# SAFARI 2000 GPCP Daily Precipitation, 1-Deg, 1999-2001

## Abstract

The Global Precipitation Climatology Project (GPCP) is an international project designed to provide improved long-record estimates of precipitation over the globe. The general approach is to combine the precipitation information available from several sources into a final merged product that takes advantage of the strengths of each data type. The GPCP has promoted the development of an analysis procedure for blending the various estimates together to produce the necessary global gridded precipitation fields. The currently operational procedure is based on Huffman et al. (1995) and has been used to produce the GPCP Version 2 Combined Precipitation Data Set, covering the period January 1979 through the present. The primary product in the Version 2 dataset is a combined observation-only dataset, that is, a gridded analysis based on gauge measurements and satellite estimates of rainfall. Beginning in October of 1996, the GPCP began producing 3-hourly merged global infrared (IR) brightness temperature ($T_b$) histograms on a 1 degree by 1 degree grid, which became the impetus for this product, also known as the 1 degree daily (1DD) product. The data set prepared for SAFARI 2000 has been extracted from the 1DD data set for the years 1999, 2000, and 2001.

The Global Precipitation Climatology Project (GPCP) is an element of the Global Energy and Water Cycle Experiment (GEWEX) of the World Climate Research program (WCRP). The 1DD is produced by the GPCP Merge Development Centre (GMDC), located at NASA's Goddard Space Flight Center in the Laboratory for Atmospheres.

## Background Information

**Investigators:**
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David. T. Bolvin

**Project:** Global Precipitation Climatology Project (GPCP)

**Data Set Title:** SAFARI 2000 GPCP Daily Precipitation, 1-Deg, 1999-2001

**Site:** Southern Africa
**Westernmost Longitude:** 20° E
**Easternmost Longitude:** 50° W
**Northernmost Latitude:** 10° N
**Southernmost Latitude:** 50° S

**Data Set Citation:**

Huffman, George J., R. F. Adler, and D. T. Bolvin. 2004. SAFARI 2000 GPCP Daily Precipitation, 1-Deg, 1999-2001. Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

**GPCP Home Page:** http://orbit-net.nesdis.noaa.gov/arad/gpcp/ [Internet Link]
**NASA GSFC Laboratory for Atmosheres -- Global Precipitation Analysis:** http://precip.gsfc.nasa.gov/ [Internet Link]

## Data File Information

The data files are stored as monthly files of daily images. The daily images are stored in a band sequential [BSQ] format (one after the other) within the monthly files. The files for each month vary in size depending upon the number of days in the month (28, 29, 30, or 31). There may be some trailing bytes at the end of the monthly files, these are an artifact of the image processing system that produced the files and can be ignored.

Monthly multiband GPCP precipitation images were downloaded from the Global Precipitation Analysis page (http://precip.gsfc.nasa.gov/ [Internet Link]) within the GSFC Laboratory for Atmospheres. The global images were 360 sample by 180 line Real*4 images with 1440 byte headers. The files were oriented with an upper left corner of 90 degrees North at the Prime Meridian. The monthly files of daily imagery were ingested into the PCI image processing package and the East and West hemispheres were switched so that the upper-left corner was 90 degrees North and 180 degrees West. With the Prime Meridian now at the center of the image, southern Africa subsets were extracted starting at sample 161 and line 81, and are 71 samples by 61 lines in size. The data set prepared for Safari covers the years 1999, 2000, and 2001.

The machine on which the data files where originally created was a Silicon Graphics, Inc. Unix workstation, which uses the "big-endian" IEEE 754-1985 representation of REAL*4 unformatted binary words. Some CPUs including PCs and DEC machines may

require a change of representation before using the data.

**Image Parameters**

| | |
|---|---|
| Number of samples | 71 |
| Number of lines | 61 |
| Number of bands (days) per file | 28, 29, 30, or 31 |
| Bytes per pixel | 4 (REAL*4 big-endian) |
| Data Range | -99999 to ????? |
| Fill Value (missing or not valid) | -99999 |
| Data Units | millimeters/day |
| Pixel size | one degree by one degree |
| Projection | Cylindrical Equal Distance |

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## Imagery Creation Dates

The header records from the original 1DD imagery provides some important information that was not retained when the subsets of southern Africa were extracted. Some of this information was pertinent only to the global images, most of the rest has been incorporated in this document. However, the creation date from the headers were not retained and are provided in the table below in the form YYYYMMDD. Note: all the 1DD data on this CD-ROM volume were pulled from the GPCP FTP site in May 2002.

The creation dates for the imagery provided are as follows:

| Year | Month | Creation Date |
|---|---|---|
| 1999 | 1 | 20001005 |
| | 2 | 20001005 |
| | 3 | 20001005 |
| | 4 | 20001005 |
| | 5 | 20001005 |
| | 6 | 20001005 |
| | 7 | 20001005 |
| | 8 | 20001005 |
| | 9 | 20001005 |
| | 10 | 20001005 |

| Year | Month | Creation Date |
|---|---|---|
| 2000 | 1 | 20010418 |
| | 2 | 20010301 |
| | 3 | 20010301 |
| | 4 | 20010301 |
| | 5 | 20010301 |
| | 6 | 20010301 |
| | 7 | 20010301 |
| | 8 | 20010301 |
| | 9 | 20010301 |
| | 10 | 20010301 |

| Year | Month | Creation Date |
|---|---|---|
| 2001 | 1 | 20010419 |
| | 2 | 20010604 |
| | 3 | 20010628 |
| | 4 | 20010801 |
| | 5 | 20010814 |
| | 6 | 20010904 |
| | 7 | 20011017 |
| | 8 | 20011102 |
| | 9 | 20020201 |
| | 10 | 20020205 |

| | | |
|---|---|---|
| | 11 | 20001005 |
| | 12 | 20010301 |

| | | |
|---|---|---|
| | 11 | 20010301 |
| | 12 | 20010328 |

| | | |
|---|---|---|
| | 11 | 20020329 |
| | 12 | 20020402 |

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## Data Sources

The 1DD Data Set contains data from several sources:

1. GPCP Geostationary Satellite Precipitation Data Centre (IR brightness temperature histograms),
2. GPCP Merge Development Centre (GPCP SG Merged Precipitation estimate and GPROF 6.0 SSM/I fractional occurrence), and
3. GSFC Satellite Data Utilization Office (TOVS precipitation estimates).

Some of these data sets extend beyond the 1DD period in their original archival locations. Some of the single-source data sets are available from other archives at a finer resolution.

The temporal resolution of the products is one day. The temporal resolution of the original single-source data sets varies.

| Source | Temporal Resolution |
|---|---|
| geo-IR | 3 hourly |
| leo-IR | 3 hour accumulations |
| GPROF | instantaneous |
| GPCP SG | monthly |
| TOVS | daily |

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## Sensors

**SSMI**

The Special Sensor Microwave/Imager (SSM/I) is a multi-channel passive microwave radiometer that has flown on selected Defense Meteorological Satellite Program (DMSP) platforms since mid-1987. The conical scanning SSM/I provides vertical and horizontal polarization values for 19, 22, 37, and 85 GHz frequencies (vertical only at 22 GHz). The channels have resolutions that vary from 12.5x15 km for the 85 GHz to 60x75 km for the 19

GHz.

The polar orbit provides nominal coverage over the 85N-S latitude range, although limitations in retrieval techniques prevent useful precipitation estimates in cases of cold land (scattering), land (emission), or sea ice (both scattering and emission).

### IR

The infrared (IR) data are collected from a variety of sensors. The primary source of IR data is the international constellation of geosynchronous-orbit meteorological satellites -- GOES, (US), GMS (Japan), and Meteosat (EU). There are usually two GOES platforms active, GOES-EAST and -WEST, which cover the eastern and western United States, respectively. Gaps in geosynchronous coverage (most notably over the Indian Ocean prior to June 1998) must be filled with IR data from the NOAA-series polar-orbiting meteorological satellites. The geosynchronous data are collected by scanning (parts of) the Earth's disk, while the polar-orbit data are collected by cross-track scanning. The data are accumulated for processing from full-resolution (4x8 km) images.

### TOVS

The TOVS data are collected from the High-Resolution Infrared Sounder 2 (HIRS2), Microwave Sounding Unit (MSU), and Stratospheric Sounding Unit (SSU) instruments on the NOAA series of polar orbiting meteorological satellites. There are usually two such satellites with orbits roughly in quadrature. The data are accumulated for processing at varying resolutions, but the effective resolution of the retrievals is about 60x60 km.

## Computing the Combined Estimates

### Geo-IR and Leo-IR

The IR Tb histogram data set is produced by the Geostationary Satellite Precipitation Data Centre (GSPDC) of the GPCP under the direction of J. Janowiak, located in the Climate Prediction Center, NOAA National Centers for Environmental Prediction, Washington, DC, 20233 USA. Each cooperating geostationary (geo) satellite operator [the Geosynchronous Operational Environmental Satellites, or GOES (United States); the Geosynchronous Meteorological Satellite, or GMS (Japan); and the Meteorological Satellite, or Meteosat (European Community)] accumulates three-hourly infrared (IR) imagery. These are forwarded to GSPDC as 24-class histograms of Tb on a 1x1-deg lat/lon grid. The global geo-IR are then merged on a global grid.

In parallel, the NOAA-series low-earth-orbit (leo) satellite operator (United States) provides Global Precipitation Index (GPI) values on a 1x1-deg lat/lon grid accumulated to the nearest 3-hourly time. These data are used as input to 1DD processing.

**GPROF**

The Goddard Profiling Algorithm (GPROF) fractional occurrence of precipitation is computed as the ratio of the number of pixels with precipitation to the total number of valid pixels, both accumulated on a 0.5 x 0.5-deg lat/lon grid swath by swath.

The GPROF Version 6.0 is based on Kummerow et al. (1996) and Olson et al. (1999). Summarizing, GPROF is a multichannel physical approach for retrieving rainfall and vertical structure information from satellite-based passive microwave observations (here, SSM/I). Version 6 applies a Bayesian inversion method to the observed microwave brightness temperatures using an extensive library of cloud-model-based relations between hydrometeor profiles and microwave brightness temperatures. Each hydrometeor profile is associated with a surface precipitation rate. GPROF includes a procedure that accounts for inhomogeneities of the rainfall within the satellite field of view. Over land and coastal surface areas the algorithm reduces to a scattering-type procedure using only the higher-frequency channels. This loss of information arises from the physics of the emission signal in the lower frequencies when the underlying surface is other than all water. These data are used as input to 1DD processing.

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**TOVS**

The TIROS Operational Vertical Sounder (TOVS) precipitation estimate is computed from a regression relationship between collocated rain gauge measurements and several TOVS-based parameters that relate to cloud volume: cloud-top pressure, fractional cloud cover, and relative humidity profile. The relationship is allowed to vary seasonally and latitudinally. The data are delivered for daily nodes (ascending|descending) on a 1x1-deg grid. These data are used as input to 1DD processing.

See Susskind and Pfanendtner (1989) and Susskind et al. (1997) for additional details.

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**GPI**

The GPI technique is based on the use of geostationary satellite IR observations. Colder IR brightness temperatures are directly related to higher cloud tops, which are loosely related to increased precipitation rates. An empirical relationship between brightness temperature and precipitation rate was developed from data collected during the Global Atmospheric Research Programme (GARP) Atlantic Tropical Experiment (GATE). For a brightness temperature <= 235K, a rain rate of 3 mm/hour is assigned. For a brightness temperature > 235K, a rain rate of 0 mm/hour is assigned. The GPI works best over space and time averages of at least 250 km and 6 hours, respectively, in oceanic regions with deep convection.

Starting with October 1996 the GPI data are accumulated on a 1x1-deg lat/lon grid for individual 3-hourly images. In this case monthly totals are computed as the sum of all

available hours in the month.

These data are used as input to the GPCP Satellite-Gauge Precipitation Product and the leo-GPI are used as input to the TMPI.

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**AGPI**

The GPCP Merge Development Centre produces the AGPI precipitation as part of the GPCP Version 2 Combined Precipitation Data Set. The technique follows the Adjusted GPI (AGPI) of Adler et al. (1994).

During the SSM/I period (starting July 1987), separate monthly averages of nearly coincident GPI and merged SSM/I-TOVS precipitation are formed by taking cut-outs of the 3-hourly GPI values that correspond most closely in time to the local overpass time of the DMSP platform. The ratio of merged SSM/I-TOVS to GPI averages is computed and controlled to prevent unstable values. In regions of light precipitation an additive adjustment is computed as the difference between merged SSM/I-TOVS that has been smoothed, and ratio-adjusted GPI values when the merged SSM/I-TOVS is greater. The spatially varying arrays of adjustment coefficients are then applied to the full set of GPI estimates. In regions lacking geo-IR data, leo-GPI data are calibrated to the merged SSM/I-TOVS, these calibrated leo-GPI are then calibrated to the geo-AGPI. This two-step process tries to mimic the information contained in the AGPI, namely the local bias of the SSM/I and possible diurnal cycle biases in the geo-AGPI. The second step can only be done in regions with both geo- and leo-IR data, and then smooth-filled across the leo-IR fill-in.

These data are used as input to the GPCP Satellite-Gauge Precipitation Product.

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**GPCP SG**

The GPCP satellite-gauge (SG) precipitation product is produced as part of the GPCP Version 2x79 Combined Precipitation Data Set by the GPCP Merge Development Centre (GMDC). The technique is similar to the Version 1 described in Huffman et al. (1997). The monthly data are delivered on a 2.5 x 2.5-deg grid.

The combination of satellite data into a multi-satellite (MS) product is carried out differently according to data availability. Strong efforts were made to homogenize the data record:

- The period mid-1987 to the present uses geo-IR, leo-IR, TOVS, and SSM/I data. This is the combination that contributes to the 1DD. TOVS is merged in with SSM/I where the SSM/I is suspect (outside about 45 degrees N-S) or missing. Then SSM/I and geo-IR are approximately time-matched to compute local coefficients to adjust the full geo-IR GPI to the bias of the SSM/I in the 40 degrees N-S band. As well, leo-IRGPI is approximately scaled to the SSM/I. The AGPI is built from geo-IR AGPI where

possible and leo-IR AGPI elsewhere. The MS is composed of AGPI in the band 40 degrees N-S and the merged TOVS-SSM/I elsewhere.
- The period before mid-1987 is handled differently, but is not relevant to this 1DD product.

In each of the periods the MS and a gauge analysis are linearly combined into a satellite-gauge (SG) combination using weighting by inverse estimated mean-square error for each. The 1DD values are calibrated to sum to the SG on a monthly basis.

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**TMPI**

The Threshold Matched Precipitation Index (TMPI) provides GPI-like precipitation estimates in which both the IR $T_b$ threshold and the conditional rain rate for rain pixels are set locally in time and space:

- The geo-IR $T_b$ threshold ($T_{b0}$) is set locally from month-long accumulations of time/space coincident geo-IR $T_b$ and GPROF-SSM/I-based fractional occurrence of precipitation.
- The conditional rain rate is set locally from the resulting frequency of $T_b<T_{b0}$ for the ENTIRE month and the GPCP SG.
- Separately, leo-IR GPI are processed like the TOVS (see "ATOVS") because they suffer a similar over-estimate of precipitation frequency.

The available geo-IR histograms in each 3-hourly global image are processed into precipitation estimates, and the adjusted leo-GPI data are used to fill holes in the individual 3-hourly geo-IR images. Then all the available images in a UTC day (00Z, 03Z, ..., 21Z) are averaged to produce the daily estimate (on a 1x1-deg grid). These data are produced as intermediate files in 1DD processing.

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**ATOVS**

The Adjusted TOVS is produced outside 40 degrees N-S to make the 1DD globally complete. The Susskind et al. (1997) precipitation estimates from TOVS were considered to have too large a number of rain days, and we wanted to maintain consistency with the monthly GPCP SG.

Accordingly, we revise the TOVS estimates by:

- computing the ratio of TMPI rain days to TOVS rain days separately for 39-40 degrees N and 39-40 degrees S;
- using the corresponding ratio in each grid box over the entire hemisphere to reduce the

occurrence of TOVS precipitation by zeroing the (1-ratio) smallest daily TOVS rain accumulations; and
- rescaling the remaining (non-zero) TOVS rain days to sum to the monthly SG.

The daily data are gridded at 1x1 deg. These data are produced as intermediate files in 1DD processing.

## The 1DD Approach

The 1DD precipitation data set is a first approach to estimating global daily precipitation at the 1x1-degree scale strictly from observational data. It is composed of TMPI where available (40N-S) and ATOVS elsewhere. The data boundaries at 40 degrees N and S do not exhibit serious problems, probably because both the TMPI and ATOVS are responding to CLOUD features. Nevertheless, smoothing was performed at the data boundaries as follows:

- the (TMPI-ATOVS) difference was computed at all grid boxes in the bands 39-40 degrees N and 39-40 degrees S,
- the difference field is smooth-filled between the actual differences at 40 degrees N and S and a zero value at 45 degrees N and S, respectively,
- the difference field is added to the ATOVS field.

The smoothing improves continuity across the data boundary at the expense of modifying the fractional occurrence field and causing some "feathering" along sharp features.

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## Validation Results

The 1DD intercomparison results are still being developed. The time series of the global images shows good continuity in time and spatially across the data boundaries. An early validation against the Oklahoma Mesonet by the Surface Reference Data Center (SRDC) appears to show underestimation during the spring and fall (by about 20 and 15%, respectively), and overestimation during the summer (by about 20%). Mean absolute error (correlation) peaks (is minimum) in summer and is a minimum (peaks) in winter. An independent study of large-area averages over the Baltic drainage basin show reasonable behavior in all seasons (Rubel and Rudolph, 1999). Overall, the 1DD appears to be working as expected in both the TMPI and TOVS data (Oklahoma and the Baltic, respectively).

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## Updates

Updates will be released to (1) extend the data record, (2) take advantage of improved combination techniques, or (3) correct errors. Updates resulting from the last two cases will be given new version numbers.

> **NOTE:** The changes described in this section are typical of the changes that are required to keep the GPCP Combined Precipitation Data Set abreast of current requirements and science. Users are strongly encouraged to check the site http://precip.gsfc.nasa.gov/gpcp_daily_comb.html [Internet Link] periodically for upgrades, and to refer other users to that site rather than redistributing data that are potentially out of date.

At the present (July 2002) the GMDC and the GPCP are working to improve the 1DD by directly incorporating high-quality microwave estimates into the individual 3-hourly fields. The high-quality estimates will likely include SSM/I, TRMM, Advanced Microwave Sounding Unit (AMSU), and Advanced Microwave Scanning Radiometer (AMSR) estimates.

## Acronyms

| | |
|---|---|
| 1DD | One Degree Daily |
| AGPI | Adjusted GPI |
| ATOVS | Adjusted TOVS |
| CPC | Climate Prediction Center |
| DMSP | Defense Meteorological Satellite Program |
| Geo | Geosynchronous |
| GEWEX | Global Energy and Water Cycle Experiment |
| GMDC | GPCP Merge Development Centre |
| GMS | Geosynchronous Meteorological Satellite |
| GOES | Geosynchronous Operational Environmental Satellites |
| GPCC | Global Precipitation Climatology Centre |
| GPCP | Global Precipitation Climatology Project |
| GPI | Global Precipitation Index |

| | |
|---|---|
| GPROF | Goddard Profiling Algorithm |
| GSPDC | Geostationary Satellite Precipitation Data Centre |
| HIRS2 | High-Resolution Infrared Sounder 2 |
| IR | Infrared |
| Leo | Low-Earth-orbit |
| MSU | Microwave Sounding Unit |
| NASA | National Aeronautics and Space Administration |
| NCDC | National Climatic Data Center |
| NCEP | National Centers for Environmental Prediction |
| NOAA | National Oceanic and Atmospheric Adminstration |
| OLR | Outgoing Longwave Radiation |
| OPI | OLR Preciptation Index |
| SRDC | Surface Reference Data Center |
| SSM/I | Special Sensor Microwave/Imager |
| SSU | Stratospheric Sounding Unit |
| $T_a$ | Antenna Temperature |
| $T_b$ | Brightness Temperature |
| TIROS | Television Infrared Operational Satellite |
| TMPI | Threshold Matched Precipitation Index |
| TOVS | TIROS Operational Vertical Sounder |
| UTC | Universal Coordinated Time (same as GMT, Z) |
| WCRP | World Climate Research Programme |
| WMO | World Meteorological Organization |

## Additional Sources of Information

This document was created from the original 1DD documentation developed by George J. Huffman and David T. Bolvin -- available at ftp://precip.gsfc.nasa.gov/pub/1dd/1DD_doc [Internet Link].

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