IMERG V07 Release Notes

George J. Huffman, David T. Bolvin, Robert Joyce, Owen A. Kelley, Eric J. Nelkin, Andrea Portier, Erich F. Stocker, Jackson Tan, Daniel C. Watters, B. Jason West

20 November 2024

Summary

The algorithm for the Integrated Multi-satellitE Retrievals for GPM (IMERG) was upgraded to Version 07 in summer 2023. IMERG V07 involves a wide range of changes to all aspects of the algorithm, many of which are implemented in response to feedback on V06, which was the first time the IMERG record spanned the TRMM-GPM eras. IMERG V07 has been reprocessed for the entire TRMM-GPM record and thus supersedes all prior IMERG versions, as well as TRMM-based TMPA products (3B42, 3B43).

Retrospective Processing (RP) for the Final Run began on 1 July 2023 and completed on 30 August 2023. However, discovery of some 162 orbits of defective V07 GPROF precipitation estimates across all passive microwave satellites over the TRMM and GPM eras led to a second RP for the V07 Final Run, now labeled V07B. The relatively long pause between the first Final Run RP and this second is partly due to an orbit boost that the GPM Core Observatory (GPM-CO) satellite performed on 7-8 November 2023. The second RP for the entire TRMM-GPM record was completed on 8 January 2024. Subsequently, the IMERG team examined changes caused by the orbit boost on the Combined Radar-Radiometer Algorithm (CORRA) and the Precipitation Processing System (PPS) undertook a mandatory switch in operating systems. Following these actions, climatological calibrations were computed for the Early and Late Runs to the Final Run, and both Initial Processing (IP) and RP for the Early and Late Runs began on 3 June 2024, with IP taking effect starting 1 June. A gap existed between the RP and IP for Early and Late until the Final was completed for May 2024, since these RPs depend on various intermediate files computed in Final. Links to the IMERG files are listed on the Data Directory of the GPM website: https://gpm.nasa.gov/data/directory, which point to archives hosted at the Goddard Earth Sciences Data and Information Services Center (GES DISC) https://disc.gsfc.nasa.gov/datasets?keywords=gpm%20imerg%2007 and PPS https://arthurhou.pps.eosdis.nasa.gov/Documents/Master_List_of_PPS_Data_Products.html, as well as several interactive sites. Please visit https://gpm.nasa.gov/data/news for the latest updates.

Initial evaluation results suggest that the changes in V07 collectively improve the performance of IMERG estimates compared to V06 in terms of its precipitation detection, systematic bias, and random bias. This includes improvements in IMERG over frozen, orographic, and coastal surfaces; in the consistency of histograms (including extreme values) between the TRMM and GPM eras; and performance over regions lacking gauge data, particularly the oceans. See Appendix 2: Initial Evaluation of IMERG V07. The next two sections summarize changes in IMERG for V07 and then list some known issues.

Changes from V06 to V07

- *Improved intercalibration of PMW to correct for biases*. Evaluations of IMERG V06 identified a persistent overestimation, which was traced to three factors that were separately addressed:
    1. The mean GMI/TMI precipitation rate is not constant along the scan, so the GMI/TMI-constellation calibration was modified to use the full-swath GMI/TMI matched to the narrower swath of CORRA-G/T.
    2. The GPROF-GMI, GPROF-TMI, and CORRA-G/T footprint sizes differ, so CORRA-G/T is averaged on 0.2°×0.2° and 0.3°×0.3° gridbox templates to approximately match GPROF-GMI 18x11 km 18.7 GHz and GPROF-TMI 18x30 km19.35 GHz footprint sizes, respectively.
    3. The GPCP adjustment to CORRA in V06 was unrealistically raising winter precipitation over land and not capturing its longitudinal variability, so the GPCP adjustment to V07 CORRA is not applied over land in V07 IMERG.

  The net effect of these changes was to neutralize the biases that had been driven by the calibration process; however, regime-dependent biases still remain in the GPROF retrievals.
- *Upgraded to CORRA V07 and GPROF V07*. The algorithms for the inputs to IMERG have been updated to V07. Notable improvements to CORRA are: (1) a greater a priori constraint on the precipitation particle size distribution, (2) a new clutter zone correction, and (3) a consistent implementation between the GPM and TRMM algorithms; these changes result in reduced biases and greater consistency over the entire record. Notable improvements to GPROF are: (1) a finer surface classification for coasts and new classes for mountains (with further subclasses for different orographic enhancement conditions), (2) an adjustment to the a priori database for

snow, and (3) use of reanalysis data to construct the database for retrievals over sea ice; these changes lead to improved accuracies, especially under challenging conditions. [CORRA, GPROF, and all other entries to and components of IMERG are summarized in the IMERG Technical Documentation, together with background references.]

- *Upgraded the IR precipitation algorithm to PDIR–NOW*. The upgrade to PDIR–NOW, involves dynamically shifting relationships between the IR brightness temperatures and the precipitation rate (Nguyen et al. 2020), and replaced PERSIANN-CCS.
- *Implemented the SHARPEN scheme*. The averaging in the Kalman filter distorts the distribution of precipitation rates; in response, Scheme for Histogram Adjustment with Ranked Precipitation Estimates in the Neighborhood (SHARPEN) was developed and implemented in V07 to mitigate this issue (Tan et al. 2021). Effectively, this means that the SHARPEN-adjusted V07 Kalman filter precipitation rates have a distribution comparable with the aggregate of the propagated snapshot GPROF precipitation and the PDIR precpitation, weighted by their Kalman filter contributions.
- *Applied climatological adjustment to the Early and Late Runs based on the Final Run*. Procedural issues in the reprocessing prevented its intended implementation in V06, so arrangements were made to ensure that this was incorporated into the V07 near-real-time products. This ensures more consistency in the bias characteristics among the Early, Late, and Final Runs.
- *Included PMW estimates over frozen surfaces*. Prior to V07, IMERG screened out PMW retrievals for grid boxes with estimated surface type of snow/ice-covered land and sea ice. As such, the IMERG estimates were either purely IR-based (in the latitude band 60°N-S) or set to missing (outside the IR coverage) over frozen surfaces. An assessment of the GPROF V07 PMW estimates over frozen surfaces suggested that they may be useful, so they are now included as input in IMERG V07. The result is that, except for a handful of grid boxes (mostly at the poles), IMERG has complete global coverage. Nevertheless, users should be aware of the diminished performance of estimates at the polar latitudes, exercise appropriate caution in their interpretation of the results, and account for the reduced skill in their applications. Accordingly, the half-hourly Quality Index (QI) values for precipitation estimates over frozen surfaces are reduced based on You et al. (2023) to reflect the lower confidence. The monthly QI was not changed because gauges are also less certain in polar regions, but we don’t currently have a good basis for changing the gauge coefficients in the monthly QI.
- *Fixed spatial offset in gridding of CORRA and GPROF*. A long-standing bug in the gridding code causing a spatial offset of one grid box to the east was fixed, a critical improvement over all previous versions of IMERG. See Appendix 1: The IMERG Gridder Geolocation Correction.
- *Implemented the SPEEDe scheme*. Early analysis of the IMERG V07A Final Run Retrospective Processing revealed orbits in which GPROF retrievals provided unphysical, generally anomalously high estimates. An auto-encoding routine (Satellite Precipitation Estimate Error Detector, or SPEEDe [Tan et al. 2024]) was developed and integrated into IMERG to detect these bad orbits in both the archived record and in future data, then a second retrospective processing created IMERG V07B Final Run. See Appendix 3 for more details. Note that SPEEDe is not designed to catch cases where the GPROF estimates are unphysically low.
- *Implemented automated IR quality control*. The geostationary IR Tb field sporadically exhibits distinct anomalously cold artifacts (stripes and arcs) in the Early and Late Runs and required manual intervention in the Final Run. A quality control mechanism was implemented in V07 that automatically scans for anomalous features and attempts to mask out these artifacts.
- *Implemented a joint Fuchs-Legates undercatch correction to the gauge analysis*. The Legates-Wilmott scheme for undercatch in the GPCC gauges is too high at high latitudes according to analysis with GRACE data (Behrangi et al. 2018), so a climatological Fuchs adjustment was implemented in V07 over Eurasia north of 45°N, while Legates-Wilmott continues to be used for all other land areas.
- *Refined precipitation phase specification using gridded variables*. The precipitation phase estimates are calculated using thermodynamic variables from ERA5 for the Final Run and JMA forecast data for the Early and Late Runs, with a correction to the calculation of the wet-bulb temperature. The lookup tables used to estimate the precipitation phase also were recalculated using gridded variables from ERA5 and JMA, as appropriate. These improvements result in higher probability of liquid phase estimates in V07 compared to V06, on average, especially near the 0°C wet-bulb temperature.
- *Changed and reorganized variable names*. To minimize misinterpretation of the variable names, reflect changes in the algorithm, and emphasize the most commonly accessed fields, several variables were renamed and/or moved to a group called “Intermediate” within the half-hourly HDF5 file. <u>The V07 name/location for the variable relevant to most users is</u>:

- Grid/*precipitationCal* → <u>Grid/*precipitation*</u>

  Changes in other variables are:
  - Grid/*HQprecipitation* → Grid/Intermediate/*MWprecipitation*
  - Grid/*HQprecipSource* → Grid/Intermediate/*MWprecipSource*
  - Grid/*HQobservationTime* → Grid/Intermediate/*MWobservationTime*
  - Grid/*IRprecipitation* → Grid/Intermediate/*IRprecipitation*
  - Grid/*IRkalmanFilterWeight* → Grid/Intermediate/*IRinfluence*
  - Grid/*precipitationUncal* → Grid/Intermediate/*precipitationUncal*

  See Table 5 in the IMERG ATBD for definitions of the variables. The variable names for the monthly file are not changed in V07.
- *Changed source of motion vectors*. In V06, IMERG switched to motion vectors based on reanalysis/model-based total precipitable water vapor (TQV) fields for morphing (Tan et al. 2019) instead of GEO-IR brightness temperatures (Tb). However, deficiencies in the motion vectors near orography led us to modify this calculation from a single variable in V06 to a hierarchy of reanalysis/model variables in the following order in V07: precipitation, total precipitable liquid water, then TQV. Evaluation of this change suggests an appreciable improvement in orographic regions and a marginal improvement globally.
- *Combined instantaneous PMW retrievals with propagated precipitation*. Motivated by the potential contribution of propagated precipitation (You et al. 2021), instantaneous PMW estimates are merged with propagated precipitation estimates—except the combination of instantaneous imagers and propagated sounders is not permitted over ocean—in the Kalman filter, leading to reduced inter-sensor differences and slightly improved performance in standard metrics. Furthermore, SHARPEN is now applied when the merger is performed. These changes increase the half-hourly Quality Index values on average and give a smoother visual appearance to animations.
- *Excluded SAPHIR from the PMW inputs*. Animations of preliminary V07 precipitation demonstrated that SAPHIR presented spatial patterns that were very different from those of other PMW sensors, although spatially aggregated validation statistics for SAPHIR were reasonable. The IMERG team was unable to develop satisfactory adjustments in time for use in V07, so they chose to withhold SAPHIR data to allow continued development.
- *Increased the precipitation rate cap to 200 mm / hr*. This was intended to be implemented in V06 but remnant internal checks capped the maximum rates to 50 mm / h in the IR module and 120 mm / h in the PMW module. These remnant caps were eliminated in V07, allowing the possibility of greater extremes in the IMERG estimates when the retrievals compute them.
- *Rounded off precipitation rate values*. Precipitation rates are rounded to the nearest 0.01 mm / hr for half-hourly datasets and 0.001 mm / h for the monthly datasets. Motivated primarily by the improved dataset compression—about 25-30% reduction in file size—this rounding is not considered to have a practical effect as these thresholds are well below the expected uncertainties for the precipitation rates.
- *Extended IMERG V07B to Jan 1998*. As of 7 Nov 2024, the start of the IMERG V07B record has been extended backwards from 01 Jun 2000 to 01 Jan 1998. This relies on the use of GridSat-B1 IR Tb due to the lack of CPC IR during this period and, as such, may possess inconsistencies compared to the record after 01 Jun 2000. See Appendix 4: IMERG Data for Jan 1998–May 2000.

New Issues in V07

- *Effect of rounding on monthly data.* As a result of the rounding difference between the half-hourly and monthly datasets, the monthly mean of the half-hourly *precipitation* may not equal the monthly *precipitation* especially over regions of very light precipitation.
- *IMERG estimates for snowfall should be examined critically.* As described above, the IMERG team believes that GPROF retrievals over frozen surfaces are sufficiently advanced that IMERG V07 includes such retrievals (for the first time), effectively providing fully global estimates, but they are flagged with low Quality Index values. Retrievals over Antarctica are particularly problematic due to the very low (and so hard-to-detect) rates of snowfall. Recent analysis shows low precipitation rates for snowfall over land due to deficiencies in the detection and rate retrieval by CORRA, which is used to intercalibrate the PMW estimates, and consequently suppresses the apparent skill in the GPROF retrievals.

- *The V07 GPM background climatological calibration file for January has shifts in its distribution.* This is apparent by examining the histograms for January data outside the latitude band 37°N-S during the TRMM era and is a result of spin-up issues when constructing the calibration files.
- *Anomalously high spots of precipitation at high latitudes*. While the climatological calibration of the PMW constellation sensors to GMI/TMI generally works to ensure a consistent distribution across all sensors, it has been observed to produce isolated spots over land of anomalously high precipitation at high latitudes. Specifically, mean precipitation rates for the month of December 2023 exceeding 1 mm / h have been observed north of the Aldan River (~63°N) in eastern Siberia in the Final Run. The exact reason for the miscalibration is unclear, but it likely arose from limited sampling in the region and extensive frozen surface during this month.
- *Reduced quality and inconsistent behavior in Jan 1998–May 2000*. The use of GridSat-B1 IR Tb in place of the CPC 4-km merged IR Tb may introduce characteristics that are inconsistent with the rest of the record. Specifically, preliminary analysis suggested that the IR precipitation derived from GridSat-B1 is of lower quality compared to the CPC 4-km IR. We recommend that users avoid using these data if it is unnecessary for their purpose. We strongly urge users to pay close attention to the expected artifacts. As well, users should account for the presence of missing data (nominally recorded as -9999.9). See Appendix 4: IMERG Data for Jan 1998–May 2000.
- *Jumps in the CORRA and GPROF record.* The CORRA and GPROF products have apparent jumps in values at (1) the TRMM orbit boost (August 2001), (2) the shift from TRMM- to GPM-based estimates (June 2014), and (3) the GPM-CO orbit boost (November 2023). For example, the CORRA tropical values are reduced around 6% over ocean and 4% over land from the pre- to the post-boost TRMM record. Since IMERG relies on both products for most of the estimates and for calibration, these jumps have an effect in the IMERG record. We identified this issue too recently to develop, implement, and test a fix in V07 IMERG. For the IMERG Final Run, the gauge adjustment helps mitigate the jumps in the record over land. The CORRA and GPROF teams are examining this issue for V08.
- *Reduced weights for instantaneous sounder estimates over the ocean during the TRMM era*. An issue inherited from the V06 code that was not discovered until after V07A reprocessing had begun is the fact that instantaneous sounder estimates over the ocean during the TRMM era were assigned an artificially low weight in the Kalman filter. However, this same issue has a more consequential impact in V07 due to the inclusion of instantaneous PMW estimates in the Kalman filter, which effectively diminishes the contribution of instantaneous sounders during the TRMM era. This issue arose because the weights rely on climatological values computed from the GPM era, and the statistics between both eras are sufficiently different to trigger procedures intended to prevent unphysical behaviors.

Known Issues in V07

- *IMERG prioritizes fine-scale accuracy over climate-scale consistency.* IMERG is designed to give the best precipitation estimate for each grid box at each time, using whatever inputs are available, a design known as a High Resolution Precipitation Product (HRPP; Turk et al. 2008). This contrasts with products such as the Global Precipitation Climatology Project (GPCP) datasets, which are designed to provide long-term homogeneity by downselecting the input data sets to a few long-term, carefully intercalibrated data sources, a design known as Climate Data Records (CDR; National Research Council 2004). Therefore, any studies using IMERG for climate-scale studies (e.g., trends and interannual variability) should examine the consistency of the data's time series to ensure that the observed characteristics are not artifacts arising from an evolving constellation.
- *Residual differences between the histograms of TMI and GMI are embedded in the IMERG results.* This means that, while the time series of mean values is consistent, the occurrence of extreme IMERG values and precipitation detection frequency will be somewhat different between the eras of TRMM and GPM calibration.
- *Skill in the GPROF V07 retrievals varies by surface type.* The GPROF V07 algorithm, used to retrieve precipitation from all PMW inputs for IMERG, has made progress in handling difficult surface types that tend to yield lesser quality results, including frozen surfaces, orographic areas, and coastal zones. It remains to be demonstrated how well the resulting retrievals work in each of these areas, and users should seek confirmation of the values in the corresponding IMERG estimates.
- *Calibration for estimates in the TRMM era outside the latitude band 37°N-S are somewhat more approximate.* TRMM only provides calibration for the constellation in the latitude band 37°N-S due to its orbital inclination of

35°. Outside of that band, a monthly climatology of GPM-based corrections is used, with an adjustment to match the TRMM-based corrections in the latitude band 30°-40° in each hemisphere.

Additional Notes

The IMERG development team welcomes user feedback on any aspect of IMERG performance. This information can be used to better inform other dataset users, and has proved valuable in the past for alerting the team to deficiencies that required attention.

Key IMERG Documents

Algorithm Theoretical Basis Document
https://gpm.nasa.gov/resources/documents/imerg-v07-atbd
The ATBD describes the IMERG V07 algorithm in detail.

Technical Documentation
https://gpm.nasa.gov/resources/documents/imerg-v07-technical-documentation
The Technical Documentation is a detailed log of all information and news relating to IMERG, including decisions made in previous versions.

Release Notes
https://gpm.nasa.gov/resources/documents/imerg-v07-release-notes
[This document.] The Release Notes summarizes key changes in the IMERG V07 algorithm, together with important information about its use.

Algorithm Concept
Huffman et al. (2020), https://link.springer.com/chapter/10.1007/978-3-030-24568-9_19
The Algorithm Concept is a published book chapter that contains the general idea of IMERG and is agnostic to version changes.

FAQ for IMERG V07 Applications Users
https://gpm.nasa.gov/resources/documents/imerg-v07-faq-applications-users
This FAQ document provides information specifically aimed at IMERG V07 Applications Users.

References

Behrangi, A., A. Gardner, J.T. Reager, J.B. Fisher, D. Yang, G.J. Huffman, R.F. Adler, 2018: Using GRACE to Estimate Snowfall Accumulation and Assess Gauge Undercatch Corrections in High Latitudes. *J. Climate*, **31**, 8689-8704. *doi:10.1175/JCLI-D-18-0163.1*

Huffman, G.J., D.T. Bolvin, D. Braithwaite, K. Hsu, R. Joyce, C. Kidd, E.J. Nelkin, S. Sorooshian, E.F. Stocker, J. Tan, D.B. Wolff, P. Xie, 2020: Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement (GPM) mission (IMERG). Chapter 19 in *Adv. Global Change Res.*, *Vol. 67, Satellite Precipitation Measurement*, V. Levizzani, C. Kidd, D. Kirschbaum, C. Kummerow, K. Nakamura, F.J. Turk (Ed.), Springer Nature, Dordrecht, ISBN 978-3-030-24567-2 / 978-3-030-24568-9 (eBook), 343-353, *doi:10.1007/978-3-030-24568-9_19*

National Research Council. 2004: Climate Data Records from Environmental Satellites: Interim Report. Washington, DC: The National Academies Press, 150 pp., *doi:10.17226/10944*

Nguyen, P., M. Ombadi, V.A. Gorooh, E.J., Shearer, M. Sadeghi, S. Sorooshian, K. Hsu, D. Bolvin, M.F. Ralph, 2020: PERSIANN Dynamic Infrared–Rain Rate (PDIR-Now): A Near-Real-Time, Quasi-Global Satellite Precipitation Dataset. *J. Hydrometeor.*, **21**, 2893–2906, *doi:10.1175/JHM-D-20-0177.1*

Tan, J., G.J. Huffman, D.T. Bolvin, E.J. Nelkin, 2019: IMERG V06: Changes to the Morphing Algorithm. *J. Atmos. Oceanic Technol.*, **36**, 2471–2482, *doi:10.1175/JTECH-D-19-0114.1*

Tan, J., G.J. Huffman, Y. Song, 2024: Automated Quality Control Scheme for GPM Satellite Precipitation Products. *Geophys. Res. Lett.*, **51**, 9 pp., *doi: 10.1029/2024GL108963*.

Tan, J., G.J. Huffman, D.T. Bolvin, E.J. Nelkin, M. Rajagopal, 2021: SHARPEN: A Scheme to Restore the Distribution of Averaged Precipitation Fields. *J. Hydrometeor.*, **22**, 2105–2116, *doi:10.1175/JHM-D-20-0225.1*

Turk, F.J., P. Arkin, E. Ebert, M. Sapiano, 2008: Evaluating High Resolution Precipitation Products. *Bull. Amer. Meteor. Soc*., **89**, 1911–1916, *doi:10.1175/2008BAMS2652.1*

You, Y., C. Peters-Lidard, S.J. Munchak, J. Tan, S. Braun, S. Ringerud, W. Blackwell, J.X. Yang, E. Nelkin, J. Dong, 2021: Improving Cross-track Scanning Radiometers' Precipitation Retrieval over Ocean by Morphing. *J. Hydrometeor.*, **22**, 2393–2406, *doi:10.1175/JHM-D-21-0038.1*

Appendix 1: The IMERG Gridder Geolocation Correction

Daniel C. Watters, George J. Huffman
12 July 2023

The Problem

The first step in the IMERG algorithm is to grid the Level 2 precipitation estimates from each of the TRMM/GPM passive microwave (PMW) constellation members onto the 0.1° grid for a particular half-hour (Huffman et al. 2019). In Summer 2022, a geolocation error was identified in the IMERG V06 gridding code (Figure 1); **IMERG's PMW estimates were incorrectly geolocated by 0.1° eastward in the latitude band 75°N-S in V06 and all preceding versions.** A similar geolocation error was also present for the CORRA estimates, used to calibrate the PMW estimates, but by 0.025° eastward in the latitude band 75°N-S in V06 and all preceding versions because the CORRA estimates are first mapped onto a fine 0.025° grid using the IMERG gridder before coarsening to 0.1°. **These geolocation errors directly affect the PMW component of IMERG V06, but their effect propagates through the morphing algorithm to affect most of the precipitation estimates. In V07, this gridder geolocation error was rectified.**

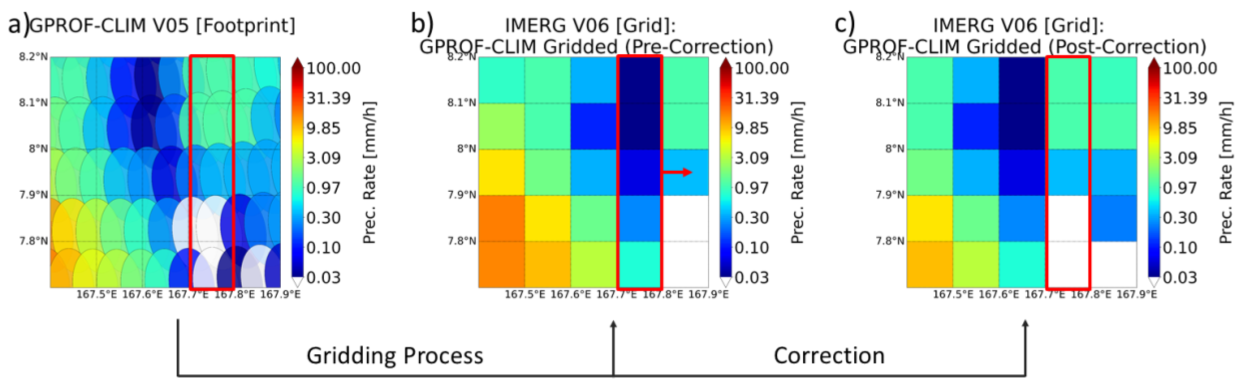

Figure 1: An example (July 12, 2019; GMI Granule 30509) of the IMERG PMW gridder geolocation error and the necessary correction. a) The GPROF climate product (GPROF-CLIM) V05B precipitation estimates computed from the GMI footprint measurements. b) The original gridding of the GPROF-CLIM V05B precipitation estimates by the IMERG V06B algorithm, which includes the geolocation error. c) The corrected version of the IMERG V06B gridding (showing a 0.1° [one-pixel] shift westward for all grid boxes). The red box highlights cases where the geolocation error in the IMERG gridding is clear; however, note tha the one-gridbox offset applies to all gridboxes. Also, note that these gridded values are not yet calibrated, which happens in computing the HQprecipitation variable (called MWprecipitation in V07).

We remark that, **when present (in V06 and all prior versions), this geolocation error cannot be corrected in any of the precipitation outputs because it occurs in the first step of the IMERG algorithm**, and each of the IMERG file precipitation outputs are from later steps in the algorithm that (in general) would have mixed in information that is correctly gridded.

The Details

- *Is the PMW geolocation in IMERG V07 correct?*
  Yes, gridding for IMERG V07 was corrected and does not include the offset error.

- *Which versions of IMERG are affected by the gridded PMW geolocation error?*
  IMERG V06 and all preceding versions include this error.

- *Why does the PMW geolocation error only occur at latitudes between 75°N-S?*
  The IMERG algorithm grids PMW footprints separately in three zones: 75-90°N, 75°N-75°S, and 75-90°S. The geolocation error was caused by an indexing mistake in one line of code for the central band; however, the indexing is correct in the polar regions.

- *Why are PMW footprints gridded using different codes for polar and central regions?*
  The output is provided on a global cylindrical equidistant (CED) projection, so grid boxes near the poles have a much smaller surface area than those closer to the equator due to the convergence of longitude lines to the poles.

For stability, the polar regions are first gridded to a tangent plane, then transformed to the global CED grid, while the central band is gridded directly to the CED grid.

- *Can I correct the PMW geolocation error in IMERG V06 (and earlier versions) myself?*
  No, the PMW geolocation error is mixed with other correctly gridded fields.

- *Why has this error not been identified before now?*
  The IMERG PMW gridder was originally developed on a four-times-finer grid (i.e., 0.025° spatial resolution) that was averaged up to the IMERG grid resolution (i.e., 0.1°). The error, which is a shift to the east by one grid box, was less identifiable and consequential at 0.025°, and this error was further obscured in the averaging to the IMERG grid. Then, when IMERG switched to the current approach of gridding the PMW precipitation estimates straight to a 0.1°-resolution grid, this error in the code eluded notice despite now having a more severe impact and being more easily identified in visualizations such as Figure 1.

Example Statistics

To better understand the impact of this gridded PMW geolocation error, the IMERG V06B PMW-gridded precipitation rates are compared to those from the ground radar (GR) on the Kwajalein Atoll. Three case studies are considered in Table 1, with a visualization of one of the case studies shown in Figure 1. Note that the Kwajalein GR precipitation rates, as provided using the GPROF-footprint scale in the GPM Validation Network GRtoGPROF matchup files (Gatlin et al., 2020; NASA-GSFC, 2015), are gridded using IMERG's method for gridding PMW footprints.

Table 1: Statistical comparison between IMERG V06B PMW-gridded precipitation estimates and those from the Kwajalein Atoll ground-based radar (GR) for both original and corrected data. The statistics are deduced from all pixels within 125-km of the GR (see Figure 2). The mean relative bias is defined as the sum of IMERG-PMW estimates minus GR estimates, divided by the sum of GR estimates. Red text highlights better statistics.

Case Study	Mean Relative Bias [%]		Standard Deviation [%]		Correlation	
	Pre-Correction	Post-Correction	Pre-Correction	Post-Correction	Pre-Correction	Post-Correction
20151006 G009116 14:30-14:59	64	57	94	86	0.39	0.50
20190712 G030509 20:00-20:29	47	51	119	85	0.70	0.87
20201223 G038755 22:00-22:29	63	63	159	121	0.44	0.68

Table 1 demonstrates that the standard deviation in differences between IMERG-PMW and the GR in the Kwajalein oceanic domain consistently decreases across different case studies when the offset correction is applied. This is expected as the geolocation offset increases the variability in pixel-by-pixel differences. Furthermore, the correlation between IMERG-PMW and GR precipitation rates increases once the correction is applied. However, the mean relative bias does not always decrease in the data because it depends on the values that get shifted into or out of the averaging domain across the (curved) east and west boundaries (e.g., see Figure 2).

Figure 2 showcases the third case study in Table 1. While the satellite-GR differences are smaller with the geolocation correction (particularly note the decreased standard deviation and increased correlation), the satellite-GR standard deviation remains large due to the innate differences between the satellite and GR precipitation estimates (i.e., satellite observing precipitation from a spaceborne vantage, GR range effects due to Earth's curvature, etc.).

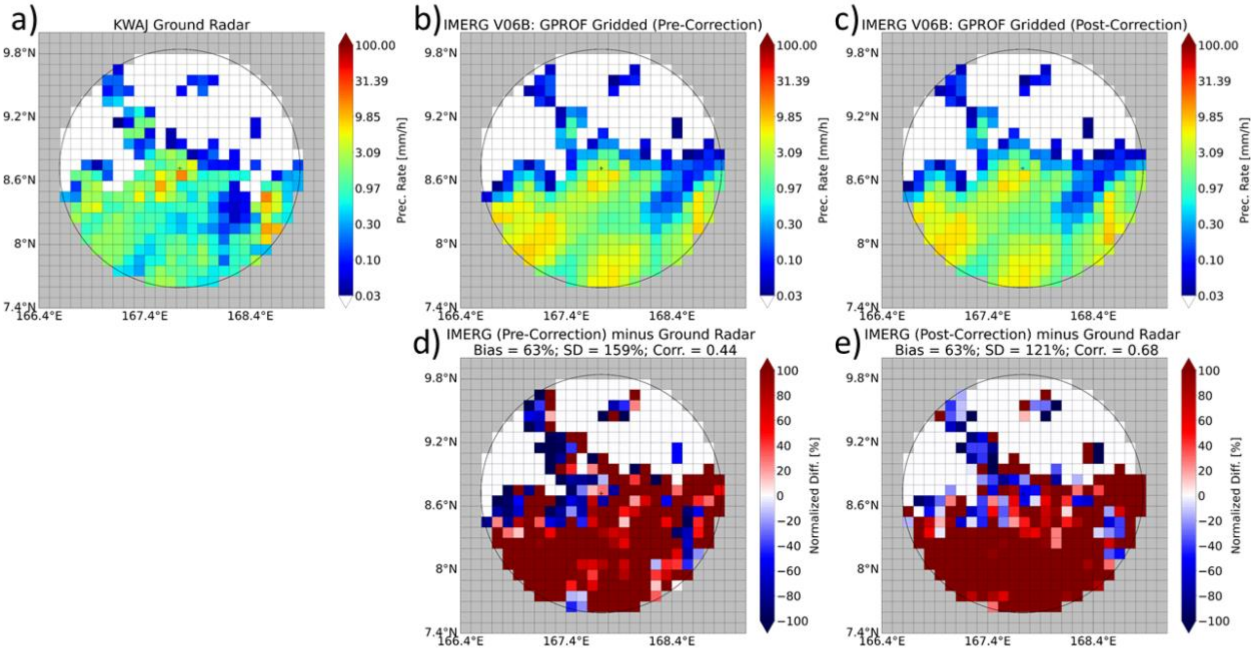

Figure 2: A comparison on December 23, 2020 - 22:00-22:29; (GMI granule 038755). a) The Kwajalein GR precipitation estimates and the IMERG-PMW V06B precipitation estimates, b) prior to the geolocation correction and c) with the geolocation correction. IMERG-PMW d) pre-correction and e) post-correction minus the GR are both normalized by the GR estimates.

The Impact

The IMERG PMW gridded geolocation offset in V06 and earlier versions has several impacts:

- *Fine-Resolution Data*

  IMERG validation studies and applications using V06 data (and earlier versions) at the native 0.1° spatial resolution are affected the most by this error. Note that the error is greater for GPM PMW constellation sensors with finer footprint sizes (e.g., GMI, AMSR2), while IMERG assessments at coarser spatial resolutions are less affected. Early analyses of the PMW-only component of IMERG at the native resolution (Table 1 and Figure 2) suggest that the correction reduces the standard deviation in pixel biases and increases the correlation with GR estimates.
- *Aggregated Data*

  Studies that use aggregated IMERG data (e.g., histograms collected across time and/or space) are minimally affected by the error. The examples in Table 1 and Fig. 2 evidence this by showing that the mean relative bias is minimally affected by the offset.
- *Publications*

  Users of IMERG V06 (and earlier versions) should note this error in reports/publications in which it is likely to affect their results.

References

Adler, R.F., G.J. Huffman, A. Chang, R. Ferraro, P.-P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, P. Arkin, and E. Nelkin, 2003: The Version-2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979–present). *J. Hydrometeor.*, **4**, 1147–1167, *doi:*10.1175/1525-7541(2003)004<1147:TVGPCP>2.0.CO;2

Adler, R.F., M.R.P. Sapiano, G.J. Huffman, J.-J. Wang, G. Gu, D. Bolvin, L. Chiu, U. Schneider, A. Becker, E. Nelkin, P.-P. Xie, R. Ferraro, and D.-B. Shin, 2018: The Global Precipitation Climatology Project (GPCP) Monthly Analysis (New Version 2.3) and a Review of 2017 Global Precipitation. *Atmosphere*, **9**, 138, *doi:*10.3390/atmos9040138

Gatlin, P.N., W.A. Petersen, J.L. Pippitt, T.A. Berendes, D.B. Wolff, and A. Tokay, 2020: The GPM Validation Network and Evaluation of Satellite-Based Retrievals of the Rain Drop Size Distribution. *Atmosphere*, **11**, 1010, *doi:*10.3390/atmos11091010

Grecu, M., and W.S. Olson, 2020: Precipitation Retrievals from Satellite Combined Radar and Radiometer Observations. *Satellite Precipitation Measurement*, V. Levizzani, C. Kidd, D.B. Kirschbaum, C.D. Kummerow, K. Nakamura, and F.J. Turk, Eds., Springer, 231–248, *doi:10.1007/978-3-030-24568-9_14*

Huffman, G.J., D.T. Bolvin, D. Braithwaite, K. Hsu, R. Joyce, C. Kidd, E.J. Nelkin, S. Sorooshian, J. Tan, and P.-P. Xie, 2019: NASA Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG). Algorithm Theoretical Basis Document Version 06, 38 pp, https://gpm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V06.pdf

Kidd, C., 2019: NASA Global Precipitation Measurement (GPM) Precipitation Retrieval and Profiling Scheme (PRPS). Algorithm Theoretical Basis Document Version 01-02, 17 pp, https://pps.gsfc.nasa.gov/Documents/20180203_SAPHIR-ATBD.pdf

Passive Microwave Algorithm Team Facility, 2018: GPROF2017 (used in GPM V5 processing). Algorithm Theoretical Basis Document, Version 1 and Version 2, 65 pp, https://gpm.nasa.gov/sites/default/files/2020-05/ATBD_GPM_V5B_April15_2018.pdf

NASA-GSFC, 2015: GPM Ground Validation System - Validation Network. Data Product User's Guide, Volume 2, 107 pp, https://gpm.nasa.gov/sites/default/files/document_files/Val_Network_Users_Guide_Vol_2_Nov2015.pdf

Olson, W.S., 2018: GPM Combined Radar-Radiometer Precipitation. Algorithm Theoretical Basis Document, Version 5, 68 pp., https://gpm.nasa.gov/sites/default/files/2020-05/Combined_algorithm_ATBD.V05.pdf

Appendix 2: Initial Evaluation of IMERG V07

Jackson Tan, Yagmur Derin, Pierre Kirstetter, Jianxin Wang, David B. Wolff, George J. Huffman
12 July 2023

Initial evaluations of IMERG V07 Late Run test data suggest that the changes implemented lead to improved skill. A comparison of IMERG V07 against a special Ground Validation (GV) edition of the high-resolution, ground-based radar precipitation estimates from the Multi-Radar Multi-Sensor (MRMS) product, developed by the National Severe Storms Laboratory (GV-MRMS) demonstrated an appreciable increase in Heidke Skill Score and correlation coefficient as well as a reduction in the magnitude of the bias (Figure 3).

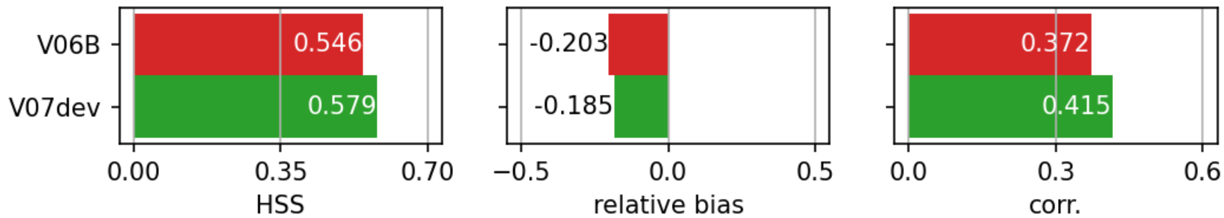

Figure 3: Evaluation of IMERG V06B precipitationCal and IMERG V07dev precipitation against GV-MRMS over the contiguous U.S. for Jun–Aug 2014.

One notable issue in IMERG V06B is a severe overestimation of wintertime precipitation events over land, especially prior to the gauge adjustment in the Final Run. For a case study of a winter storm in March 2015 over the U.S., IMERG V07 *precipitationUncal* (the satellite product without gauge adjustment) demonstrated a substantial reduction in the overestimation compared to V06of the daily accumulation (Figure 4). This is primarily due to the removal of the GPCP adjustment to CORRA over land. It is also expected that this and other changes in the intercalibration process will address the overestimation of intense satellite-only precipitation rates seen in V06. This improvement primarily affects the Early and Late Runs, as well as the Final Run over oceans. [Gauge adjustment over land already addresses this issue in the complete Final product.]

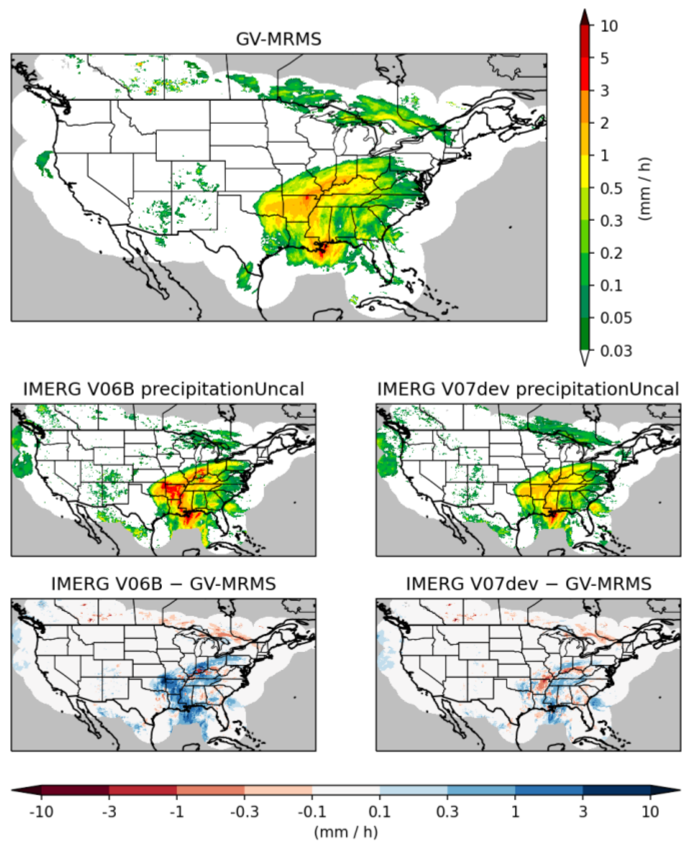

Figure 4: Comparison of the daily accumulations of IMERG V06B precipitationUncal and IMERG V07dev precipitationUncal against GV-MRMS for a winter storm on 13 March 2015.

In V06B, concerns about the skill of V05 GPROF precipitation estimates over frozen surfaces led to its masking. Effectively, this meant that estimates within 60°N/S used only IR estimates while estimates at higher latitudes were missing. However, comparisons of the V07 GPROF PMW estimates and the V07 IR estimates against GV-MRMS over frozen surfaces suggested that a greater fraction of PMW estimates are closer to GV-MRMS than IR estimates above 0.5 mm / h, which comprises about 90% of the samples (Figure 5). This result, together with visual observations of PMW estimates at polar regions, justifies the inclusion of PMW estimates over frozen surfaces in V07.

The improved skill of IMERG V07 is also observed over the ocean. An evaluation of the V07 test results against the KPOL radar on Kwajalein atoll revealed an increased correlation (Figure 6), as well as better scores in several other metrics considered. The improvement is attributed to (1) the fix to the geolocation offset, (2) full swath GMI/TMI – CORRA-G/T calibration, (3) the use of SHARPEN, (4) the inclusion of PMW estimates into the Kalman filter, and (5) refined algorithms for the input products.

A comparison of the time-series of precipitation statistics over the ocean between 60°N/S revealed salient similarities and differences between IMERG V06B and V07 (Figure 7). The most striking similarity between the two versions is that both time-series have similar variability for each of the statistics. For the mean precipitation rate, IMERG V07 is close to V06B, though with a very slight reduction. Comparing the fractions of precipitation greater than 0 mm / h and of at least 0.1 mm / h revealed the impact of SHARPEN in reducing the excessive occurrence of low precipitation rates stemming from the averaging process. Interestingly, the fraction of precipitation of at least 10 mm / hr is reduced in V07, likely from averaging the CORRA-G/T to approximately match the GMI/TMI footprint. This occurs despite the expected increase of intense precipitation due to SHARPEN, likely because of the refined PMW intercalibration process. This is a desirable outcome given the known issue of IMERG V06B overestimating intense precipitation over the ocean, and increases confidence in the V07 products.

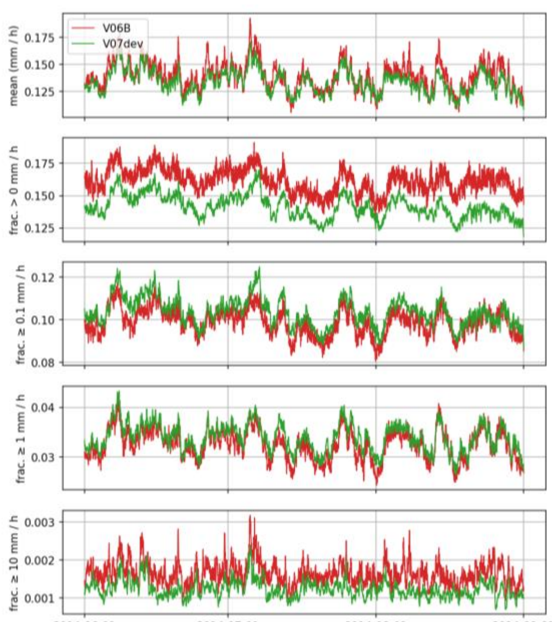

Figure 7: Time-series of IMERG V06B and V07 precipitationUncal statistics over the ocean between 60°N/S in Jun–Aug 2014.

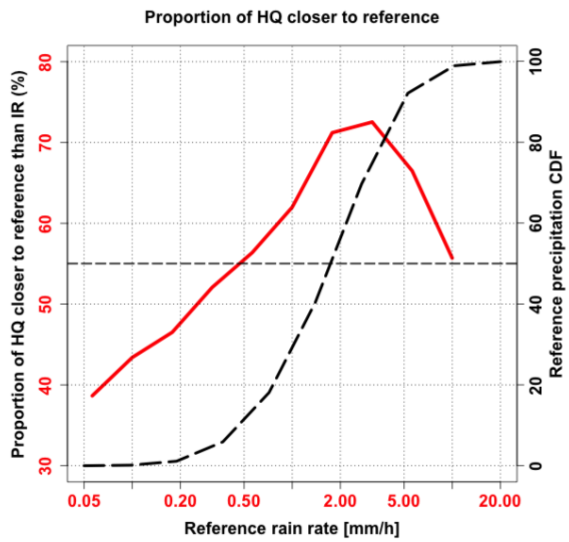

Figure 5: The proportion of the V07 PMW (or HQ) estimates that are closer to GV-MRMS compared to the V07 IR estimates as a function of intensity (red line), as well as the cumulative distribution of the GV-MRMS precipitation rates (black dashed line).

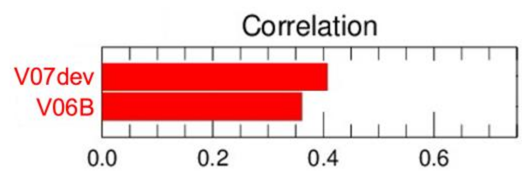

Figure 6: Correlation of IMERG V06B precipitationCal and IMERG V07 <u>precipitation</u> against KPOL over Jun–Aug 2014.

The Watters et al. (2024) study currently in review compares surface radar observations over ocean to GPROF-GMI retrievals and IMERG Final Run for half hours when there are coincident GMI and radar observations, for both V06B and V07B. The radar locations are classified as tropical, mid-latitude, and high-latitude, and of necessity these data, while restricted to "100% ocean" grid boxes, are within 100 km of the island or coastal location of the radar. The restriction to GMI overpass times (for historical reasons) represents the best-case analysis, since GMI is a very capable sensor and the other PMW sensors have an additional intercalibration to the GMI, but other work shows good consistency between the full IMERG statistics and the GMI-overpass-time statistics. All the statistics except for Mean Relative Bias are somewhat or much improved for V07B IMERG Final Run compared to V06B (Figure 8, Figure 9, Figure 10). Mean Relative Bias and Random Error improve the most for high latitudes, while Correlation improves the most for mid-latitudes. It is notable that these changes arise despite near-equivalent statistics for the input GPROF-GMI estimates in the two versions, indicating that upgrades to IMERG from V06B to V07B are responsible for the adjustments.

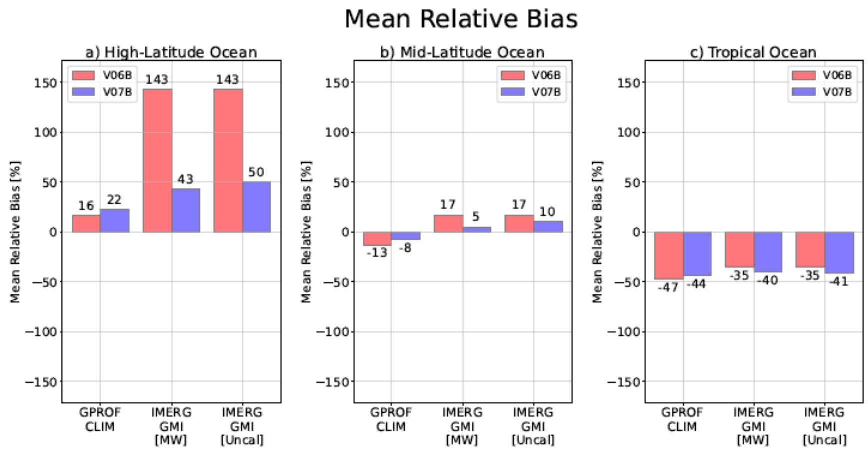

Figure 8: Mean Relative Bias compared to surface radars over ocean for the input GPROF-CLIM retrievals, IMERG merged microwave for half hours when there is a GMI overpass, and the complete IMERG estimate at those half hours at (a) high latitudes, (b) mid-latitudes, and (c) the tropics. [After Watters et al. 2024, Fig. 8.]

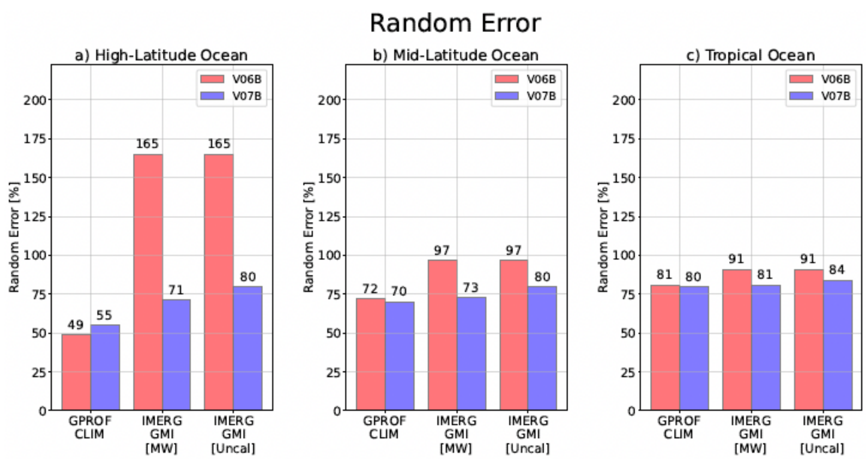

Figure 9: As in Fig. 8 for Random Error. [After Watters et al. 2024, Fig. 10.]

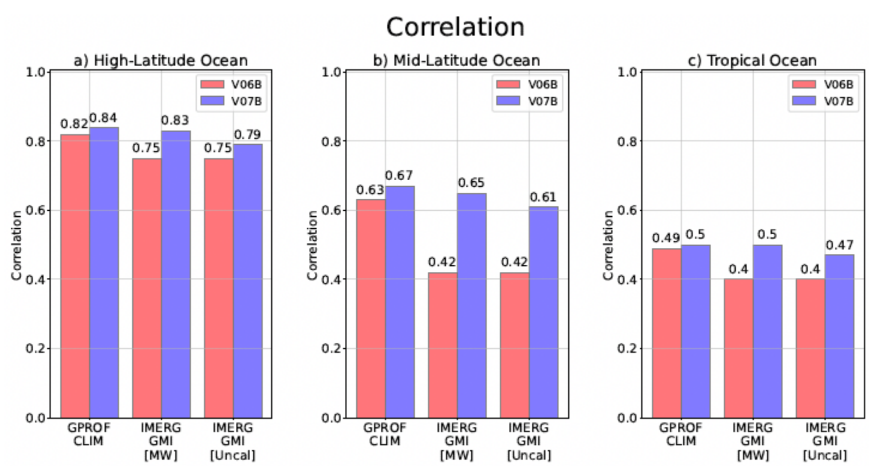

Figure 10: As in Fig. 8 for Correlation. [After Watters et al. 2024, Fig. 11]

The Wang and Wolff (2025) study currently in preparation compares the latest versions of IMERG (V06B and V07B) products over the conterminous United States (CONUS) for the period from Jun 2014 to Aug 2021 to MRMS. Several volumetric and categorical statistical metrics are used to quantitatively evaluate the performance of the two satellite-based products. The precipitation estimation errors are traced back to sensor-specific sources and morphing-based algorithms. The evaluation demonstrates the clear improvement in IMERG V07B precipitation product in comparison with V06B in terms of precipitation detection, systematic bias, and random bias. Further, IMERG V06B severely overestimated wintertime precipitation, whereas IMERG V07B overestimates these events much less, primarily due to the removal of the Global Precipitation Climatology Project (GPCP) adjustment to Combined Radar Radiometer Analysis (CORRA) over land, and to other changes. For example, data from the Sounder for Atmospheric Profiling of Humidity in the Inter-tropics by Radiometry (SAPHIR) is excluded in V07B because of its overall poor precipitation rate distribution performance, and almost no IR-only estimates were used in V07B as an investigation shows that PMW retrievals generally outperform IR retrievals even over frozen surfaces.

In summary, these initial evaluation results indicate that IMERG V07B represents improvements on multiple fronts compared to IMERG V06B.

Appendix 3: Orbits with Bad GPROF Retrievals

George Huffman, Jackson Tan, Joyce Chou
20 December 2023, rev. 15 May 2024

After the V07 IMERG Final Run was retrospectively processed, occasional orbits in various sensors displayed bad GPROF retrieval values, all of which showed anomalously high fractional coverage and/or rates. An auto-encoding routine (Satellite Precipitation Estimate Error Detector, or SPEEDe) was developed by Jackson Tan for IMERG, then adapted to Level 2 GPROF data, eventually yielding 162 bad orbits affecting the creation of 220 PPS orbit granules (out of the many thousands of orbits). A few of these orbits were previously flagged as having bad Level 1C channel values, flagging that was honored by GPROF in V05, but missed in V07. However, many more were newly discovered and therefore contaminated the GPROF record in versions before the current V07. Due to the magnitudes of the errors and the manner of IMERG processing, it was decided to again retrospectively process the entire V07 IMERG Final Run, incrementing the version number to V07B. Thereafter, SPEEDe is being run as a post-processor for GPROF orbits to catch any new problem orbits, with the intent that it will eventually be incorporated into GPROF. The screening for bad orbits was extended to the pre-TRMM DMSP record, revealing another ~200 bad orbits for F08. This is not terribly surprising given the progressive failure of both 85 GHz channels. See Tan et al. (2024) for more details. Note that SPEEDe is not designed to catch cases where the GPROF estimates are unphysically low.

Table 2: Listing of Level 2 GPROF orbit files deleted from the original V07 computation due to contamination by bad data. This includes both those orbits directly identified by SPEEDe as contaminated using sensor-dependent scoring thresholds and manual review (denoted by italic) and orbits that had to be deleted due to contamination by adjacent orbits in PPS processing. See https://gpm.nasa.gov/sites/default/files/2020-02/FileNamingConventionForPrecipitationProductsForGPMMission.pdf for the file naming convention. The lists are available as text files on request.

2A-CLIM.AQUA.AMSRE.GPROF2021v1.20020603-S021504-E035327.000435.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20020619-S192917-E210808.000679.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20020627-S152148-E170040.000793.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20020729-S183859-E201751.001261.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20021118-S233356-E011248.002895.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20021130-S122637-E140529.003063.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20030321-S114212-E132104.004679.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20030326-S120059-E133951.004752.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20031024-S032216-E050108.007834.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20031029-S151257-E165149.007914.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20031113-S043629-E061521.008126.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20031118-S144834-E162726.008205.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20040723-S185652-E203544.011819.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050514-S172207-E190059.016114.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050901-S010549-E024441.017706.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050907-S120055-E133947.017800.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050908-S223729-E001621.017821.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050909-S182406-E200258.017833.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050915-S093234-E111126.017915.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050916-S083656-E101548.017929.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050916-S165121-E183013.017934.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050922-S012416-E030308.018012.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050924-S174043-E191935.018051.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050926-S172820-E190712.018080.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050927-S131456-E145348.018092.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20050929-S193805-E211657.018125.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20051120-S105906-E123758.018877.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060204-S225627-E003520.019991.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060607-S025245-E043137.021770.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060705-S000017-E013910.022176.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060829-S131831-E145723.022985.V07A.HDF5

2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060914-S231154-E005046.023224.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20060927-S142637-E160529.023408.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20061111-S054103-E071955.024058.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20061117-S032501-E050353.024144.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20061119-S162348-E180240.024181.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20070117-S192317-E210209.025042.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20070626-S124741-E142633.027368.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20070903-S212026-E225918.028378.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071127-S001256-E015149.029603.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071202-S034917-E052809.029678.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071203-S061126-E075018.029694.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071203-S124658-E142550.029698.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071204-S015802-E033654.029706.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071204-S051548-E065440.029708.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071205-S010225-E024117.029720.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071205-S055904-E073756.029723.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071205-S173116-E191008.029730.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20071206-S131753-E145645.029742.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20090916-S221330-E235222.039213.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20090917-S031009-E044901.039216.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20090918-S184321-E202213.039240.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20091231-S211102-E224954.040756.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20100202-S070415-E084307.041228.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20100729-S160007-E173859.043811.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20110806-S143843-E161735.049242.V07A.HDF5
2A-CLIM.AQUA.AMSRE.GPROF2021v1.20111004-S060537-E074429.050096.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060304-S210453-E224648.012264.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060304-S224649-E002845.012265.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060305-S002846-E021041.012266.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060907-S095546-E113741.014899.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060907-S113742-E131938.014900.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060928-S103205-E121400.015196.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20060928-S121401-E135557.015197.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20070504-S232409-E010605.018283.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20070505-S010606-E024801.018284.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20070505-S024802-E042958.018285.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20071211-S202457-E220652.021403.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20071211-S220653-E234849.021404.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20110329-S205130-E223325.038410.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20110329-S223326-E001522.038411.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S082058-E100252.067944.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S100253-E114446.067945.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S150837-E165031.067948.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S165032-E183225.067949.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S183226-E201420.067950.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S201421-E215615.067951.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161218-S233811-E012004.067953.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161219-S012005-E030159.067954.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161219-S030200-E044354.067955.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161219-S044355-E062549.067956.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161219-S131329-E145523.067961.V07A.HDF5
2A-CLIM.F16.SSMIS.GPROF2021v1.20161219-S145524-E163717.067962.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150805-S215642-E233835.045155.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150805-S233836-E012030.045156.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S012031-E030224.045157.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S030225-E044418.045158.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S044419-E062612.045159.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S062613-E080807.045160.V07A.HDF5

2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S080808-E095001.045161.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S095002-E113155.045162.V07A.HDF5
2A-CLIM.F17.SSMIS.GPROF2021v1.20150806-S113156-E131350.045163.V07A.HDF5
2A-CLIM.F18.SSMIS.GPROF2021v1.20120214-S122504-E140702.011985.V07A.HDF5
2A-CLIM.F18.SSMIS.GPROF2021v1.20120214-S140703-E154902.011986.V07A.HDF5
2A-CLIM.F18.SSMIS.GPROF2021v1.20120214-S154903-E173101.011987.V07A.HDF5
2A-CLIM.GCOMW1.AMSR2.GPROF2021v1.20120717-S020101-E033953.000882.V07A.HDF5
2A-CLIM.GCOMW1.AMSR2.GPROF2021v1.20120717-S033954-E051846.000883.V07A.HDF5
2A-CLIM.METOPA.MHS.GPROF2021v1.20151014-S104454-E122614.046623.V07A.HDF5
2A-CLIM.METOPA.MHS.GPROF2021v1.20151014-S122615-E140736.046624.V07A.HDF5
2A-CLIM.METOPA.MHS.GPROF2021v1.20151104-S100923-E115044.046921.V07A.HDF5
2A-CLIM.METOPA.MHS.GPROF2021v1.20151104-S115045-E133205.046922.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221207-S194453-E212613.053036.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221208-S023019-E041139.053040.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221208-S041140-E055301.053041.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221210-S032945-E051106.053069.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221210-S051107-E065227.053070.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221210-S083350-E101510.053072.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221210-S101511-E115632.053073.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221211-S030847-E045008.053083.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221211-S045009-E063130.053084.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221213-S073057-E091217.053114.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20221213-S091218-E105339.053115.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230112-S085124-E103245.053541.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230112-S103246-E121406.053542.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230113-S201956-E220117.053562.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230207-S030846-E045006.053907.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230207-S045007-E063128.053908.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230217-S044313-E062434.054050.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230217-S062435-E080555.054051.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230218-S143025-E161145.054070.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230218-S161146-E175307.054071.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230223-S110413-E124533.054139.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230223-S124534-E142655.054140.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230316-S153313-E171434.054440.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230316-S171435-E185555.054441.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230403-S041129-E055250.054689.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230403-S055251-E073411.054690.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230423-S140544-E154704.054979.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230423-S154705-E172826.054980.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230501-S194441-E212601.055096.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230501-S212602-E230723.055097.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230506-S175946-E194106.055166.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230512-S205755-E223916.055253.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230512-S223917-E002037.055254.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230519-S215343-E233503.055353.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230519-S233504-E011625.055354.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230521-S211144-E225304.055381.V07A.HDF5
2A-CLIM.METOPB.MHS.GPROF2021v1.20230521-S225305-E003426.055382.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181119-S223054-E001250.000183.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S001251-E015411.000184.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S015412-E033533.000185.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S033534-E051654.000186.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S051655-E065816.000187.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S065817-E083937.000188.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20181120-S083938-E102059.000189.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20201129-S232958-E011119.010711.V07A.HDF5
2A-CLIM.METOPC.MHS.GPROF2021v1.20201130-S011120-E025241.010712.V07A.HDF5

2A-CLIM.METOPC.MHS.GPROF2021v1.20201130-S025242-E043402.010713.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20020514-S044228-E062431.008459.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20020514-S062432-E080635.008460.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20020902-S194741-E212943.010034.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20020902-S212944-E231147.010035.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20030209-S202040-E220242.012292.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20030209-S220243-E234445.012293.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20031118-S004238-E022439.016260.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20031118-S022440-E040641.016261.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20040408-S072741-E090942.018268.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20040408-S090943-E105144.018269.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20040907-S135120-E153320.020417.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20040907-S153321-E171522.020418.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050130-S144022-E162222.022464.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050130-S162223-E180424.022465.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050630-S191742-E205942.024598.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050630-S205943-E224143.024599.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050909-S052612-E070812.025592.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050909-S070813-E085013.025593.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050919-S101703-E115903.025736.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20050919-S115904-E134105.025737.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20051018-S231912-E010112.026153.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20051019-S010113-E024313.026154.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20051207-S064410-E082610.026849.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20051207-S082611-E100811.026850.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060116-S141209-E155409.027418.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060116-S155410-E173610.027419.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060128-S234509-E012709.027593.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060129-S012710-E030910.027594.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060316-S230212-E004412.028256.V07A.HDF5
2A-CLIM.NOAA16.AMSUB.GPROF2021v1.20060317-S004413-E022613.028257.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030222-S214530-E232643.003458.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030222-S232644-E010757.003459.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030501-S042148-E060300.004415.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030501-S060301-E074414.004416.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030704-S033759-E051911.005325.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20030704-S051912-E070025.005326.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20040527-S163743-E181855.009999.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20040527-S181856-E200008.010000.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20040623-S212729-E230840.010386.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20040623-S230841-E004953.010387.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20050520-S103344-E121455.015089.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20050520-S121456-E135608.015090.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20050927-S142206-E160317.016941.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20050927-S160318-E174430.016942.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20051029-S120737-E134848.017395.V07A.HDF5
2A-CLIM.NOAA17.AMSUB.GPROF2021v1.20051029-S134849-E153000.017396.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20091006-S044803-E063009.003408.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20091006-S063010-E081215.003409.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20091006-S081216-E095422.003410.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S023538-E041739.044673.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S041740-E055940.044674.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S055941-E074142.044675.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S074143-E092343.044676.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S092344-E110544.044677.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S110545-E124746.044678.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S124747-E142947.044679.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S142948-E161149.044680.V07A.HDF5

2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S161150-E175350.044681.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S175351-E193551.044682.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S193552-E211753.044683.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S211754-E225954.044684.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171009-S225955-E004156.044685.V07A.HDF5
2A-CLIM.NOAA19.MHS.GPROF2021v1.20171010-S004157-E022357.044686.V07A.HDF5
2A.NOAA20.ATMS.GPROF2021v1.20240925-S145654-E163823.035516.V07B.HDF5
2A-CLIM.NOAA21.ATMS.GPROF2021v1.20230206-S140122-E154251.001253.V07A.HDF5
2A-CLIM.NOAA21.ATMS.GPROF2021v1.20230206-S154252-E172421.001254.V07A.HDF5
2A-CLIM.NOAA21.ATMS.GPROF2021v1.20230206-S172422-E190551.001255.V07A.HDF5
2A-CLIM.NOAA21.ATMS.GPROF2021v1.20230206-S190552-E204721.001256.V07A.HDF5
2A-CLIM.NOAA21.ATMS.GPROF2021v1.20230206-S204722-E222850.001257.V07A.HDF5
2A.METOPB.MHS.GPROF2021v1.20230825-S212448-E230609.056745.V07A.HDF5
2A.METOPB.MHS.GPROF2021v1.20230825-S230610-E004730.056746.V07A.HDF5
2A.METOPB.MHS.GPROF2021v1.20230904-S225901-E004022.056888.V07A.HDF5
2A.METOPB.MHS.GPROF2021v1.20230905-S004023-E022143.056889.V07A.HDF5

b shows a particularly bad example of bad GPROF retrievals contaminating the monthly average of precipitation in IMERG V07A Final Run for December 2016. a shows the new IMERG V07B Final Run, and c shows the difference. b note the swath-shaped streaks of light precipitation in the subtropical highs in the eastern Pacific and eastern Atlantic, which c reveals to be part of the defective retrievals. Background work identified the particular orbits and helped motivate development of the SPEEDe routine for comprehensive scanning of all GPROF Level 2 orbit segments that resulted in the listing in Table 2. Note that some “bad” retrievals have a different appearance, in which the orbit granule is entirely covered by non-zero (but reasonable) precipitation values that appear as swirly patterns.

Reference

Tan, J., G.J. Huffman, Y. Song, 2024: Automated Quality Control Scheme for GPM Satellite Precipitation Products. *Geophys. Res. Lett.*, accepted.

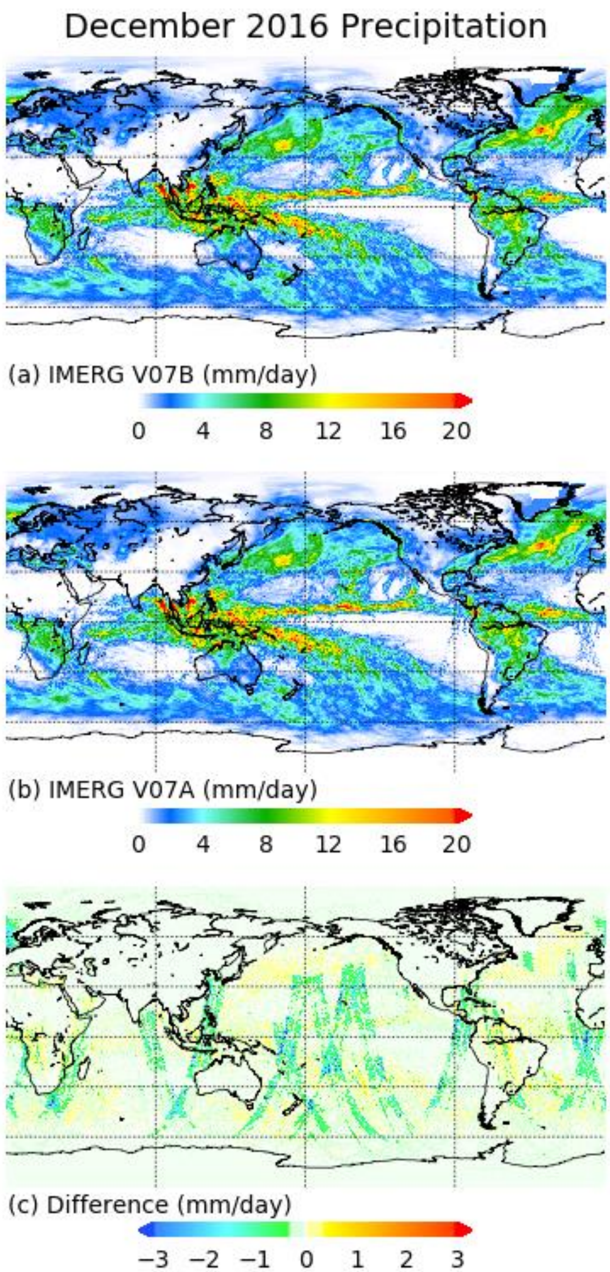

Figure 11: Example of a) re-retrospectively processed IMERG V07B Final Run, b) the original retrospectively processed IMERG V07 (now V07A) Final Run, and c) the difference for December 2016, a month with a few known bad GPROF orbits.

Appendix 4: IMERG Data for Jan 1998–May 2000

Jackson Tan, George J. Huffman
20 November 2024

On 7 November 2024, IMERG V07B data for the period of January 1998 to May 2000 were released, extending the IMERG record back to the start of the TRMM era. Prior to this, the IMERG V07B record began in June 2000 due to the partial record of NOAA CPC 4-km Merged Geostationary Earth Orbit infrared (GEO-IR) product during this 2.5-year period. [The CPC IR record is continuous beginning in the middle of 7 February 2000, but the previous IMERG V07B record began on 1 June 2000 to allow the calibration of IR precipitation to spin up.] The lack of complete CPC IR data has now been circumvented by using the GridSat-B1 IR product from NOAA NCDC for this entire 2.5-year period (Figure 12).

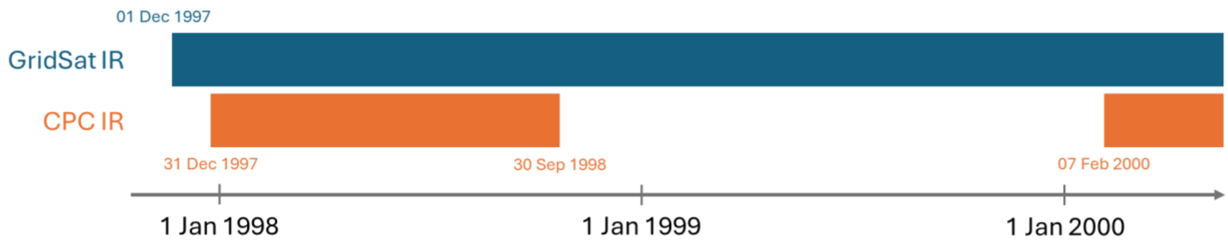

Figure 12: Availability of the GridSat-B1 IR Tb and the CPC IR Tb for the first 2.5 years of the TRMM era.

GridSat-B1 is a Climate Data Record containing the 11 μm brightness temperature (Tb) from geostationary satellites. It uses a similar set of satellite data as CPC IR, but with different processing and stitching approaches, resulting in Tb's that are similar but not exactly the same (Figure 13). It is available at a 0.07°, 3-h resolution, which necessitated the use of spatial interpolation and morphing (with SHARPEN) to map it to the same resolution as the CPC IR product. This interpolated GridSat-B1 data is then ingested into the IMERG algorithm as is (i.e., no change to the algorithm and the run configuration) to produce the IR precipitation, which serves as one of the inputs into the merged IMERG field from Kalman filter scheme.

While the use of GridSat-B1 product helps overcome the lack of CPC IR data, it is associated with several drawbacks. The first—and perhaps most prominent—issue is the inconsistency throughout the record. While reasonable efforts have been made to ensure continuity in the overall mean precipitation rates in the record, it is likely that specific regions and/or higher moments of the distribution exhibit different characteristics during this early period than the rest of the record. In fact, it is partly for this reason that we avoided switching back and forth between GridSat-B1 and CPC IR in the early part of the record (see Figure 12), instead opting to use GridSat-B1 alone until the CPC IR is continuously available starting in February 2000. The second issue is the change in the quality of the data. Our preliminary analysis suggested that the IR precipitation from the interpolated GridSat-B1 displays reduced quality at the pixel-to-pixel level but with increased half-hourly consistency compared to the CPC 4-km IR product. The third issue is the incompleteness of the data. Specifically, the IR coverage during this early TRMM period has more data dropouts and missing sectors, which—when coupled with the sparseness of the passive microwave coverage in this early TRMM era—resulted in occasional missing values (recorded as −9999.9) within 60°N/S in the complete IMERG estimate. [To be fair, this issue would affect the CPC 4-km IR product as well.] The fourth issue is artifacts

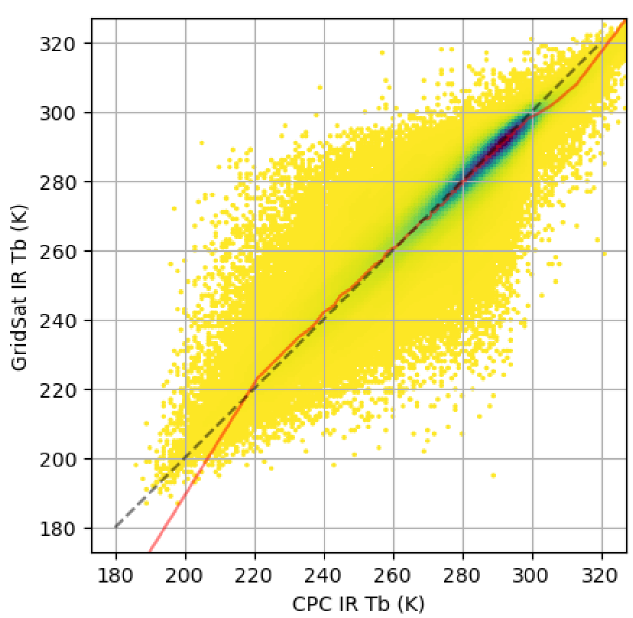

Figure 13: A density scatter diagram comparing the GridSat-B1 IR Tb to the CPC IR Tb at the synoptic 3-h observation time. The red line shows the quantile-to-quantile plot.

associated with the interpolation from the synoptic 3-h observations. While morphing—especially with SHARPEN—enabled relatively smooth half-hourly steps bridging across the 3-h gap, the intricacies associated with the IR precipitation scheme, PDIR–Now, may be sensitive to this interpolation, leading to some three-hourly cycle in the statistics.

Figure 14 shows the time-series for various half-hourly statistics of the IMERG variable *precipitation* within 60°N/S for February 2000. This month can provide useful insights due to the switch from GridSat-B1 to CPC IR on 7 February 2000, not just on the immediate transition itself but also residual effects as the 6-pentad (30-day) calibration progressively "rolls off" GridSat-B1 and onto CPC IR. Looking at the mean precipitation rate, the transition is reasonably seamless. In the standard deviation of the precipitation rate and the fractions of pixels exceeding various rates, there appears to be a slight increase in variability (i.e., more squiggly lines) after switching over to CPC IR with its higher temporal resolution, suggesting a change in the precipitation characteristics. Also worth noting is the nonzero fraction of missing pixels both during the GridSat-B1 period and the CPC IR period, an issue with which users must cope when calculating bulk statistics. For example, these pixels should be excluded when calculating the mean value, which would otherwise drastically pull down the average.

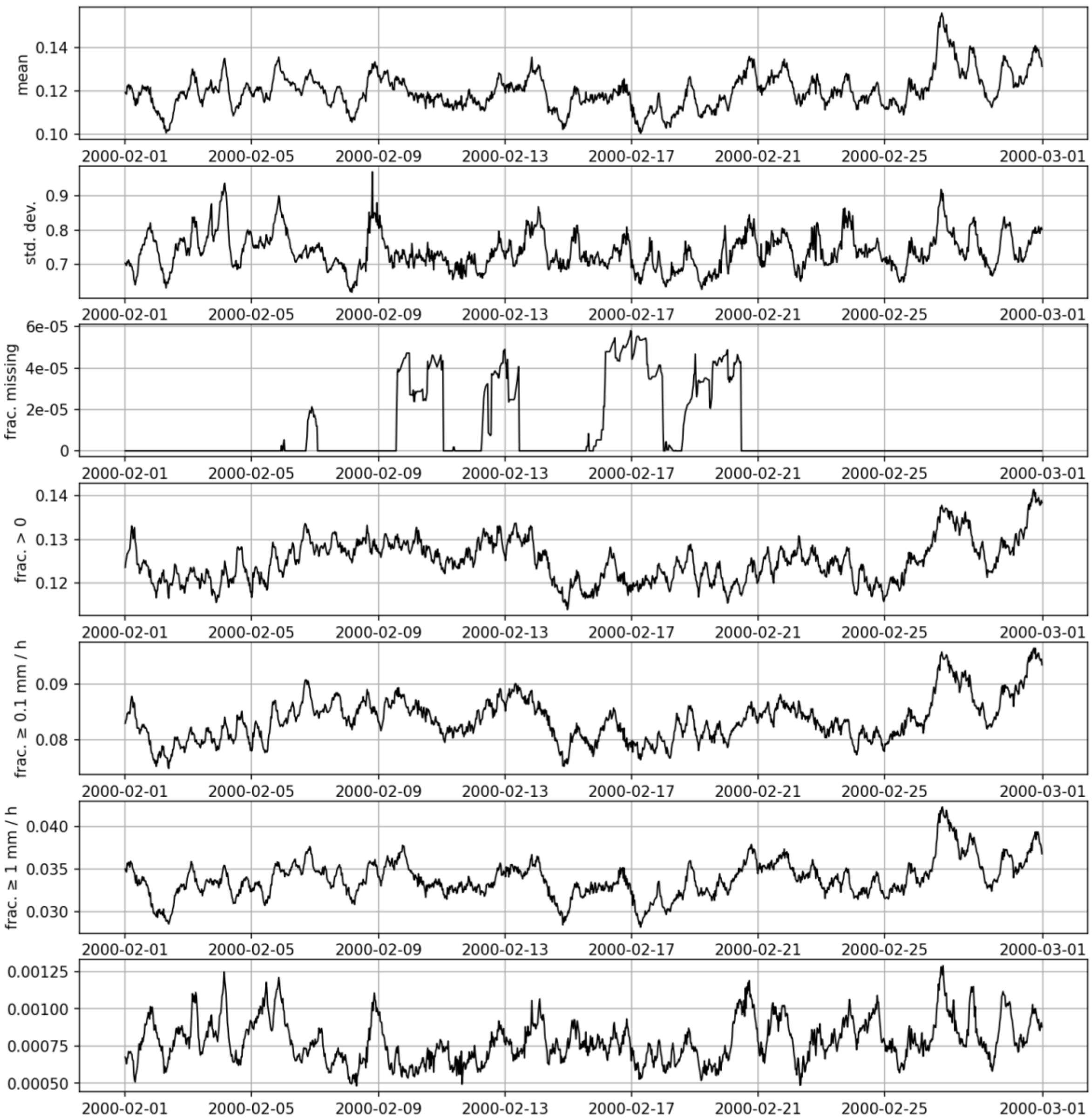

Figure 14: Time-series of various half-hourly statistics in the IMERG precipitation field within 60°N/S for February 2000. Note that the IR record transitions from GridSat-B1 to CPC IR on 7 February 2000.

Figure 15 shows a HATS diagram for the period of 1998 to 2000. A HATS diagram depicts the histogram counts of the half-hourly field in each column (*y*-axis) over the entire period (*x*-axis), but in the form of the difference against the average of the period. Figure 15 reveals several systematic shifts in the distribution of the precipitation rates during this period. The most notable shifts are those occurring in the Januarys of all the years examined (strictly speaking, from 1 January to 30 January), during which there is a higher count of light-to-moderate precipitation rates. This is not an issue limited to this 2.5-year period but encompasses the entire TRMM era (January 1998 to May 2014) and affects the mid-latitudes. Investigations have traced the issue to the climatological calibration file for PMW estimates outside the 37°N-S band having incomplete data due to spin-up issues. A notable feature—or lack thereof—in Figure 15 is the absence of a change in February 2000 associated with the switch from GridSat-B1 IR to CPC IR.

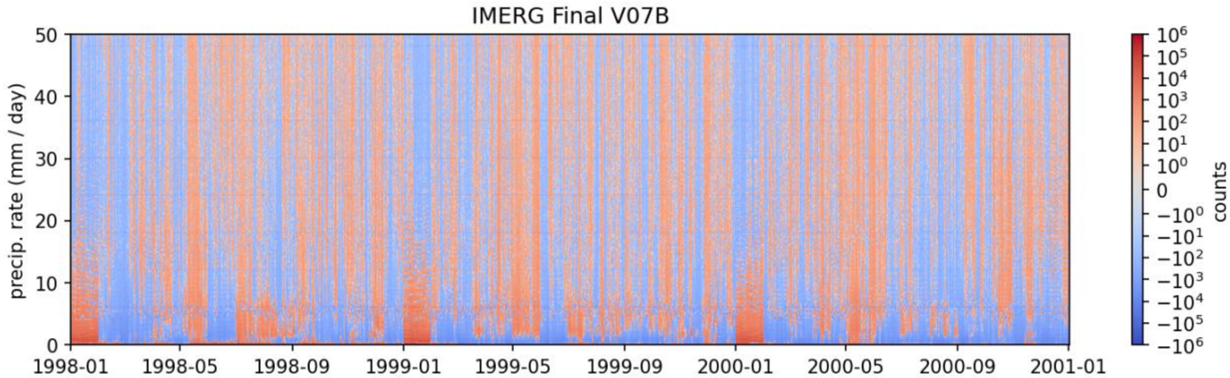

Figure 15: A Histogram Anomaly Time-Series (HATS) diagram for the half-hourly precipitation within 60°N/S from 1998 to 2000. A Savitzky–Golay filter of order 3 and window length 11 was applied to emphasize systematic changes.

In short, the use of GridSat-B1 permits the IMERG record to be extended back to the start of the TRMM era in January 1998, with caveats. We recommend that users avoid using data from this period if it is unnecessary for their purpose. If used, we strongly urge users to pay close attention to the expected artifacts and to the increased presence of missing data (value of −9999.9).