The Transition in Multi-Satellite Products from TRMM to GPM (TMPA to IMERG)

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The transition from the Tropical Rainfall Measuring Mission (TRMM) data products to the Global Precipitation Measurement (GPM) mission products is completed. This document specifically addresses the multi-satellite products, namely the TRMM Multi-satellite Precipitation Analysis (TMPA), the real-time TMPA (TMPA-RT), and the Integrated Multi-satellitE Retrievals for GPM (IMERG).

1. TRMM Status and Future

The TRMM satellite reentered the Earth's atmosphere on 17 June 2015, and whatever debris survived landed in the southern Indian Ocean well west of Australia. The terminal phase began when fuel was exhausted in July 2014. On 7 October 2014 the satellite descended to an altitude that precluded useful TRMM Precipitation Radar data, with a brief revival as TRMM descended past the original altitude of 350 km. Meanwhile, the TRMM Microwave Imager (TMI) continued to function with slowly changing characteristics until it was shut down on 8 April 2015 as part of the decommissioning, or "passivation" of the satellite. The actual demise of TRMM is not the substantive issue for the TMPA and TMPA-RT.

2. Final Phase for TMPA

Starting with data for October 2014, the intercalibration of the passive microwave precipitation estimates had to change for production 3B42, and this created at least a slight inhomogeneity, primarily over the oceans. We already know that calibrations involving PR have a different interannual behavior than calibrations based solely on passive microwave. The character of the 3B42 has changed somewhat, since the calibrator no longer involves radar data, so it is recommended that projects that require the best homogeneity only use 3B42 for the period January 1998 to September 2014. Nonetheless, we ran 3B42 in parallel with IMERG through December 2019. [Note that this is much later than some early planning called for; see the IMERG timeline, below.] One unavoidable issue is that the loss of TMI data reduces the amount of conical-scan imager data going into the TMPA and TMPA-RT. All of the TMPA datasets continue to be called TRMM Version 7 despite these changes.

3. Final Phase for TMPA-RT

Meanwhile, the 3B42RT system was already computed with a climatological intercalibration for the passive microwave precipitation estimates (i.e., they are not calibrated with current data), so 3B40RT, 3B41RT, and 3B42RT continue to function as they have. One unavoidable issue is that the loss of TMI data reduces the amount of conical-scan imager data going into both the TMPA and TMPA-RT. We recognized the application focus for 3B42RT, and ran it for several months after the equivalent IMERG products are satisfactory. Completion of a satisfactory retrospective IMERG processing was completed in August 2019 (again, much later than stated in earlier versions of this document), and we ceased producing TMPA and TMPA-RT products after

computing all products through the end of December 2019. We suppose that some users would have wanted the old product forever, but changing IR security rules, aging computer hardware and software, and declining availability of satellites from the TRMM era necessitate this timing.

4. IMERG Timeline

- The "Day 1" Version 03 IMERG Final Run data sets (for the GPM era, mid-March 2014 to the present, delayed about 3 months) were released in late December 2014.
- In Version 03, the IMERG Late Run data sets began 7 March 2015, while the Early Run started 1 April 2015.
- The first retrospectively processed GPM-era IMERG data sets were released as GPM Version 04 in Spring 2017 (somewhat later than previously announced).
- Another retrospectively processed GPM-era IMERG data set was released as Version 05 in November 2017.
- Initial Processing (i.e., with new data) for Early and Late Runs were upgraded to V06 as of 00 UTC 1 May 2019.
- The extension of IMERG back to the TRMM era happened in Summer 2019 as part of Version 06.
    - Final Run retrospective processing for the GPM era (first release is June 2014) began 4 June 2019 (after two starts that revealed processing errors) and the complete record from June 2000 to early 2019 finished on 3 July.
    - The Early and Late were retrospectively processed for the entire record, with completion on 20 August 2019.

The goal is to start the IMERG record at the beginning of 1998, but at the present the appropriate geo-infrared data are not available before mid-February 2000. This issue affects all runs, including the Final, and it's being worked.

Given the sea change in algorithms from TRMM to GPM, the project chose to use the retrospective processing for IMERG in place of a final reprocessing for the TMPA/TMPA-RT. [This final reprocessing would have been labeled "TRMM Version 8".]

5. Further Information

The best published reference for IMERG is:

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*

The IMERG Algorithm Theoretical Basis Document (ATBD) is currently the best technical reference for IMERG. It is accessible at

https://pmm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V6.pdf

The technical document is located at

https://pmm.nasa.gov/sites/default/files/document_files/IMERG_doc_190909.pdf

The GPM web site

https://gpm.nasa.gov/

is the right general source for news, and its IMERG data access page contains hot links to the latest versions of these documents, as well as release notes. Specific IMERG announcements will be posted to the IMERG mailing list, and you're always free to ask if you think we're too quiet or you hear a rumor. If you wish to be added to the IMERG mailing lists, please e-mail

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Together with all GPM and TRMM data sets, IMERG data set locations are posted on the consolidated GPM data access pages, available through

https://gpm.nasa.gov/data-access/

The best place to ask questions (because they go to more than one person), is the "contact us" link at the bottom of the GPM web page

https://gpm.nasa.gov/contact?edit[cid]=3

5. IMERG-TMPA Design Comparison

Both TMPA and IMERG use a constellation of passive microwave satellites, and within the general umbrella groups of "sounder" and "imager" the inputs are much the same, although at the end of the TRMM era the TMPA was not upgraded to include the newer satellites. The direct inputs of the TMI and GMI are swamped by the amount of data from the rest of the microwave sensors, so the absence of TMI in the last 4.5 years of TMPA was not a major problem. At the back end of the multi-satellite algorithms, both TMPA and IMERG use the same scheme for combining satellite data with the GPCC analysis, although IMERG uses the GPCC Final analysis up through 2018, which tends to be more accurate than the GPCC Monitoring analysis that the TMPA used for the last ~9 years. What's different? The algorithms for the Combined products are very different (2B31 for TMPA and CORRA for IMERG), and that is what provides calibration. The GPROF algorithm has been upgraded for use in IMERG – still Bayesian, but with the libraries of profiles sourced and organized differently. The IR scheme has shifted from VAR to PERSIANN-CCS – very different approaches. Compared to the simple chunking of data into 3-hour intervals in TMPA, note the massive amount of time spent in IMERG on morphing and the Kalman filter. The goal is two-fold:

1) Provide a finer time resolution so that system evolution is more accurately captured, compared to the 3-hour interval in TMPA. This improved evolution not only provides more-frequent data values, but it should also make the IMERG time averages (such as daily) more accurate, since precipitation changes so rapidly in space and time.
2) Reduce the use of IR estimates, which have low quality, by time-interpolating the microwave estimates, which have better quality. The hard part here is that the interpolation has to be done in a quasi-Lagrangian framework because the rain systems move. So, IMERG's morphing/Kalman framework is intended to minimize the IR contribution, even though IR is still seen as necessary in regions with long microwave gaps.

TMPA-IMERG Comparison

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algorithm	TRMM Multi-satellite Precipitation Analysis	Integrated Multi-satellitE Retrievals for GPM
basic acronym	TMPA	IMERG
data sets	• 3B42/3B43 production multisatellite-gauge combination • 3B40RT/3B41RT/3B42RT real-time merged microwave, microwave-calibrated IR, multisatellite	• 3IMERGHH/3IMERGM Final Run multisatellite-gauge combination • 3IMERGL Late Run near-real-time • 3IMERGE Early Run near-real-time
spatial grid; coverage	0.25°x0.25° lat/lon; 50°N-S	0.1°x0.1° lat/lon; 90°N-S
current version	7 (7A for parts, but this is a technicality)	06B (6B for parts, but this is a technicality)
time interval; span	• 3 hr centered at 00, 03, …, 21 UTC; 1 Jan 1998-present (production), 15 Feb 2000-present (real-time) • monthly; Jan 1998-present (production) • other value-added products in data centers	• 30 min; June 2000-present (delayed for corresponding latencies), to be extended to Jan 1998 when feasible • monthly; June 2000-(delayed) present (Final), to be extended to Jan 1998 when feasible • other value-added products in data centers
latency	• 3B42/3B43 2.5 mo after the month's end • 3B40RT/3B41RT/3B42RT 8 hr after obs. time	• Final 3.5 mo after the month's end • Late 14 hr after obs. time • Early 4 hr after obs. time
native format	• HDF4 (production) • binary (RT) • other value-added products in data centers	• HDF5 • other value-added products in data centers
algorithm summary	• calibrate microwave precip rates to TRMM Combined Instrument • merge microwave (HQ), giving preference to conical-scanners • compute VAR microwave-calibrated IR precip rates • fill holes in HQ merged microwave with IR estimates • include gauge data by - computing monthly satellite-gauge and then scaling 3 hr data to sum to the monthly in each grid box (production) - scaling 3 hr to 3B42 with climatological coefficients (RT)	• calibrate microwave precip rates to GPM Combined Instrument, which are climatologically calibrated to GPCP V2.3 • merge microwave (HQ), giving preference to conical-scanners • compute PERSIANN-CCS microwave-calibrated IR precip rates • use CMORPH-style motion vectors based on vertically integrated water vapor (from numerical analyses) to forward/backward propagate microwave maps, then use a Kalman filter to combine these and the IR estimates into a weighted estimate (Early is forward-only) • include gauge data by - computing monthly satellite-gauge and then scaling 30 min data to sum to the monthly in each grid box (Final) - (future) scaling 30 min to Final with climatological coefficients (Late and Early)
input microwave algorithms	• GPROF versions 2010v2 and 2004v for various conical scanners • NOAA MSPPS for cross-track scanners	• GPROF2017, except • PRPS V2 for SAPHIR

transition	• continued to be run for several months after IMERG was retrospectively processed for the TRMM era to allow a transition for users • Ended with December 2019	• V06 retrospectively processed back through the TRMM era, initially starting with June 2000; this stands in for the TRMM V8 last processing

Data Fields in TMPA V7 (top left), TMPA-RT V7 (top right), and IMERG V06 (bottom)

	3-hourly data file (3B42)
1	*Multi-satellite precipitation*
2	*Multi-satellite precipitation error*
3	Sat. obs. time
4	PMW precipitation
5	IR precipitation
6	Satellite source identifier
	Monthly data file (3B43)
1	*Satellite-Gauge precipitation*
2	*Satellite-Gauge precipitation error*
3	Gauge relative weighting

	Merged microwave data file (3B40RT)
1	*Merged PMW precipitation*
2	*Merged PMW precipitation error*
3	# pixels
4	# ambig. pixels
5	# rain pixels
6	PMW source identifier
	IR data file (3B41RT)
1	*PMW-cal. IR precipitation*
2	*PMW-cal. IR precipitation error*
3	# pixels
	Multi-satellite data file (3B42RT)
1	*Calibrated precipitation*
2	*Calibrated precipitation error*
3	Satellite source identifier
4	Uncalibrated precipitation

	Half-hourly data file (IMERG Early, Late, Final)
1	*Calibrated multi-satellite precipitation*
2	*Uncalibrated multi-satellite precipitation*
3	*Calibrated multi-satellite precipitation error*
4	PMW precipitation
5	PMW source identifier
6	PMW source time
7	IR precipitation
8	IR KF weight
9	*Probability of liquid-phase precipitation*
10	*Quality Index*
	Monthly data file (IMERG Final)
1	*Satellite-Gauge precipitation*
2	*Satellite-Gauge precipitation error*
3	Gauge relative weighting
4	*Probability of liquid-phase precipitation*
5	*Quality Index*