# Introduction to Satellite Precipitation Estimates

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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

| | infrared | microwave |
|---|---|---|
| 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 weak | hydrometeors strong |

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

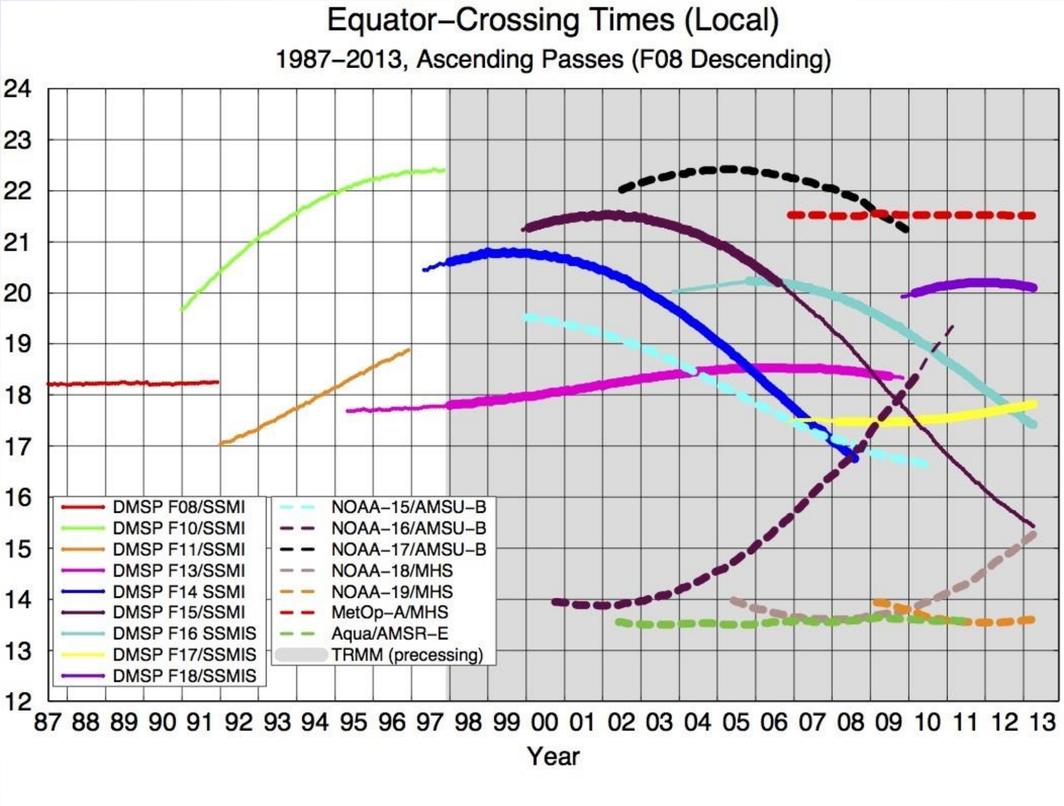
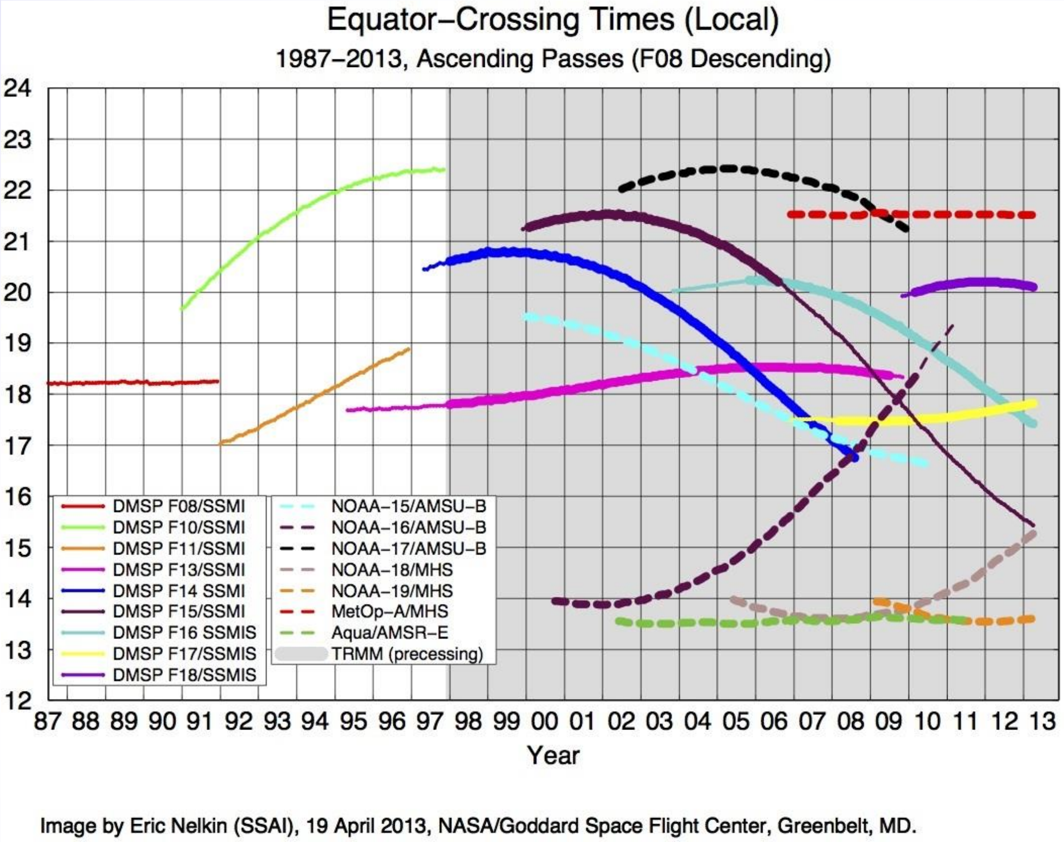


Image by Eric Nelkin (SSAI), 19 April 2013, NASA/Goddard Space Flight Center, Greenbelt, MD.

# 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 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)



# 2. TMPA – Flow Chart (1/2)

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

Microwave precip:

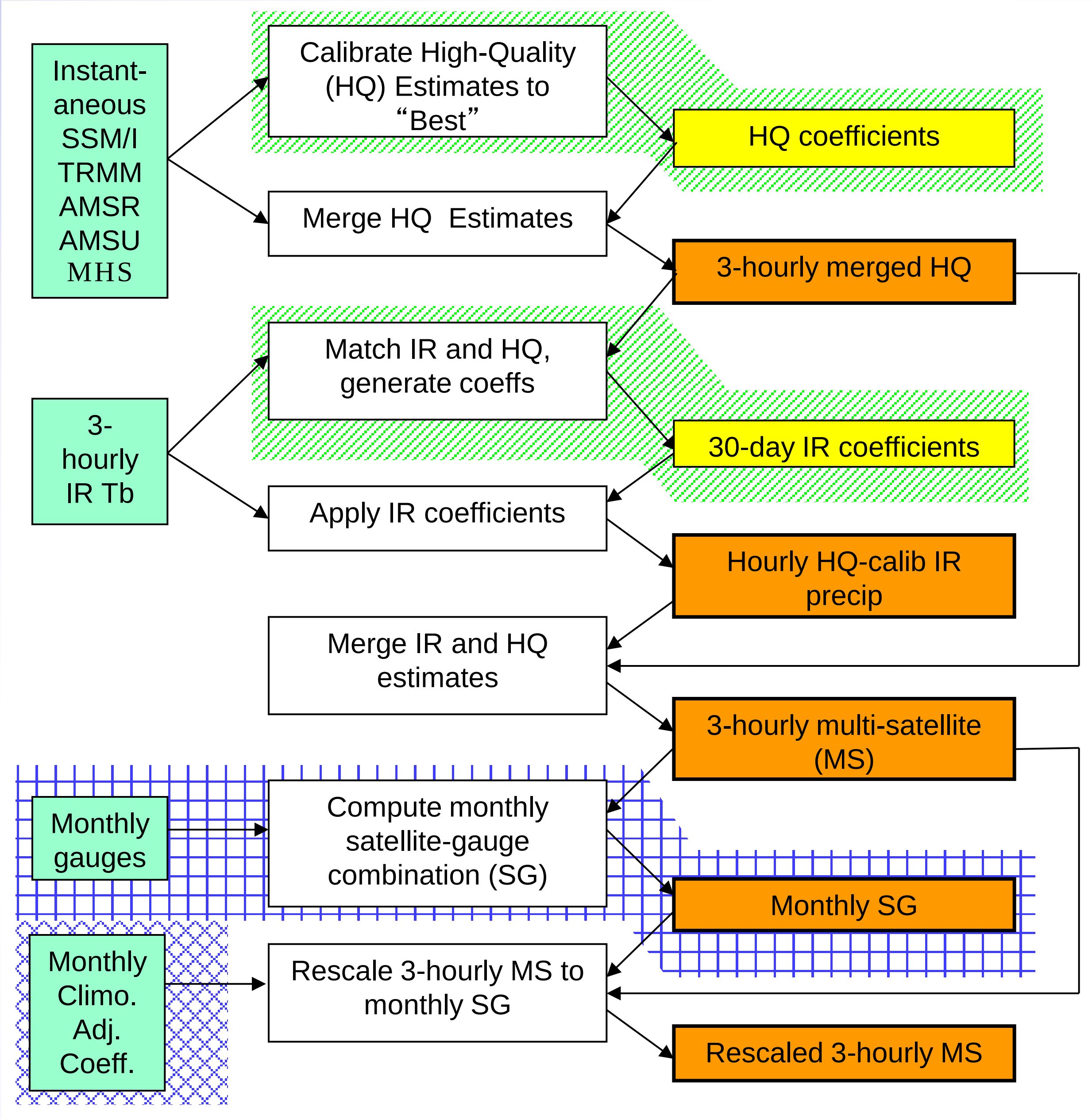
- intercalibrate to TMI/PR combination for P
- intercalibrate to TMI for RT
- then combine, conical-scan first, then sounders

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)

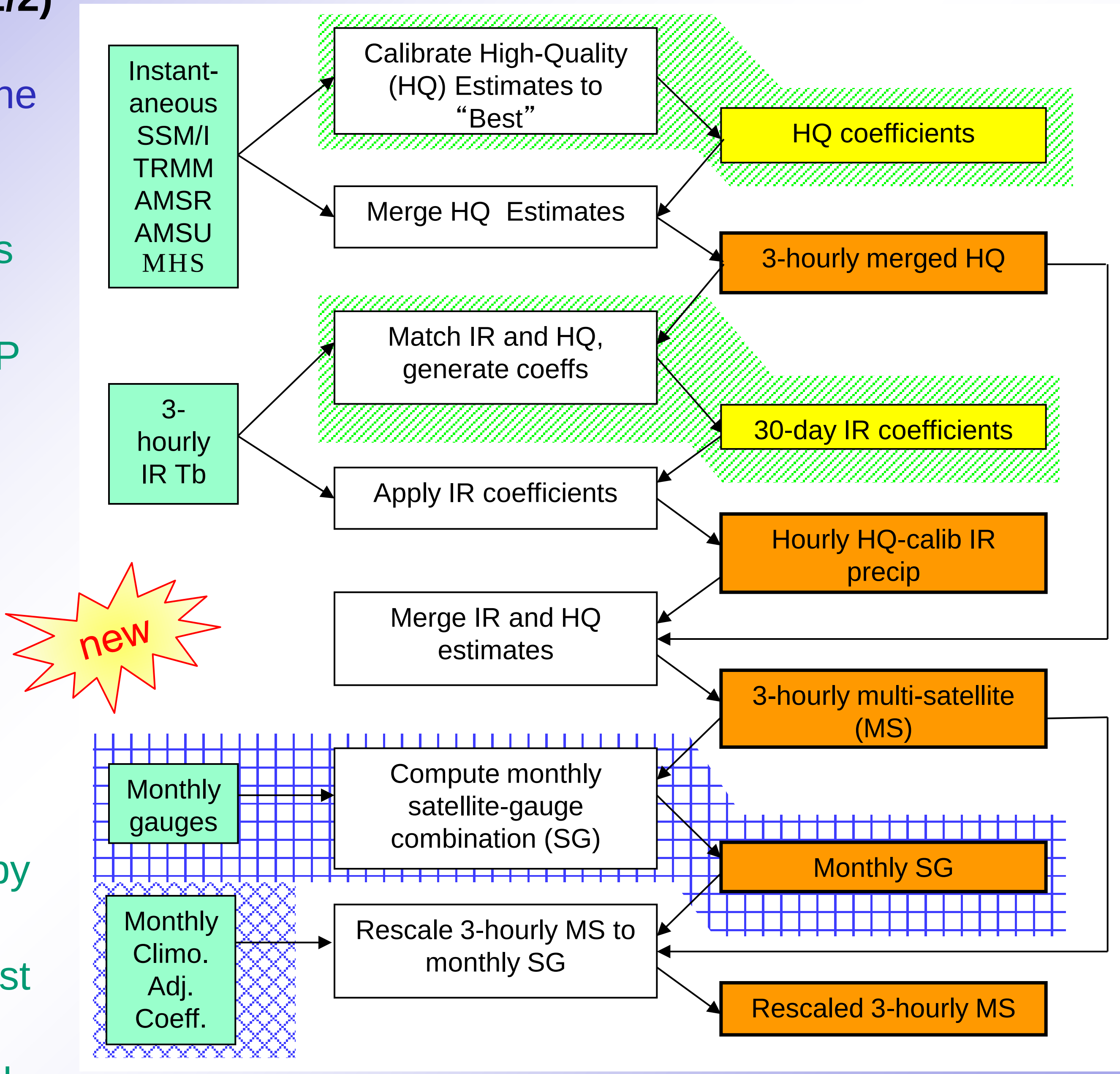
- P uses monthly gauges
- RT uses climatological calibration to TMI/PR, P

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 – V.7 vs. V.6

"Production" TMPA

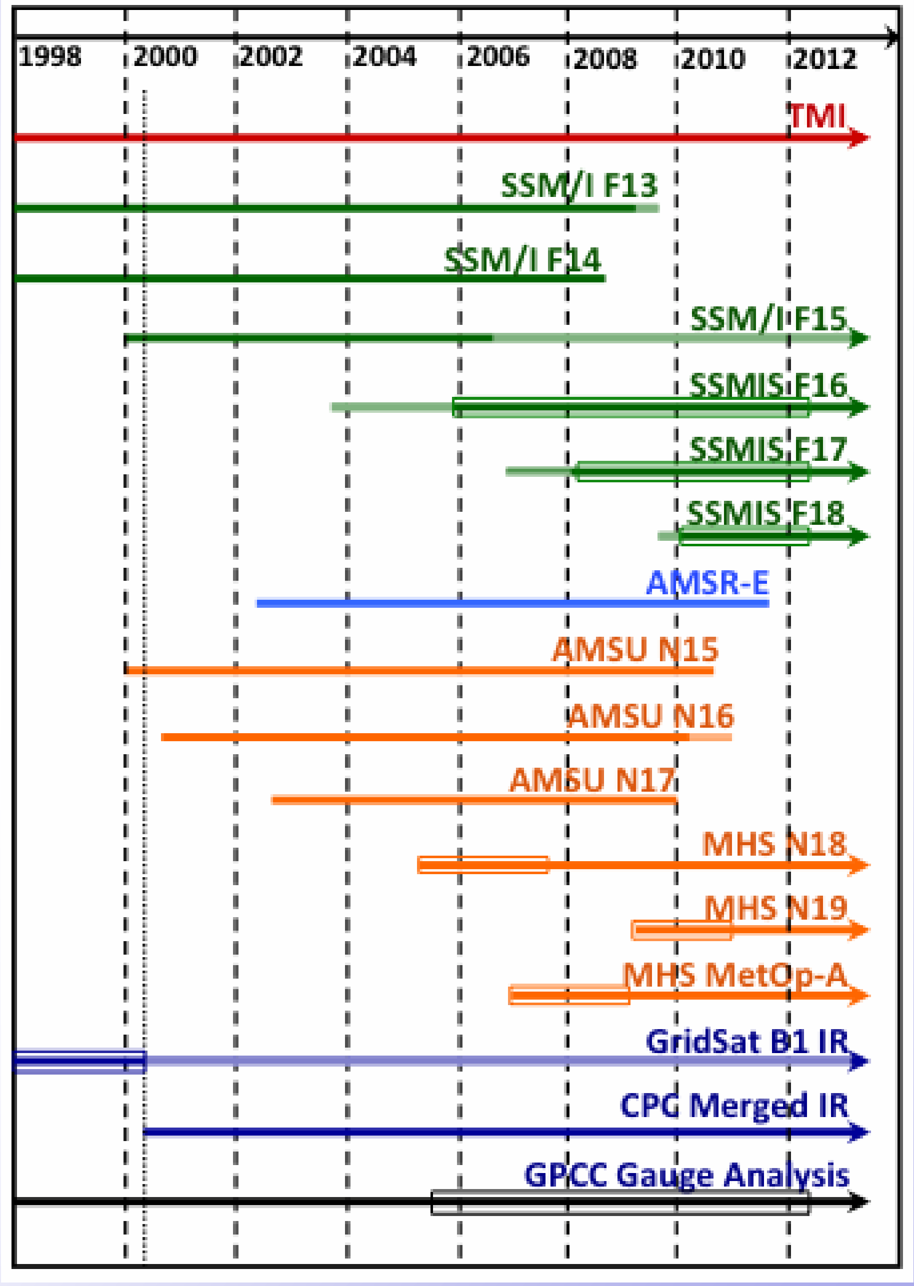
- additional periods of data (boxes)
- improved IR record for 1998 – February 2000
- updated algorithms (GPROF, MSPPS)
- consistently reprocessed input data
- single source of gauge analysis
- publication of additional intermediate data fields

"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

## 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

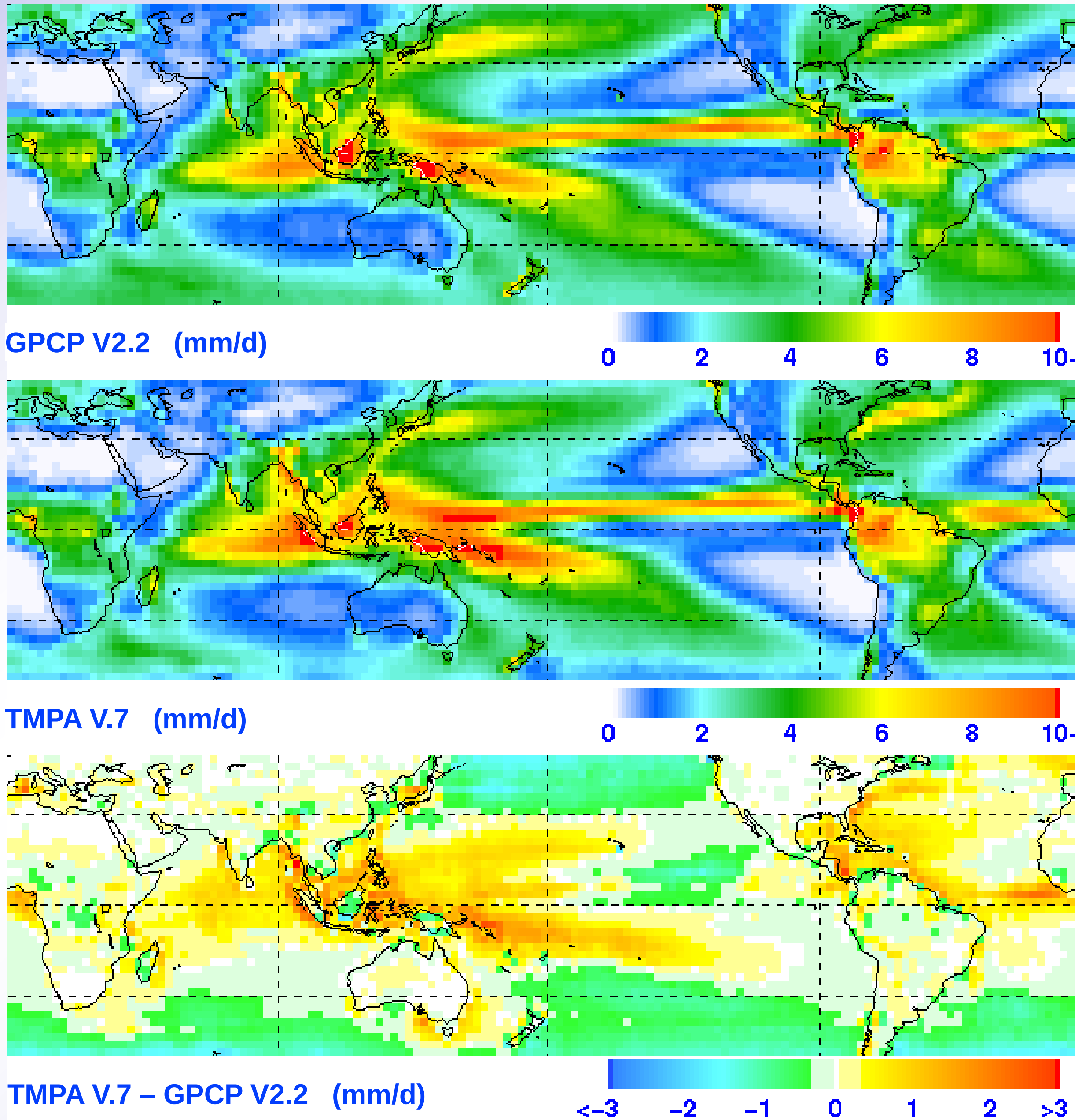
# 3. TMPA V.7 vs. GPCP V2.2

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



## 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 GPM Day-1 multi-satellite algorithm will be 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

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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

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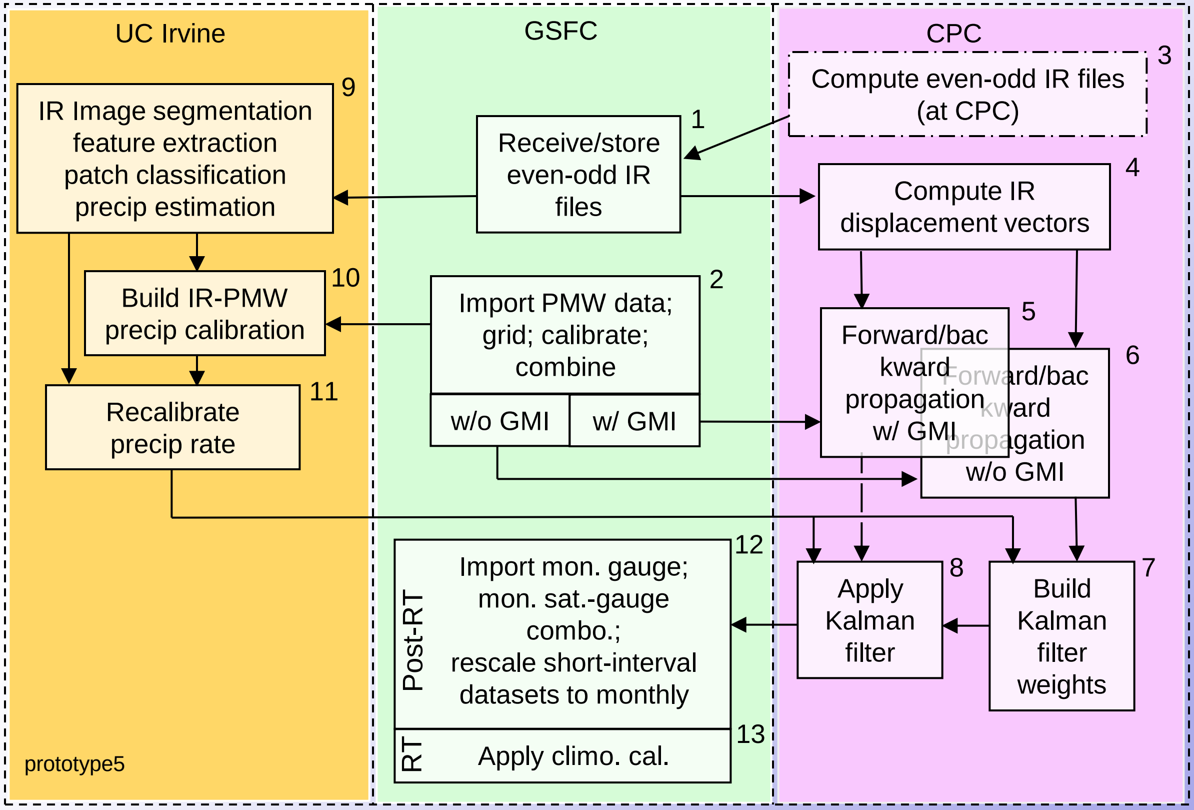
Institutions are shown for module origins, but

- package will be an integrated system
- goal is single code system appropriate for all runs
- "the devil is in the details"



# 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 Summer 2013
- 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 end of 2014 is likely

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 users
- episodic retrospective processing for all 3 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
- fields are 1-byte integer, and scaled 2-byte integer or 4-byte real
- but HDF5 internal compression means smaller disk files
- PPS will provide subsetting

"Typical user" fields in italics, darker shading

| | ***Half-hourly data file (early, late, final)*** | ***Size (MB) 96 / 161*** |
|---|---|---|
| *1* | *Calibrated multi-satellite precipitation* | *12 / 25* |
| 2 | *Uncalibrated multi-satellite precipitation* | 12 / 25 |
| *3* | *Calibrated multi-satellite precipitation error* | *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* | *Probability of liquid-phase precipitation* | *6* |
| | ***Monthly data file (final)*** | ***Size (MB) 36 / 62*** |
| *1* | *Satellite-Gauge precipitation* | *12 / 25* |
| *2* | *Satellite-Gauge precipitation error* | *12 / 25* |
| 3 | Gauge relative weighting | 6 |
| *4* | *Probability of liquid-phase precipitation* | *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

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