINMAP10v2/gprof_description.html*; Kummerow et al. 2011) and the Microwave Emission Brightness Temperature Histograms (METH; Chiu et al. 1993, Chiu and Chokngamwong 2010). Infrared data from the global collection of geosynchronous weather satellites are converted to precipitation estimates using the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks Climate Data Record (PERSIANN-CDR), which is produced by NOAA in conjunction with the National Centers for Environmental Information (NCEI; Ashouri et al. 2015). The NASA/GSFC Sounder Research Team provides precipitation estimates from the Television-InfraRed Operational Satellite (TIROS) Operational Vertical Sounder (TOVS) sensors that flew on selected TIROS- and NOAA-series satellites, and on the Advanced Infrared Sounder (AIRS) instrument aboard the Earth Observing System Aqua satellite (Susskind and Pfaendtner 1989; Susskind et al. 1997; Susskind et al. 2003; Susskind et al. 2014). The TRMM Combined Climatology (TCC) is provided by the University of Maryland, and the Merged CloudSat, TRMM and GPM (MCTG) climatology is provided by the University of Arizona. Finally, global gauge analyses are provided by the Deutscher Wetterdienst (DWD) Global Precipitation Climatology Centre (GPCC; Schneider et al. 2017; Schneider et al. 2014; Becker et al. 2013). These seven data sets form the basis of the GPCPV3.2 Monthly product. These data are merged via a set of algorithms to take advantage of the strengths of each data set and minimize the weaknesses to create a single, best precipitation estimate with associated ancillary fields. A brief algorithm description is provided in the next section.

1.2 Algorithm Background

The basis of the GPCPV3.2 Monthly algorithm is to use sparse, high-quality GPROF precipitation estimates, which span the range 90°N–90°S (although only considered reliable in the latitude band 60°N-S), to calibrate the more frequent, near-global (60°N–60°S) PERSIANN-CDR estimates. GPROF-based SSMI /SSMIS estimates are provided at the orbit level with ~15 orbits/day, METH-based SSMI/SSMIS precipitation estimates are provided for monthly 2.5° gridboxes over ocean, and the PERSIANN-CDR, based on IR estimates, covers the entire 60°N–60°S area every three hours. The GPROF Level 2 estimates are gridded to the 0.5° resolution, and the PERSIANN-CDR estimates are regridded from the native 0.25° resolution to the 0.5° resolution for consistency.

Calibration is performed by accumulating temporally matched GPROF estimates and PERSIANN-CDR estimates into a multi-level histogram for a calendar month. At the end of the month, a PERSIANN-CDR calibration look-up table is generated based on the histogram-matched estimates. The 3-hourly PERSIANN-CDR estimates are then calibrated to the GPROF estimates, accumulated for the month, and calibrated to the monthly METH estimates. The monthly PMW-calibrated PERSIANN-CDR estimates are adjusted by monthly climatological blended TCC/MCTG ratios as this provides the best long-term average (Adler et al. 2009; Wang et al. 2014; Behrangi et al. 2012; 2014; Behrangi and Song 2020). Starting at around 25°N and S the TOVS/AIRS estimates are increasingly weighted in with the (PMW-calibrated) PERSIANN-CDR (reflecting the fact that PERSIANN-CDR becomes less reliable at higher latitudes), reaching dominant weighting at 58°N and S, at the limits of PERSIANN-CDR coverage.

Starting at these latitudes the TOVS/AIRS estimates, adjusted by monthly climatological MCTG ratios, are used at the high latitudes (58°–90° N and S) to smoothly shift from a zonal average of the combination of PERSIANN-CDR and TOVS/AIRS at 58°N. Above 58° N over ocean, TOVS/AIRS adjusted by MCTG are used as is. Over land, between 58°N and 70°N, the combined PERSIANN-CDR and TOVS/AIRS transitions the zonal average of the available GPCC values at 70°N. 70°N was chosen as the highest latitude that provides reasonable gauge coverage. Note that the Legates-Wilmott wind-loss correction (Legates and Willmott 1990) is applied to the GPCC gauge analysis, with a climatology of the Fuchs et al. (2001) correction used over Eurasia poleward of 45°N. Above 70°N, the zonal-average GPCC adjustment ratio computed at 70°N is used. The corresponding 70°S zonal average is based on a climatological average of a historical collection of GPCC gauges since the gauge population is sparse and sporadic in that zone, and GPCC no longer analyzes precipitation over Antarctica. This field constitutes the satellite-only estimate even though it contains gauge influence at higher latitudes.

Because the GPROF estimates are currently only continuously available starting in January 1992, the period January 1983 – December 1991 is based on PERSIANN-CDR that has been seasonally climatologically calibrated to the PMW-calibrated PERSIANN-CDR for the overlap period January 1993 – December 2018.

Next, the global satellite-only estimates and the global wind-loss-corrected GPCC gauge analysis are merged. The first step in the merge process is to adjust the satellite-only estimate to the large-scale mean of the gauge analysis. The second step is to merge the adjusted satellite-only estimate with the GPCC gauge analysis based on inverse error variance to produce the final precipitation estimate.

Finally, the field of Probability of Liquid Phase is computed based on MERRA2 analyses of surface temperature, humidity, and pressure using a diagnostic lookup table developed by Sims and Liu (2015). Following Sims and Liu, the not-liquid precipitation class is “solid” (snow, graupel, etc.), while the relatively rare “mixed” precipitation class (both liquid and solid in a single observation) is included in “liquid”, since mixed is presumed to generally melt and therefore be a liquid.

Details of the algorithm can be found in Huffman et al. (2022).

1.3 Data Limitations

GPCPV3.2 Monthly is the second release of the GPCPV3 Monthly data set and is considered stable but has some known limitations. Specifically, the period January 1983 – December 1991 lacks GPROF estimates, so GPCPV3.2 is based on seasonal climatological calibration of the PERSIANN-CDR estimates during this period, introducing a possible inhomogeneity in the data record. Also, the TOVS/AIRS record is not as homogeneous as we expect for a CDR, and the IR input on which PESIANN-CDR is based has some noticeable seams. Users should account for these limitations in the use of the V3.2 Monthly data. The team continues to work toward improving these issues in a future release.

The GPCPV3.2 Monthly data set was carefully constructed to produce global, homogeneous precipitation estimates, so users should use all estimates provided. To determine the relative errors for each grid box, users can examine the satellite-gauge precipitation random error field. Errors over land will vary greatly depending upon the gauge density. For example, areas such as the U.S., Europe, and eastern Australia will have lesser error due to substantial gauge density, whereas areas such as central Africa, which is deficient in gauge coverage, will have reduced quality. Over ocean, the quality of the input data is fairly uniform, so the associated error estimates will be correspondingly uniform.

1.3.1 Data Citation

The data set source should be acknowledged when the data are used. The American Meteorological Society guidelines contain suggested formats for referencing data sets (*https://www.ametsoc.org/ams/index.cfm/publications/authors/journal-and-bams-authors/formatting-and-manuscript-components/references/dataset-references/*). Following their example for data that are dynamically updated with uniformly computed processing runs:

Huffman, G.J., A. Behrangi, D.T. Bolvin, E.J. Nelkin, 2022: GPCP Version 3.2 Monthly SG Combined Precipitation Data Set, last updated January 21, 2022. GES DISC, Greenbelt, MD, accessed February 12, 2022, https://doi.org/ 10.5067/MEASURES/GPCP/DATA304

1.3.2 Contact Information

If you have general questions or comments regarding the GPCPV3.2 Monthly data set, please contact George Huffman (*george.j.huffman@nasa.gov*), while questions about accessing and reading the data should be directed to Zhong Liu (*zhong.liu-1@nasa.gov*).

1.4 What's New?

GPCPV3.2 Monthly is the follow-on to the initial V3.1 release. Rolling up improvements over V2.3, V3.2 includes:

- consistent GEO-IR Tb datasets, expanded from 40° N-S to 60° N-S
- upgraded PMW and IR algorithms
- consistent AIRS-IR record
- shift from calibration of AIRS-to-TOVS to improved TOVS-to-AIRS-IR
- modern climatological calibrators (TCC over 20° N-S, MCTG outside 35° N-S, blended cross-over in between) applied to both PERSIANN-CDR and TOVS/AIRS
- new data fields: probability of liquid phase, gauge relative weighting, quality index
- Fuchs gauge undercatch coefficients substituted for Legates-Wilmott over Eurasia (above 45°N)

2.0 Data Organization

The dataset consists of monthly data, one file per month.

2.1 File Naming Convention

GPCPMON_L3_yyyymm**_V3.2.nc4**

Where:
- yyyy = 4 digit year number [1983-2020].
- mm = 2 digit month number [01-12]

Filename example: GPCPMON_L3_200702_V3.2.nc4

2.2 File Format and Structure

Data set files are in netCDF version 4 format developed at the University Corporation for Atmospheric Research (UCAR) and Unidata (https://www.unidata.ucar.edu/software/netcdf/), with extensions that facilitate the creation of Grid, Point, and Swath data structures. The GPCP V3.2 Monthly dataset uses the Grid structure.

2.3 Key Science Data Fields

See tables in Section 3.3 for lists of data fields.

3.0 Data Contents

3.1 Dimensions

Each netCDF file contains three dimensions:

latitude – latitude of the center of each row of data (WGS84 reference datum). This one-dimensional array has 360 elements.

longitude – longitude of the center of each column of data (WGS84 reference datum). This one-dimensional array has 720 elements.

time – the begin and end times of the month in minutes since January 1, 1979 00:00. This two-dimensional array has 1 x 2 elements.

3.2 Global Attributes

In addition to SDS arrays containing variables and dimension scales, global metadata is also stored in the files. Some metadata are required by standard conventions, some are provided to meet data provenance requirements, and others are provided as a convenience to users of GPCP V3.2 products. A summary of global attributes present in all files is shown in Table 1.

A list of key metadata fields is given in Table 2. These and other metadata fields can found in the "**CoreMetadata.0**" global attribute. Global attributes in a GPCP V3.2 file can be viewed with *ncdump* software as described in Section 4.1 [*ncdump –h –c <GPCPV3.2 file>*].

Table 1. Global metadata attributes associated with each SDS.

Attribute Name	Description	Data Type
ShortName	GES DISC short name	string
LongName	GES DISC long name	string
VersionID	version identification number	string
LocalGranuleID	dataset file name	string
Format	dataset format (netCDF-4)	string
RangeBeginningDate	data begin date	string
RangeBeginningTime	data begin time	string
RangeEndingDate	data end date	string
RangeEndingTime	data end time	string
ProductionDateTime	file production date time	string
Conventions	file convention (CF-1.5)	string
Northernmost_Latitude	northernmost latitude contained in the file	float
Southernmost_Latitude	southernmost latitude contained in the file	float
Westernmost_Longitude	westernmost longitude contained in the file	float
Easternmost_Longitude	easternmost longitude contained in the file	float
Latitude_Resolution	latitudinal resolution of the data	float
Longitude_Resolution	longitudinal resolution of the data	float
Entry_ID	GES DISC dataset identifier	string
Entry_Title	GES DISC dataset title	string
Title	description of the dataset	string
Science_Keywords	dataset keywords	string
ISO_Topic_Category	ISO standard dataset category	string
Data_Center_ShortName	GES DISC short name	string
Data_Center_LongName	GES DISC long name	string
Data_Center_URL	GES DISC URL	string
Data_Center_Role	GES DISC role	string
Data_Center_Last_Name	GES DISC support group name	string
Data_Center_Email	GES DISC email	string
Data_Center_Phone	GES DISC phone number	string
Data_Center_Fax	GES DISC Fax number	string
Data_Center_Address	GES DISC address	string
Data_Set_Progress	current state of the dataset	string
Data_Set_Quality	description of the quality of the dataset	string
Summary	description of the dataset	string
Validation_Data	data used to validate the dataset	string
Source	dataset input sources	string
MapProjection	dataset map projection	string
Dataset_Creator	dataset creators	string
Dataset_Title	full dataset title	string
Dataset_Series_Name	dataset name	string
Dataset_Release_Date	release date of current dataset	string
Datset_Release_Place	address of current release	string
Dataset_Publisher	publisher of current dataset	string
IdentifierProductDOI	dataset DOI	string
Data_Presentation_Form	dataset type	string
RelatedURL	alternative URL for the dataset	string
References	dataset references	string

Table 1, continued.

Attribute Name	Description	Data Type
Role	role identifier (science investigator)	string
First_Name	first name of investigator	string
Last_Name	last name of investigator	string
Phone	phone number of science investigator	string
FAX	fax number of science investigator	string
Email	email of science investigator	string
Contact_Address	street address of science investigator	string
City	city of science investigator	string
Province_or_State	state of science investigator	string
Postal_Code	zip code of science investigator	string
Country	country of science investigator	string
Use_Constraints	constraints on the use of the dataset	string
Distribution_Media	form of dataset access	string
Distribution_Size	size of dataset file	string
Distribution_Format	dataset format (netCDF-4)	string
IdentifierProductDOIAuthority	DOI authority	string
ProcessingLevel	dataset processing level	string
Institution	where the data were produced	string
Fees	costs for use of the dataset	string

Table 2. Key Metadata Items

Name	Type	Description
_FillValue	float or short int	Value used to identify missing data.
long_name	string	ad hoc description of the variable.
valid_range	float or short int	valid data value ranges for the variable
units	string	The units of the variable.
cell_methods	string	Temporal unit of data

3.3 Products/Parameters

The list of data fields contained in each GPCP V3.2 Monthly dataset is given in Table 3, together with brief descriptions and native units.

Table 3. Data fields in the GPCP V3.2 Monthly dataset. The latitude/longitude use the WGS84 reference datum.

Data Field Name	Description	Units
latitude	latitude of the center of the grid element	degrees_north
longitude	longitude of the center of the grid element	degrees_east
time	begin date and time of the data	minutes since 1979-01-01 00:00:00
sat_gauge_precip	combined satellite-gauge precipitation estimate	mm/day
sat_gauge_error	combined satellite-gauge precipitation random error estimate	mm/day
satellite_precip	satellite-only precipitation estimate	mm/day
satellite source	source of the contributing satellite estimate *	index values
gauge_precip	wind-loss adjusted gauge precipitation	mm/day
probability_liquid_phase	probability of liquid phase precipitation	percent
gauge_relative_weight	relative weighting of gauges in sat_gauge_precip	percent
quality index	equivalent number of gauges	unitless

* The satellite source field has the index values 0 = PMW-adj. IR, 2 = blend of PMW-adj. IR and TOVS/AIRS, 4 = TOVS/AIRS.

4.0 Options for Reading the Data

It is important that the GPCP V3.2 Monthly be as accessible as possible to a wide range of users. The MEaSUREs project selected netCDF as it is designed to store scientific data and is easily accessible with command-line tools and standard application packages. If you have trouble reading the data please contact Zhong Liu at zhong.liu-1@nasa.gov.

4.1 Command Line Utilities

There are several built-in netCDF utilities that are available to access the GPCP V3.2 Monthly data. See *https://www.unidata.ucar.edu/software/netcdf* for a complete list of netCDF command-line utilities. The most useful is *ncdump*:

ncdump

The ncdump tool can be used as a simple browser for netCDF data files, to display the dimension names and sizes; variable names, types, and shapes; attribute names and values. The most common use of ncdump is with the –h option, in which only the header information is displayed.

```
ncdump [-c|-h] [-v ...] [[-b|-f] [c|f]] [-l len] [-n name] [-d n[,n]] filename
Options/Arguments:
    [-c]  Coordinate variable data and header information
    [-h]  Header information only, no data
    [-v var1[,...]]  Data for variable(s) <var1>,... only data
```

[-f [c|f]] Full annotations for C or Fortran indices in data
[-l len] Line length maximum in data section (default 80)
[-n name] Name for netCDF (default derived from file name)
[-d n[,n]] Approximate floating-point values with less precision
filename File name of input netCDF file

4.2 Tools/Programming

Any application package that supports the netCDF file format can be used to read these data. If you are new to netCDF or to the GPCP V3.2 datasets, the following tool might be a useful starting point:

- Panoply **(***https://www.giss.nasa.gov/tools/panoply/*)

For more advanced users or programmers:

- C/C++
- Fortran 90/95
- GrADS (*http://cola.gmu.edu/grads/*)
- IDL (*http://www.harrisgeospatial.com/SoftwareTechnology/IDL.aspx*)
- Java
- Matlab (*http://www.mathworks.com/products/matlab/*)
- Python

As well, the GPCP V3.2 Monthly data are accessible through the Giovanni web-based visualization and analysis application, *https://giovanni.gsfc.nasa.gov/giovanni/.*

5.0 Data Services

The data are currently available through the **Data Holdings** page of the **MEaSUREs portal** at *https://disc.gsfc.nasa.gov/measures*.

If you need assistance or wish to report a problem:
Email: gsfc-dl-help-disc@mail.nasa.gov
Voice: 301-614-5224
Fax: 301-614-5268
Address:
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6.0 More Information

For more information on our project or data, please refer to the Algorithm Theoretical Basis Document (Huffman et al. 2022).

7.0 Acknowledgements

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References

Adler, R.F., J.-J. Wang, G. Gu, G.J. Huffman, 2009: A Ten-Year Tropical Rainfall Climatology Based on a Composite of TRMM Products. *J. Meteorol. Soc. Japan*, **87A**, 281-293.

Ashouri, H., K-L. Hsu, S. Sorooshian, D.K. Braithwaite, K.R. Knapp. L.D. Cecil, B.R. Nelson, O.P. Prat, 2015: PERSIANN-CDR, Daily Precipitation Climate Data Record from Multisatellite Observations for Hydrological and Climate Studies. *Bull. Amer. Meteor. Soc.*, 96, 69-83. *doi:10.1175/BAMS-D-13-00068.1*

Becker, A., P. Finger, A. Meyer-Christoffer, B. Rudolf, K. Schamm, U. Schneider, M. Ziese, 2013: A Description of the Global Land-Surface Precipitation Data Products of the Global Precipitation Climatology Centre with Sample Applications Including Centennial (Trend) Analysis from 1901–Present. *Earth Syst. Sci. Data*, **5**, 71-99. *Doi:10.5194/essd-5-71-2013*

Behrangi, A., G. Stephens, R.F. Adler, G.J. Huffman, B. Lambrigtsen, M. Lebsock, 2014: An Update on the Oceanic Precipitation Rate and Its Zonal Distribution in Light of Advanced Observations from Space. *Journal of Climate,* **27**, 3957-3965. *doi:10.1175/jcli-d-13-00679.1*

Behrangi, A., M. Lebsock, S. Wong, B. Lambrigtsen, 2012: On the quantification of oceanic rainfall using spaceborne sensors. *J. Geophys. Res. Atmos.*, **117**. *doi:10.1029/2012jd017979*

Behrangi, A., Y. Song, 2020: A New Estimate for Oceanic Precipitation Amount and Distribution Using Complementary Precipitation Observations from Space and Comparison with GPCP. *Environ. Res. Lett.*, **15**. *doi:10.1088/1748-9326/abc6d1*

Chiu, L., A. Chang, J.E. Janowiak, 1993: Comparison of Monthly Rain Rates Derived from GPI and SSM/I Using Probability Distribution Functions. *J. Appl. Meteor.*, **32**, 323–334. *doi: 10.1175/1520-0450(1993)032<0323:COMRRD>2.0.CO;2*

Chiu, L.S., R. Chokngamwong, 2010: Microwave Emission Brightness Temperature Histograms (METH) Rain Rates for Climate Studies: Remote Sensing Systems SSM/I Version6 Results. *J. Appl. Meteor. Climatol.*, **49**, 115-123. *doi:10.1175/2009JAMC2204.1*

Fuchs, T., J. Rapp, F. Rubel, B. Rudolf, 2001: Correction of Synoptic Precipitation Observations Due to Systematic Measuring Errors with Special Regard to Precipitation Phases. *Phys. Chem. Earth Part B Hydrol. Oceans Atmos.*, **26**, 689–693. *doi: 10.1016/S1464-1909(01)00070-3*

Huffman, G.J., R.F. Adler, A. Behrangi, D.T. Bolvin, E.J. Nelkin, M.R. Ehsani, 2022: Algorithm Theoretical Basis Document (ATBD) for Global Precipitation Climatology Project Version 3.2 Monthly Precipitation Data. MEaSUREs project, Greenbelt, MD, 32 pp. Available online: *https://docserver.gesdisc.eosdis.nasa.gov/public/project/MEaSUREs/GPCP/GPCP_ATBD_V3.2_Monthly.pdf* (last accessed: January 21, 2022).

Kummerow, C.D., S. Ringerud, J. Crook, D. Randel, W. Berg, 2011: An Observationally Generated A Priori Database for Microwave Rainfall Retrievals. *J. Atmos. Oc. Technol.*, **28**, 113-130. *doi:10.1175/2010JTECHA1468.1*

Legates, , D.R., C.J. Willmott, 1990: Mean Seasonal and Spatial Variability in Gauge-Corrected, Global Precipitation. *Internat. J. Climatol*., **10**, 111-127.

Schneider, U., A. Becker, P. Finger, A. Meyer-Christoffer, M. Ziese, B. Rudolf, 2014: GPCC's New Land Surface Precipitation Climatology Based on Quality-Controlled In Situ Data and its Role in Quantifying the Global Water Cycle. *Theor. Appl. Climatol.,* **115**, 15, *doi:10.1007/s00704-013-0860-x*

Schneider, U., P. Finger, A. Meyer-Christoffer, E. Rustemeier, M. Ziese, A. Becker, 2017: Evaluating the Hydrological Cycle over Land Using the Newly-Corrected Precipitation Climatology from the Global Precipitation Climatology Centre (GPCC). *Atmosphere*, **8**, 52, *doi:10.3390/atmos8030052*

Sims, E.M., and G. Liu, 2015: A Parameterization of the Probability of Snow–Rain Transition. *J. Hydrometeor*., **16**, 1466–1477. *doi:10.1175/JHM-D-14-0211.1*

Susskind, J., C.D. Barnet, J.M. Blaisdell, 2003: Retrieval of Atmospheric and Surface Parameters from AIRS/AMSU/HSB Data in the Presence of Clouds. *IEEE Trans. Geosci. Rem. Sens*., **41**, 390-409. *doi:10.1109/TGRS.2002.808236*

Susskind, J.M. Blaisdell, L. Iredell, 2014: Improved Methodology for Surface and Atmospheric Soundings, Error Estimates, and Quality Control Procedures: The Atmospheric Infrared Sounder Science Team Version-6 Retrieval Algorithm. *J. Appl. Rem. Sens*., **8**, Art. No. 084994. *doi:10.1117/1.JRS.8.084994*

Susskind, J., J. Pfaendtner, 1989: Impact of Interactive Physical Retrievals on NWP. *Report on the Joint ECMWF/EUMETSAT Workshop on the Use of Satellite Data in Operational Weather Prediction: 1989-1993, Vol. 1*, T. Hollingsworth, Ed., ECMWF, Shinfield Park, Reading RG2 9AV, U.K., 245-270.

Susskind, J., P. Piraino, L. Rokke, L. Iredell, A. Mehta, 1997: Characteristics of the TOVS Pathfinder Path A Dataset. *Bull. Amer. Meteor. Soc*., **78**, 1449-1472.

Wang, J., R.F. Adler, G.J. Huffman, and D. Bolvin, 2014: An Updated TRMM Composite Climatology of Tropical Rainfall and Its Validation. *J. Climate,* **27**, 273–284. *doi:10.1175/JCLI-D-13-00331.1*