GPCP One-Degree Daily (1DD) Precipitation

1. Intent of This Document and POC

1a) This document is intended for users who wish to compare satellite-derived precipitation estimates with climate model output in the context of the CMIP5/IPCC historical experiments. Users are not expected to be experts in satellite-derived Earth system observational data. This document summarizes essential information needed for comparing this dataset to climate model output. References are provided at the end of this document to additional information.

This dataset, which is computed by NASA as a contribution to the Global Water and Energy Exchange (GEWEX) project is provided as part of an experimental activity to increase the usability of NASA and related satellite observational data for the modeling and model analysis communities. This particular archive of data is not a standard NASA satellite instrument product, but does represent an effort on behalf of data experts to repackage a standard product that is appropriate for routine model evaluation. The data may have been reprocessed, reformatted, or created solely for comparisons with climate model output. Community feedback to improve and validate the dataset for modeling usage is appreciated. Email comments to HQ-CLIMATE-OBS@mail.nasa.gov .

Dataset File Names (as they appear on the ESG):

pr_GPCP-1DD_L3_v1.2_*YYYYMMD1*-*YYYYMMD2*.nc

where *YYYY* = year
MM = month
D1 = first day (of the month)
D2 = last day (of the month)

1b) Technical point of contact for this dataset:

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2. Data Field Description

CF variable name, units:	pr (precipitation_flux), units of kg / m^2 / s
Spatial resolution:	1°x1° latitude/longitude
Temporal resolution and extent:	Daily averages, October 1996 – July 2011 in monthly files
Coverage:	latitudes 90°N – 90°S

3. Data Origin

The One-Degree Daily data set has the identifier "1DD" within the Global Precipitation Climatology Project (GPCP). Within the ESG these datasets are posted with file names of the form

pr_GPCP-1DD_L3_v1.2_*YYYYMMD1*-*YYYYMMD2*.nc

The 1DD is designed to provide fully global, consistently processed precipitation estimates based on a relatively homogeneous set of input data. This design meets Climate Data Record (CDR) standards, although the 1DD pre-dates the formulation of the CDR concept. In fact, in Version 1.2 the Special Sensor Microwave Imager (SSMI) and Special Sensor Microwave Imager/Sounder (SSMIS) input was restricted to the 6 a.m./p.m. Defense Meteorological Satellite Program (DMSP) platforms to better conform to the CDF concept. In previous versions multiple satellites were used when available. Data are drawn from four sources, namely GPCP Satellite-Gauge (SG) monthly estimates of precipitation, passive microwave (PMW) radiances at multiple frequencies and polarizations observed from the DMSP sensors at 6 a.m./p.m. during the 1DD period of record (F13 SSMI and F17 SSMIS), thermal infrared brightness temperatures (IR Tb; observed by the international constellation of low-Earth-orbit [leo] and geosynchronous-Earth-orbit [geo] satellites), and atmospheric soundings computed from National Oceanic and Atmospheric Administration (NOAA)-series Television-Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) and NASA Aqua Advanced Infrared Sounder (AIRS) data.

The GPCP SG product is produced as part of the GPCP Version 2.2 Combined Precipitation Data Set by the GPCP Merge Development Centre (GMDC; Adler et al. 2003, Huffman et al. 2009). The monthly data are delivered on a 2.5ºx2.5º grid. The geo-IR, leo-IR, TOVS, AIRS, SSMI, and SSMIS satellite data enter the SG combination. TOVS(AIRS) is merged in with SSMI(SSMIS) where the SSMI(SSMIS) is suspect (outside about 45ºN-S) or missing. Then SSMI(SSMIS) and geo-IR are approximately time-matched to compute local coefficients to adjust the full geo-IR Geosynchronous Orbit Environmental Satellite (GOES) Precipitation Index (GPI; Arkin and Meisner 1987) to the bias of the SSMI(SSMIS) in the 40ºN-S band. As well, leo-IR GPI is approximately scaled to the SSMI(SSMIS). This Adjusted GPI (AGPI) is built from geo-IR AGPI where possible and leo-IR AGPI elsewhere. The Multi-Satellite (MS) intermediate product is composed of AGPI in the band 40ºN-S and the merged SSMI(SSMIS)–TOVS(AIRS) elsewhere. The SG MS is computed differently outside the 1DD period of record. Throughout, the MS and Global Precipitation Climatology Centre (GPCC) gauge analysis are linearly combined into a satellite-gauge (SG) combination using weighting by inverse estimated mean-square error for each.

Each of the PMW data streams is processed into precipitation estimates using sensor-specific versions of the Goddard Profiling Algorithm Version 2004 (GPROF2004) algorithm, but only used to provide the fractional occurrence of precipitation, computed as the ratio of the number of pixels with precipitation to the total number of valid pixels, both accumulated on a 0.5°x0.5° lat/lon grid swath by swath. GPROF2004 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, SSMI and SSMIS). Version 2004 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. Because SSMIS observes at 91 GHz, while GPROF2004 expects 85 GHz data, we applied a 91 GHz-based 85 GHz proxy channel developed by Vila et al. (2012).

Throughout the period of record the IR Tb data are processed as part of the 1DD algorithm (see below).

The TOVS(AIRS) precipitation estimate is based on Susskind and Pfaendtner (1989) and Susskind et al. (1997). The TOVS(AIRS) precipitation estimates infer precipitation from deep, extensive clouds. The technique uses a multiple regression relationship between collocated rain gauge measurements and several TOVS(AIRS)-based parameters that relate to cloud volume: cloud-top pressure, fractional cloud cover, and relative humidity profile. This relationship is allowed to vary seasonally and latitudinally. Furthermore, separate relationships are developed for ocean and land. The TOVS data are used for the period October 1996 – April 2005 and are provided at the 1º spatial resolution and at the daily temporal resolution. The data covering the span up to February 1999 are based on information from two satellites. For the period March 1999 – April 2005, the TOVS estimates are based on information from one satellite. In addition, the date span 1-17 February 2004 experienced partial (1^{st} and 17^{th}) or total (2-16) loss of TOVS data, so AIRS data are used for February 2004 and after April 2005.

Within the latitude band 40°N-S the Threshold Matched Precipitation Index (TMPI) provides GPI-like precipitation estimates in which both the IR Tb threshold and the conditional rain rate for raining pixels are set locally in time and space from GPCP SG amounts and GPROF-SSMI(SSMIS) fractional occurrence. The available geo-IR histograms in each 3-hrly global image are processed into precipitation estimates, and the adjusted leo-GPI data are used to fill holes in the individual 3-hrly geo-IR images. Then all the available images in a UTC day (00, 03, ..., 21 UTC) are averaged to produce the daily TMPI estimate (on a 1ºx1º grid).

The Adjusted Sounding-based precipitation estimates (AdSND) are computed with both TOVS and AIRS estimates, and are produced outside 40ºN-S to make the 1DD globally complete. The Susskind et al. (1997) precipitation estimates from TOVS(AIRS) 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(AIRS) estimates to match the TMPI frequency at 40°N and 40°S.

The 1DD is composed of TMPI where available (40ºN-S) and AdSND elsewhere. The data boundaries at 40ºN and 40ºS do not exhibit serious problems, probably because both the TMPI and AdSND are responding to <u>cloud</u> features. Nevertheless, some light feathering is applied just outside the boundary to reduce potential discontinuities.

In the CMIP5 collection the precipitation is referred to as field pr (precipitation_flux). The formal reference for 1DD is Huffman et al. (2001), while the detailed technical documentation (Huffman and Bolvin 2012) is posted at *ftp://precip.gsfc.nasa.gov/pub/1dd-v1.2/1DD_v1.2_doc.pdf*. The GPCP version number for this series of 1DD is Version 1.2. A summary of the upgrades from Version 1.1 to Version 1.2 is provided in the technical document. Updates are planned to the CMIP collection of 1DD after each additional month of the data is computed.

Note that, unlike the monthly GPCP SG, the GPCP 1DD does not have a standard error at present. Its computation is a matter of current research.

For most of the period of record essentially every grid box has a value, so sampling is not typically an issue. The primary sampling issue is that the Indian Ocean sector lacked geo-IR data before July 1998. As a partial offset, we employed GPI data computed from leo-IR data, but even in combination with the PMW data the sampling is reduced.

The precipitation research group in the NASA/GSFC Mesoscale Atmospheric Processes Laboratory is responsible for technical development and maintenance for the 1DD. Gerald L. Potter developed the conversion routines to CMIP-standard files.

4. Validation and Uncertainty Estimate

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 of the original 1DD against the Oklahoma Mesonet by the Surface Reference Data Center 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 for the original 1DD (Rubel and Rudolph 1999). Analysis against dense gauge data in Finland also shows reasonable behavior for the original 1DD, with better results in the summer than the winter (Bolvin et al. 2009). Overall, the original 1DD appears to have worked as expected in both the TMPI and TOVS(AIRS) data, and this should continue to be true in Version 1.2. Huffman et al. (2001) contains additional statistics for the original 1DD.

5. Considerations for Model-Observation Comparisons

Collecting the issues raised in other parts of this document:

- There is a boundary between IR- and TOVS(AIRS)-based data at 40°N and S. A linear feathering scheme is applied in the zone just poleward of these boundaries to reduce possible discontinuities
- TOVS data are used outside the latitude band 40°N-S in the early part of the record, while AIRS data are used for February 2004 and after April 2005. There is good, but not perfect agreement between the two, with 1DD typically having somewhat higher values at high latitudes during the AIRS epoch.
- Likewise, in the latitude belt 40°N-S there is a transition from the F13 SSMI to F17 SSMIS starting January 2009. The fractional coverage by precipitation is somewhat higher over ocean in the SSMIS epoch. The fact that total precipitation is constrained by the GPCP SG monthly field implies that the conditional precipitation rate should be somewhat lower during the SSMIS epoch.
- There tends to be higher uncertainty at the finest resolutions, which is improved by averaging, either implicitly or explicitly.

As well, a few additional factors should be noted:

- Coastal zones present special challenges for retrievals due to the heterogeneity of the surface scene. GPROF, in particular, seems to have trouble detecting precipitation in near-coastal waters for certain weather/surface configurations, and sometimes generates artifacts in near-coastal deserts (both within about 50 km of the coastline). In a few cases where the land/ocean contrast in precipitation is strong (such as Jamaica), the gauge values tend to bleed into the surrounding coastal waters on 2.5°x2.5° blocks related to the SG resolution.
- Orographic enhancement of precipitation is sometimes a challenge for the satellite schemes. The issue arises when the enhancement takes place (mostly) in the liquid phase, which current PMW algorithms cannot "see" over land, causing underestimation. On the other hand, in a few places the orography provokes very inefficient storms that create large amounts of ice near cloud top relative to the precipitation reaching the ground. The satellites consequently overestimate the rainfall in these cases.
- Current PMW schemes cannot make retrievals over snowy or frozen surfaces, which yield signals similar to frozen precipitation. This is a problem both because it denies direct use of PMW estimates in the dataset and because it denies use of the PMW estimates in the IR calibration. The SG and 1DD substitute TOVS(AIRS) estimates, but these are presumed to be of lower quality. As a result, statistics over cold-season land situations should be examined for possible degradation by these snow effects.

6. Instrument Overview

The instruments contributing to the 1DD are drawn from a wide variety of sources. The goal of the 1DD dataset is to use a relatively homogeneous set of quasi-global precipitation estimates from the international constellation of precipitation-relevant satellites to create a High-Resolution Precipitation Product with complete coverage over the chosen domain and period of record (global, October 1996-present). Fig. 1 summarizes the periods of record for the various inputs:

- GPCP SG, although not an instrument per se, is taken as the calibrator for the precipitation amounts in the 1DD. As described above, the SG is a monthly 2.5°x2.5° precipitation estimate based on satellites and a gauge analysis.
- PMW radiometers in the form of selected SSMI and SSMIS conical-scan imagers that fly on the DMSP series, which feature multiple channels and dual polarization well-suited to estimating precipitation; provide constant footprint sizes, although these sizes differ for different channels.
- GEO-IR imagers, whose data are ingested as 24-class histograms of IR Tb's accumulated on a 1°x1° lat./long. grid for individual 3-hourly images. In parallel, all leo-IR data from the NOAA series of polar orbiting meteorological satellites are accumulated to the nearest 3-hour time on a 1°x1° grid.
- TOVS(AIRS) soundings are retrieved from a series of sensors. Up through April 2005, the TOVS dataset of surface and atmospheric parameters is derived from

analysis of High-Resolution Infrared Sounder 2 (HIRS2) and Microwave Sounding Unit (MSU) data aboard the NOAA series of polar-orbiting operational meteorological satellites. Thereafter, the AIRS dataset of surface and atmospheric parameters is derived from analysis of High-Resolution Infrared Sounder data aboard the Aqua polar-orbiting satellite. In both cases the retrieved fields include land and ocean surface skin temperature, atmospheric temperature and water vapor profiles, total atmospheric ozone burden, cloud-top pressure and radiatively effective fractional cloud cover, outgoing longwave radiation and longwave cloud radiative forcing, and precipitation estimate.

The 1DD technical document (Huffman and Bolvin 2012) provides expanded summaries for each sensor and references to relevant documentation.

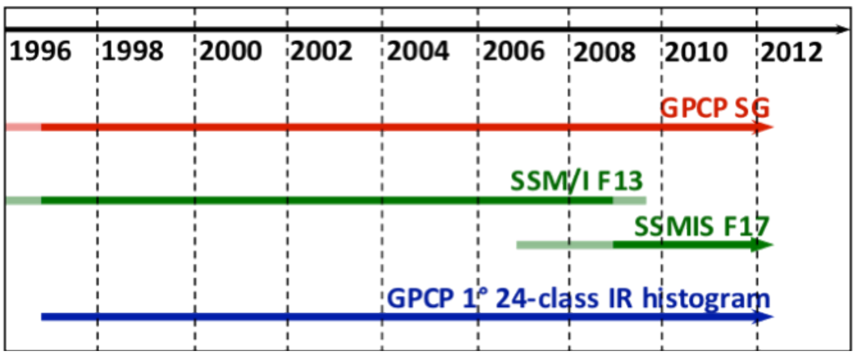

Fig. 1. Periods of record for the various data sets used in computing the 1DD (solid lines). Some of these sensors' periods of record extend beyond the periods of use, shown in light colors.

7. References

The International Polar Year (IPY) Data policy guidelines (http://.ipydis.org/data/citations.html) suggest a formal reference for data sets of the form

> Huffman, G.J., D.T. Bolvin, R.F. Adler, 2012, last updated 2012: *GPCP Version 1.2 1-Degree Daily (1DD) Precipitation Data Set*. WDC-A, NCDC, Asheville, NC. Data set accessed <date> at http://www.ncdc.noaa.gov/oa/wmo/wdcamet-ncdc.html.

As an "Acknowledgment", one possible wording is: "The 1DD data were provided by the NASA/Goddard Space Flight Center's Mesoscale Atmospheric Processes Laboratory, which develops and computes the 1DD as a contribution to the GEWEX Global Precipitation Climatology Project."

Additional details: At frequencies below about 37 GHz the radiative transfer signal in PMW sensor channels is primarily a combination of emission from the surface and then from the overlying atmosphere, including cloud and precipitation liquid water. At higher frequencies the useful signal results from scattering of the upwelling radiant energy out of the line of sight. Unfortunately, the land surface is radiometrically emissive and heterogeneous, so current-generation algorithms, including GPROF, can only use the emission channels over ocean. The restriction to frozen hydrometeors alone over land is an issue because they only represent the upper reaches of clouds, while the liquid phase tells about precipitation nearer the surface. Thus, conical-scan radiometers, which span both radiometric regimes, provide better answers over ocean than land. This is also the basis for the issues with retrievals over snowy/frozen surfaces and when orographic enhancement is in the liquid phase.

Data source:

http://www.ncdc.noaa.gov/oa/wmo/wdcamet-ncdc.html

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8. Revision History

Rev 0 – 9/25/2012 – This is a new document/dataset [G.J. Huffman]