

Introduction to Satellite Precipitation Estimates

George J. Huffman

NASA/Goddard Space Flight Center

and thanks to R.F. Adler, D.T.
Bolvin, D. Braithwaite, K. Hsu,
R. Joyce, E.J. Nelkin, P. Xie

Background

TMPA Algorithms and Inputs

Results

GPM and IMERG

User Issues

Concluding Remarks

1. Background (1/2)

A diverse, changing, uncoordinated set of input precip estimates, with various

- periods of record
- regions of coverage
- sensor-specific strengths and limitations

	<u>infrared</u>	<u>microwave</u>
latency	15-60 min	3-4 hr
footprint	4-8 km	5-30+ km
interval	15-30 min (up to 3 hr)	12-24 hr (~3 hr)

“physics” cloud top hydrometeors
 weak strong

- additional microwave issues over land include
 - scattering channels only
 - issues with orographic precip
 - no estimates over snow

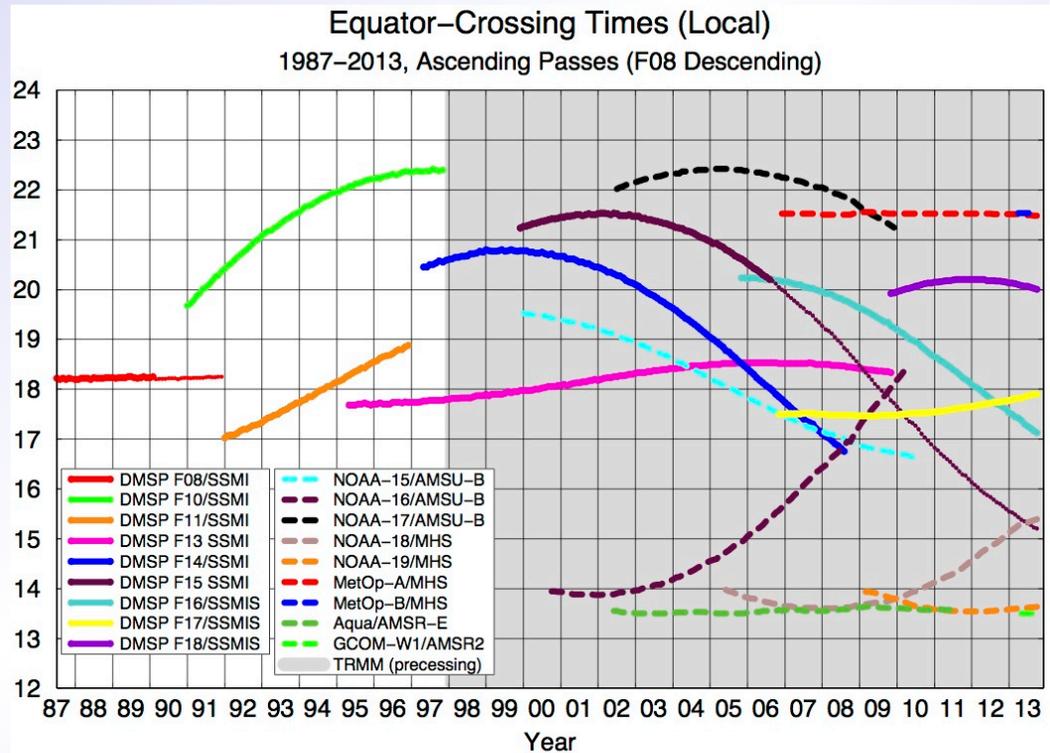


Image by Eric Nelkin (SSAI), 23 October 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

1. Background (2/2)

Combination products discussed here are High-Resolution Precipitation Products (HRPP)

- emphasize fine-scale accuracy over homogeneity
 - but homogeneity still valued
- not a Climate Data Record
- current products summarized in IPWG data listings:
 - <http://www.isac.cnr.it/~ipwg/data/datasets.html>
 - planning to beef up user-oriented information
- examples
 - CPC Morphing algorithm (CMORPH)
 - Global Satellite Map of Precipitation (GSMaP)
 - Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN)
 - Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR)
 - TRMM Multi-satellite Precipitation Analysis (TMPA)

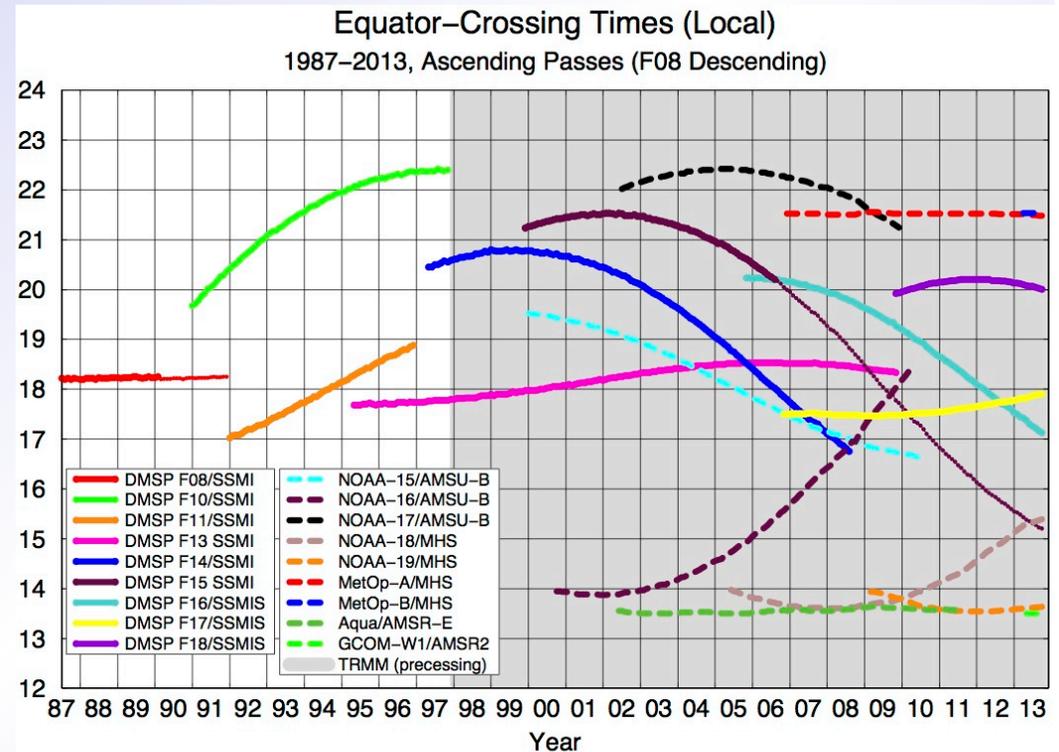


Image by Eric Nelkin (SSAI), 23 October 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

2. TMPA – Flow Chart (1/2)

Computed in both real and post-real time, on a 3-hr 0.25° grid

Microwave precip:

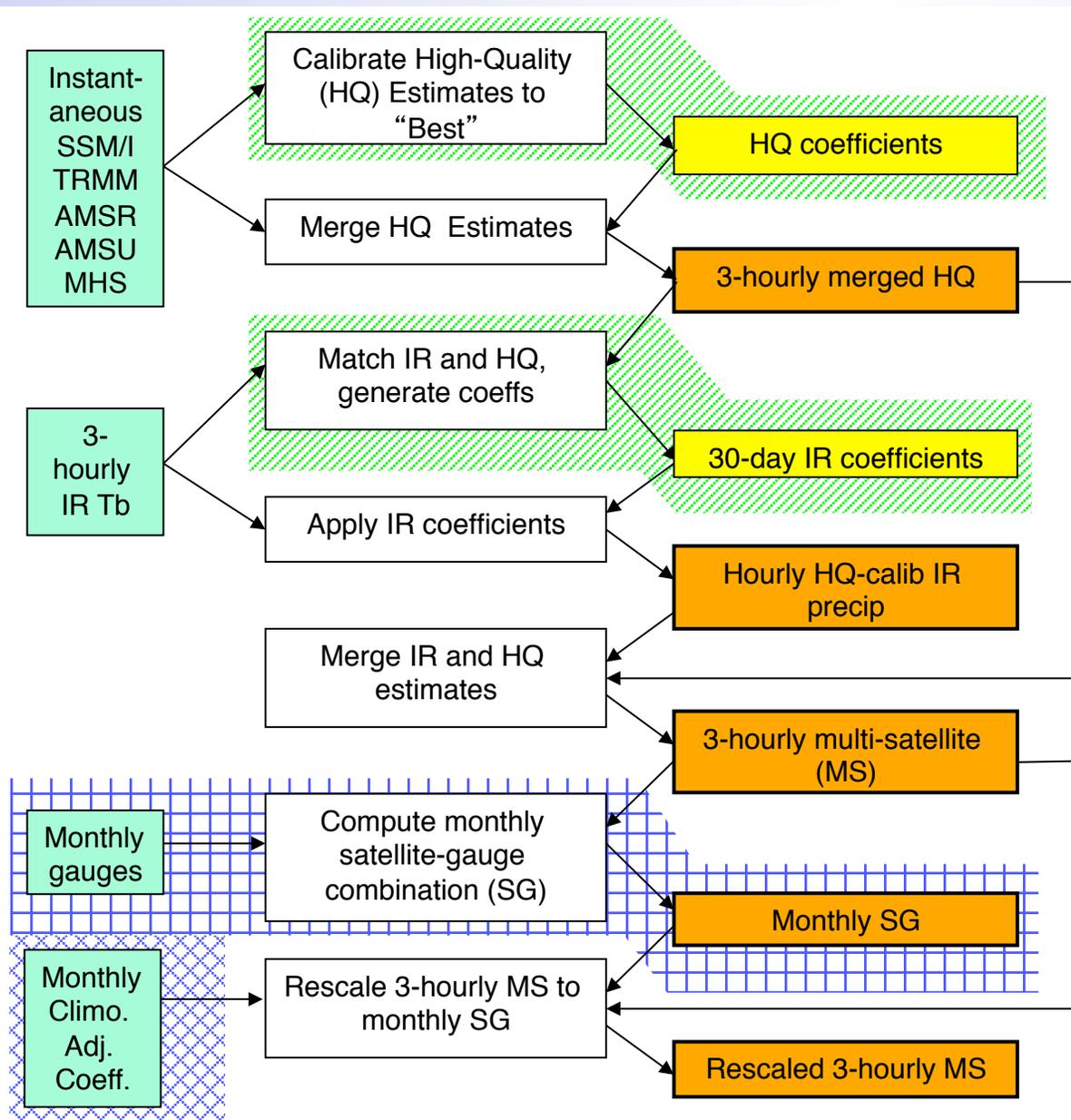
- intercalibrate to TMI/PR combination for P
- intercalibrate to TMI for RT
- then combine, conical-scan first, then sounders

IR precip:

- calibrate with microwave

Combined microwave/IR:

- IR fills gaps in microwave



2. TMPA – Flow Chart (2/2)

Both RT and P calibrate the initial 3-hr multi-satellite (MS)

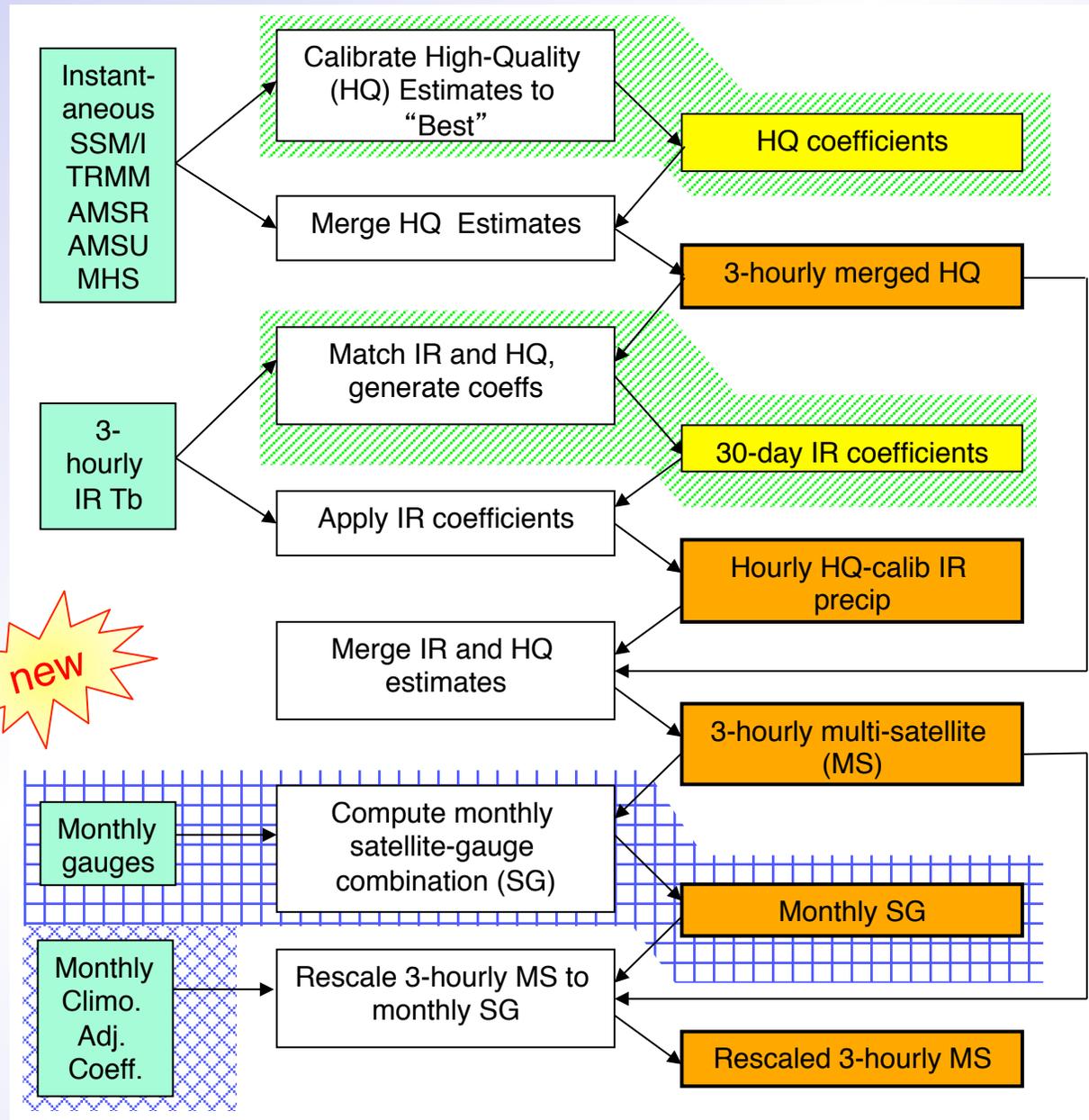
- P uses monthly gauges
- RT uses climatological calibration to TMI/PR, P

In V.7, both RT and P

- provide both cal. and uncal. 3-hr estimates
- include SSMIS data

V.7 RT features retrospective processing starting March 2000

- start date determined by IR dataset
- implements concept first developed for GPM
- driven by user feedback



2. TMPA – Final Calibration

Production TMPA

- monthly MS and GPCC gauge analysis combined to Satellite-Gauge (SG) product
- weighting by estimated inverse error variance
- 3-hrly MS rescaled to sum to monthly SG

Real-Time TMPA

- 3-hrly MS calibrated using climatological TCI, 3B43 coefficients

Each product should tend to follow its calibrators

- over land – the GPCC gauge analysis
- over ocean – satellite calibrator
- climatological calibration only sets long-term bias, not month-to-month behavior
- current work with U. Wash. group uncovering regional variations

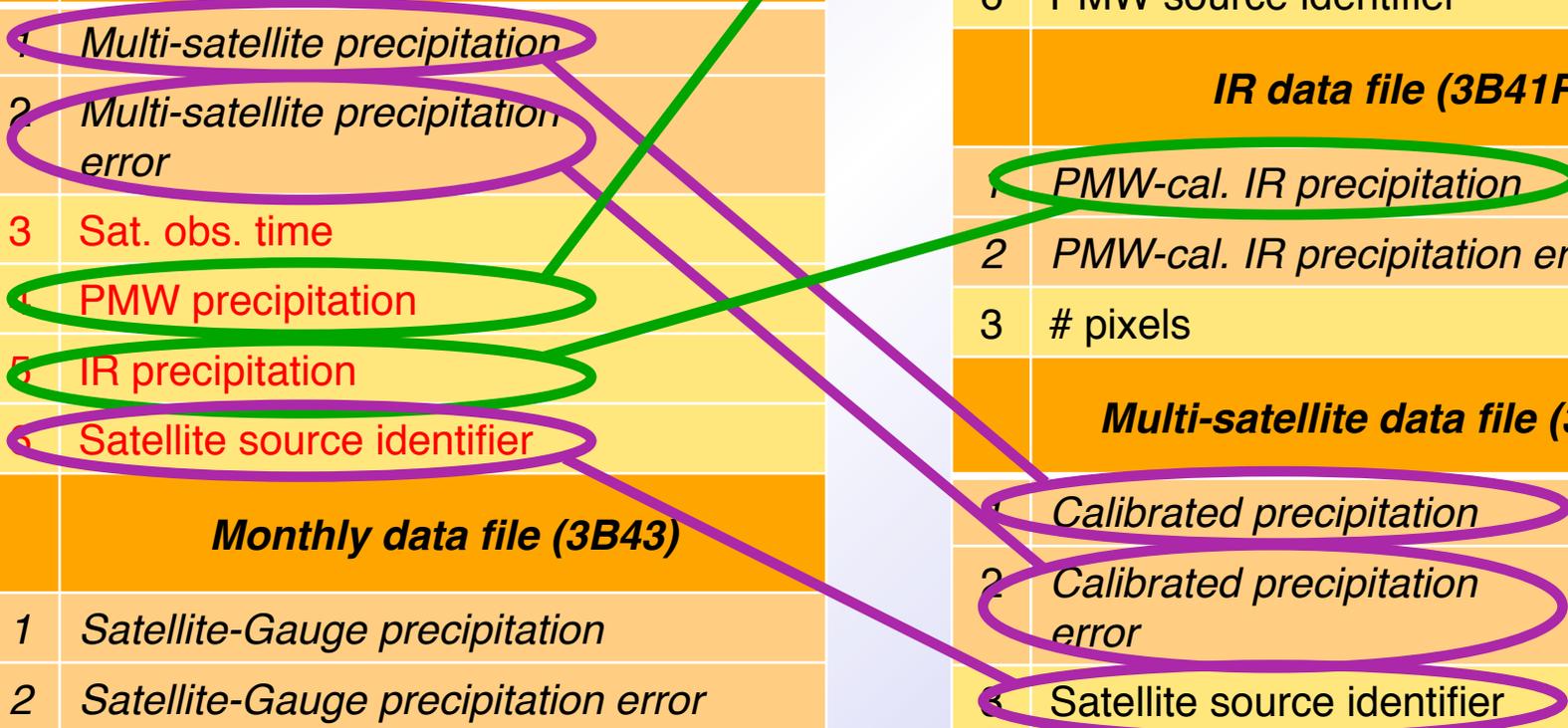
2. TMPA – Data Fields

Output datasets include intermediate data fields

- required by users and developers
 - more extensive in Version 7 (in red)

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



3. Dominant Controls on Performance

Fine-scale variations

- land and ocean: occurrence of precipitation in the individual input datasets
- inter-satellite calibration attempts to enforce consistency in distribution
- event-driven statistics depend on satellites, e.g. bias in frequency of occurrence

Differences between sensors tend to be noticeable

- different sensors “see” different aspects of the same scene
- limited opportunities to “fix” problems with the individual inputs on the fly
- satellite sensors tend to be best for tropical ocean
- satellite sensors and rain gauge analyses tend to have more trouble in cold areas and complex terrain

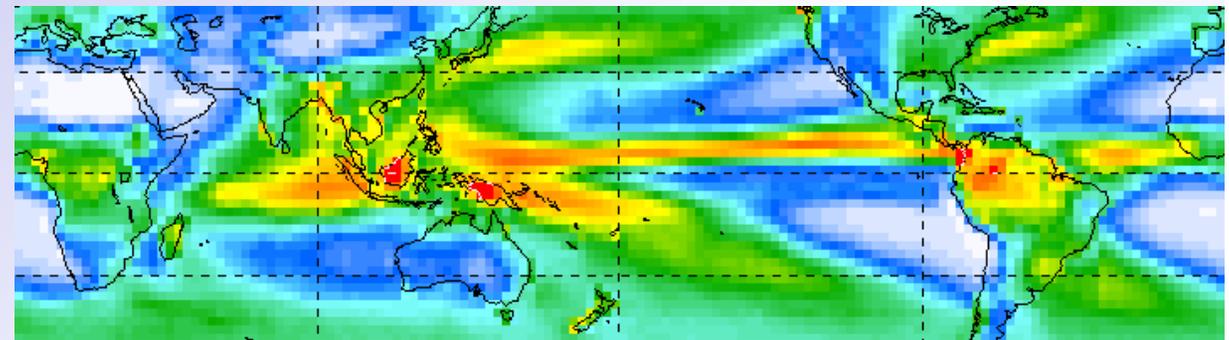
3. TMPA V.7 vs. GPCP V2.2

TMPA averaged to 2.5° grid

Monthly (and longer) bias in amount governed by

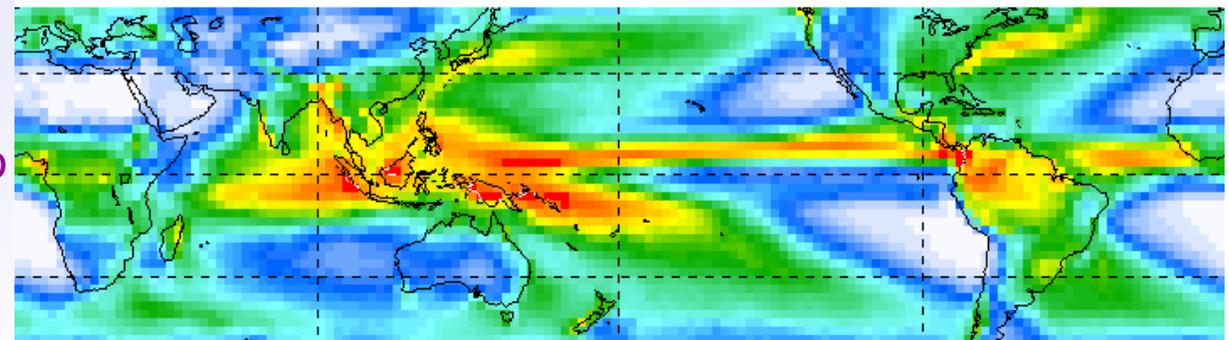
- land: rain gauge analysis
 - very similar
 - both use the latest GPCC analysis
 - some differences due to details of averaging at original grid scales
- ocean: different satellite calibrators
 - TMPA higher in tropics
 - lower in mid-latitudes
 - coasts a particular issue

1998-2010



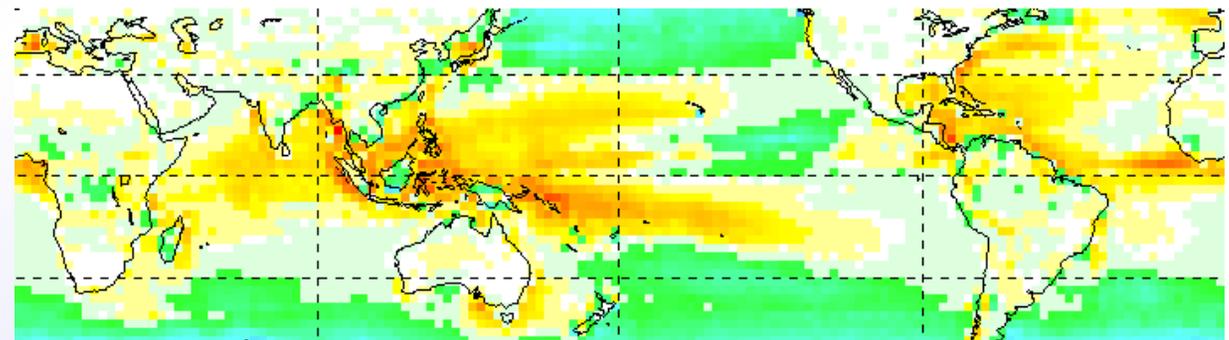
GPCP V2.2 (mm/d)

0 2 4 6 8 10+



TMPA V.7 (mm/d)

0 2 4 6 8 10+



TMPA V.7 – GPCP V2.2 (mm/d)

<-3 -2 -1 0 1 2 >3

4. GPM Innovations

Instruments

- Dual Precipitation Radar
 - vs. single PR for TRMM
- GPM Microwave Imager
 - more channels
 - better resolution

Higher-inclination orbit

- 65°, vs. 35° for TRMM

Use of constellation as a central mission focus

- informal for TRMM
- still just satellites of opportunity in GPM

4. IMERG Design – Processing (1/2)

The U.S. GPM Day-1 multi-satellite algorithm is a unified U.S. algorithm

- **Integrated Multi-satellitE Retrievals for GPM – IMERG**
 - NASA TMPA: intersatellite calibration, gauge adjustment
 - NOAA CMORPH: Lagrangian time interpolation
 - U.C. Irvine PERSIANN: neural-net microwave calibrated IR
 - NASA PPS: input data assembly, processing environment

The Japanese GPM multi-satellite algorithm is GSMAP

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Interpolate between PMW overpasses, following the cloud systems. The current state of the art is

- estimate cloud motion fields from geo-IR data
- move PMW swath data using these displacements
- apply Kalman smoothing to combine satellite data displaced from nearby times

Currently being used in CMORPH, GSMaP (Japan)

Introduces additional correlated error

4. IMERG Design – Processing (2/2)

IMERG plan

- 0.1°x0.1° half-hourly gridded data
- cover 50°N-S (later global) for the period 1998-present
- first PPS test datasets expected early 2014
- at-launch runs will be computed with TRMM calibration
- TMPA, TMPA-RT will be computed until IMERG is approved in the GPM check-out
 - continuation through early 2015 is likely
 - TRMM should last into 2016
 - contingency plan in place if TRMM suddenly ends before GPM is ready



We will expand on the (near-)real-time and after-real-time production concept

- address different user needs in 3 “runs”
 - “early” (~4 hr after observation; flood, landslide)
 - “late” (~12 hr after observation; drought, crops)
 - “final” (with gauge, ~2 months after observation; research quality)
 - possible additional RT run, depending on analysis of user needs
- episodic retrospective processing for all runs

4. IMERG Design – Example



4. IMERG – Data Fields

Output dataset includes intermediate data fields

- users and developers require
 - processing traceability
 - support for algorithm studies

0.1° global CED grid

- 3600x1800 = 6.2M boxes
- but HDF5 internal compression means smaller disk files
- PPS will provide subsetting

“User” fields in italics, darker shading, similar to TMPA

	Half-hourly data file (early, late, final)	Size (MB) 96 / 161
1	<i>Calibrated multi-satellite precipitation</i>	12 / 25
2	<i>Uncalibrated multi-satellite precipitation</i>	12 / 25
3	<i>Calibrated multi-satellite precipitation error</i>	12 / 25
4	PMW precipitation	12 / 25
5	PMW source 1 identifier	6
6	PMW source 1 time	6
7	PMW source 2 identifier	6
8	PMW source 2 time	6
9	IR precipitation	12 / 25
10	IR KF weight	6
11	<i>Probability of liquid-phase precipitation</i>	6
	Monthly data file (final)	Size (MB) 36 / 62
1	<i>Satellite-Gauge precipitation</i>	12 / 25
2	<i>Satellite-Gauge precipitation error</i>	12 / 25
3	Gauge relative weighting	6
4	<i>Probability of liquid-phase precipitation</i>	6

4. IMERG Future

We will continue seeking to employ all precip-relevant satellite data

- IR data from international geo-satellites (merged at NOAA)
- microwave data from “all” DoD, EUMETSAT, NASA, NOAA, other partner (Japan, France/India, ...) leo-satellites
- next-generation precip inputs from groups at NASA, NOAA; others in planning
- improved DWD precip gauge analyses

We expect to add a parallel model-observation product set

- model precip is better at high latitudes, satellite are better in the tropics
- IMERG framework is a natural for using both
- main issue is merging sometimes-very-different precip system depictions

Error estimation is a major issue

- errors are a weird amalgamation of errors from inputs, sampling, and combination
- monthly random error estimate is reasonable
- monthly bias has some draft concepts
- short-interval error is a work in progress
- user requirements tend to be fuzzy
- likely need to have “expert” and “simple” estimates

5. User Issues

We need to manage the TMPA-to-IMERG transition for current users

Trends in usage include

- more attention from hydrology
- more attention to snow as we expand to higher latitudes
- expanded range of non-expert users
 - more use as ancillary/control variable (economics, ecology, etc.)
 - risk and response agencies
 - social media

Trends at the data center level

- addition of output formats, including shapefile averages
 - need to assess the computational load
 - particularly if supporting interactive requests
- non-expert (and expert) users require
 - wider range in output formats
 - more training/tutorial/guidance materials

6. Concluding Remarks

Combined precip algorithms are critical for providing uniform fine-scale data

Issues in combined datasets are usually traceable to

- input data problems
- calibrations in combined algorithm

Morphing is now the state of the art, but really a first approximation

Error expressions are still a work in progress

More users and more choices for users means more work for data providers collectively to assist users in understanding and making these choices

6. Concluding Remarks

Web site: <http://precip.gsfc.nasa.gov>
E-mail: george.j.huffman@nasa.gov

2. TMPA – V.7 vs. V.6

“Production” TMPA

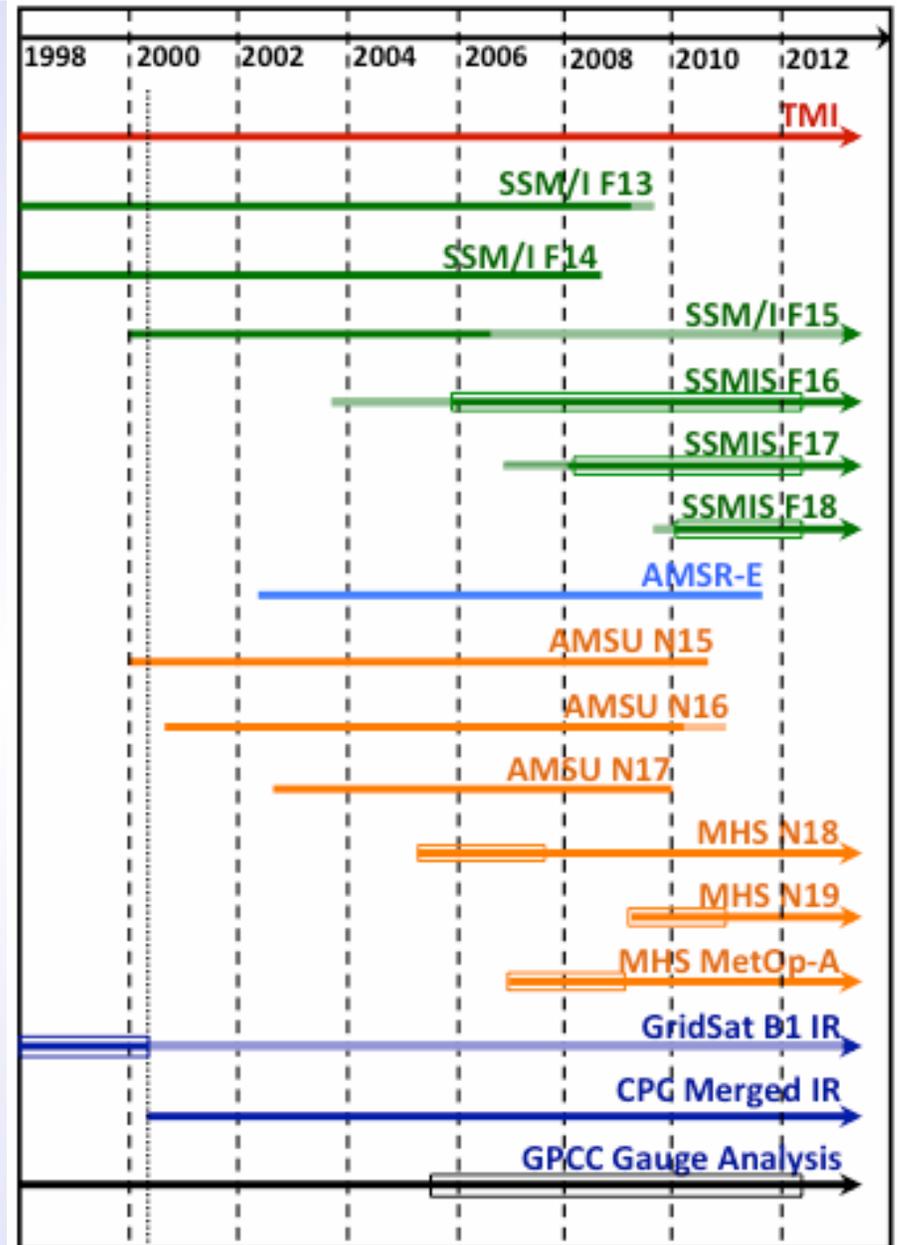
- additional periods of data (boxes)
- improved IR record for 1998 – February 2000
- updated algorithms (GPROF, MSPPS)
- consistently reprocessed input data
- single source of gauge analysis
- publication of additional intermediate data fields

“Real-Time” TMPA

- additional periods of data – SSMIS
- updated algorithms (GPROF)
- consistently reprocessed input data
- retrospective processing back to March 2000

Second processing necessary in V.7

- AMSU ignored the first time



Periods of record not used in the datasets are shown in lighter color

Additional data records used in TMPA V.7 are boxed