IMERG V07 (at Long Last) and What Comes Next

George J. Huffman[1], David T. Bolvin[1,2], Robert Joyce[1,2], Eric J. Nelkin[1,2], Jackson Tan[1,3]

1 NASA Goddard Space Flight Center, Greenbelt, MD, USA
2 Science Systems and Applications, Inc., Lanham, MD, USA
3 University of Maryland Baltimore County, Baltimore, MD, USA

george.j.huffman@nasa.gov

Top V07 Enhancements

(Floating) bias in calibration process was corrected

- there were three factors contributing!

Include PMW estimates over frozen surface

Scheme for Histogram Adjustment with Ranked Precipitation Estimates in the Neighborhood (SHARPEN)

- undo distortion of PDF due to averaging in Kalman filter

Switch from PERSIANN-CCS to PERSIANN Dynamic Infrared–Rain Rate (PDIR-Now)

A long-standing bug in the PMW gridder was fixed

- systematic shift of PMW east by 1 grid box (0.1^0)

Variable name changes

- reduce user confusion about “right” variable
- yes, breaks some current code – sorry!

Satellite Precipitation Estimate Error Detector (SPEEDe)

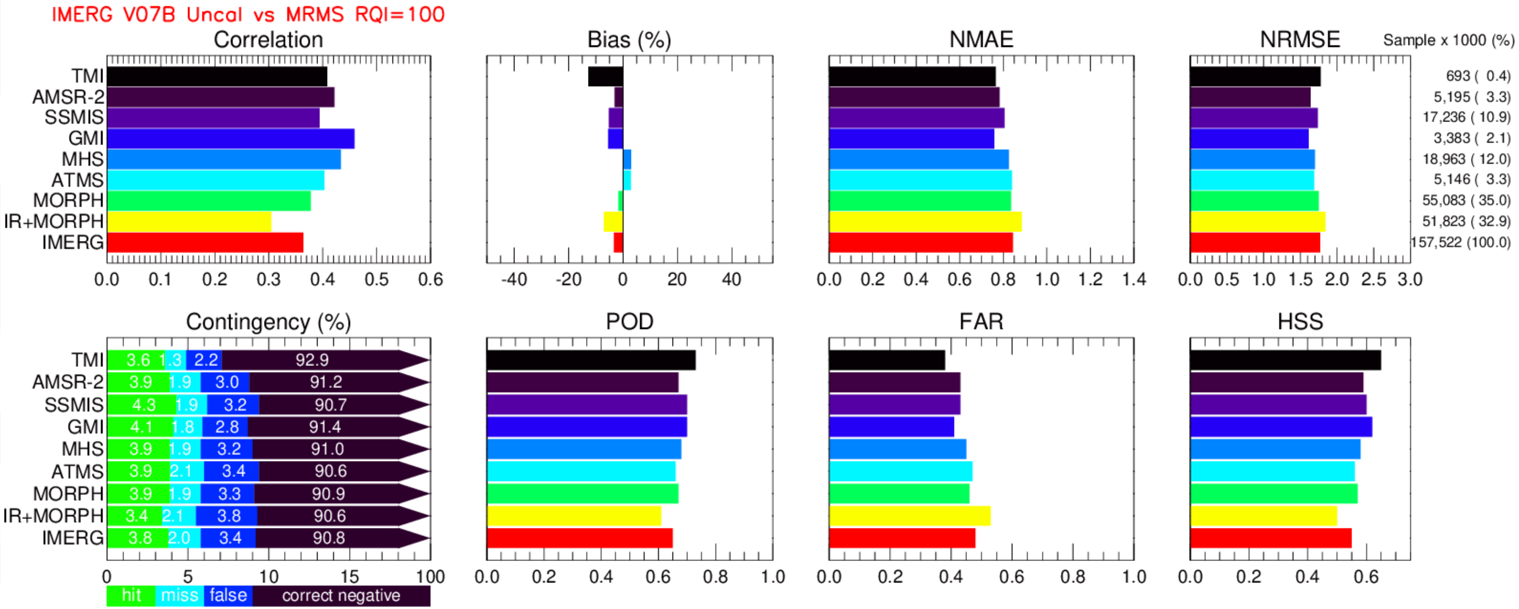
- quality control for (very) occasional anomalous PMW orbits

V07 GV for CONUS

IMERG V07 Final before gauge calibration vs. MRMS for RQI = 100, June 2014-December 2023

broken out by satellite overpass type

- GMI is “best” overall
- imagers and sounders are comparable
- closer-to-overpasses “Morph” is reasonable
- farther-from-overpasses “IR+Morph” is worse



Jerry Wang (SSAI; WFF)

IMERG – Recent Week Visualization

Updated on the web every hour: *https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4285*

Rain/snow determined with 50% threshold on probabilityLiquidPrecipitation

V08 IMERG priority actions

Improve the homogeneity between the TRMM and GPM eras and across the TRMM and GPM-CO boosts

- perhaps by comparison to satellites that have a consistent record across the boundary

Accommodate new PMW sensors, including the next generation of small-sats

- TROPICS, H8-STP (TEMPEST+COWVR combination)

Re-integrate SAPHIR into the IMERG inputs

Implement a more modern water surface file in IMERG

Refine priorities for sensor types and overpass times when they overlap in a half hour

Devise additional automated quality control for artifacts in the IR Tb's

Compute the instantaneous Kalman correlations in the Kalman module instead of using climatological values

evaluate and revise the schemes in V07 that rectify temporal artifacts caused by the time interpolation that fills the gaps between the various PMW sensor overpasses (SHARPEN, t=0 KF)

revisit/revise the specification algorithm for the probability of liquid phase

refine the intercalibration scheme among CORRA, TMI, and GMI

After V08

Input data

- plan for post-GPM intercalibration standard
- more small-sat PMW radiometers
- AVHRR-based precipitation estimates (most useful in high latitudes)
- ISCCP-Next Generation and GEO-Ring projects for analysis-ready access to multiple GEO-satellite channels, which enables improved algorithms compared to GEO-IR alone, as we've known for at least 15 years:
  - Behrangi, A., and co-authors, 2009: *J. Hydrometeor., doi:10.1175/2009JHM1139.1*

Processing

- develop error estimates – consider quantile estimates?
- shift to equal area grid for internal computations
- shift to Cloud computing with a testbed design for IMERG system
- orographic enhancement in the propagation (morphing) scheme
- incorporate sub-monthly gauge data
  - Funk, C.C. and co-authors, 2022: *Bull. Amer. Meteor. Soc., doi:10.1175/BAMS-D-20-0245.1*
- adding a satellite-gauge-reanalysis/model estimate

Future

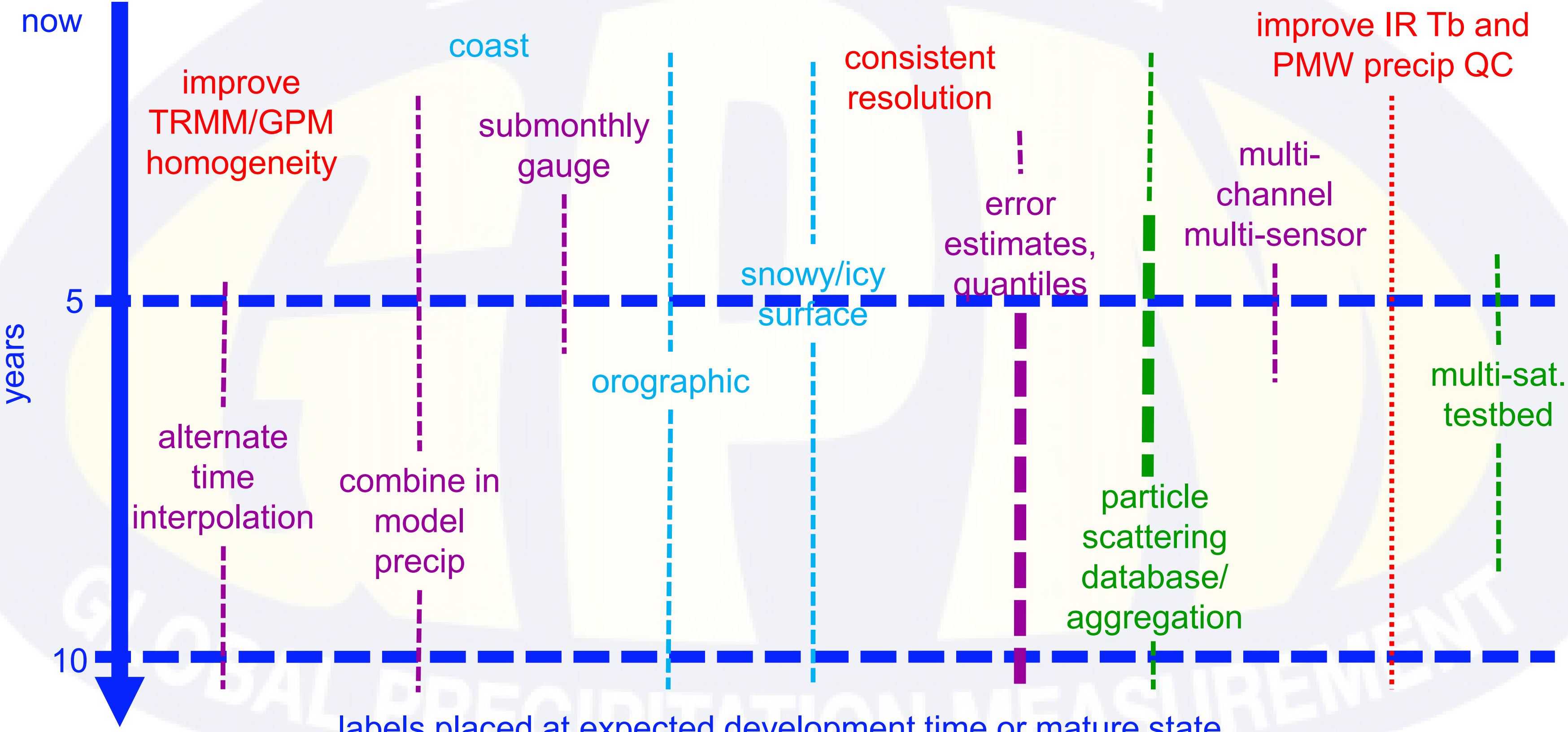
How does the U.S. team move to the next-generation multi-satellite product?

- we have a wide user community
- we have the constellation
  - but need to ensure continued resolution and channel selection that support high-quality precip estimates
- we need to continue the active/passive calibrator in an inclined orbit
- see Jackson's talk 4.5 this afternoon

NASA is investigating a revised institutional strategy

- for 2 satellite generations (TRMM, GPM) the mission has carried the cost
- AOS is not funded to support multi-satellite products

Algorithm Timeline Forecast



labels placed at expected development time or mature state

lines show period of effort

Closing comments

Quantifying precipitation around the globe is a tough problem

- but we can't not do it – this is the source of the fresh water that we need

Flying the right satellite sensors makes this possible

- this effort stretches across agencies, companies, and countries
- new generations of satellites – both governmental and commercial – must continue to deliver the quality of observations needed by the precipitation algorithms

We're not done

- snowfall, precipitation over mountainous regions and the coastal zone, and solid error estimation are works in progress
- even so, we know more about the precipitation that fell in 2010 than when it happened because advances in retrievals are applied to the entire archive of data

As the precipitation products get better, there is increased demand

- more applications can use higher-quality data
- but we can only deliver (and advance) the level of quality if we have enough high-quality precipitation-relevant sensors
- numerical models continue to improve as well, but their skill in key tropical heavy-rain regions is still deficient

Making the best use of advanced datasets requires dataset producers and users to work together to bridge "the last mile"

Supplementary Slides

V07 Enhancements (1/3)

Scheme for Histogram Adjustment with Ranked Precipitation Estimates in the Neighborhood (SHARPEN)

- undo distortion of PDF due to averaging in Kalman filter combination of forward- and backward-propagated PMW, IR

Modified Kalman Averaging Scheme

- apply Kalman filter at PMW overpass times
- modest improvement in skill, but mitigates "flashing" in animations

Switch from PERSIANN-CCS to PERSIANN Dynamic Infrared–Rain Rate (PDIR-Now)

- UC-Irvine ported PDIR-Now from MatLab to C

A long-standing bug in the PMW gridder was fixed

- systematic shift of PMW east by 1 grid box (0.1^0)
- escaped notice in code validation done a decade ago at 0.025^0

SAPHIR removed pending better spatial calibration

V07 enhancements (2/3)

(Floating) bias in calibration process was corrected

- there were three factors contributing!
  - GPROF outside/inside the Ku swath differ by +/- 2%
  - needed consistent spatial resolution
  - GPCP calibration over land in V06 was not helpful

Variable name changes

- reduce user confusion about "right" variable
- yes, breaks some current code – sorry!

HQprecipitation	➔ MWprecipitation
HQobservationTime	➔ MWobservationTime
HQprecipSource	➔ MWprecipSource
precipitationCal	➔ precipitation
IRkalmanFilterWeight	➔ IRinfluence

V07 enhancements (3/3)

Precipitation motion vectors recomputed using multiple MERRA-2/GEOS-5 model variables

- Precip (PRECTOT), then Total Precipitable Liquid Water (TQL), then TQV

Blended Fuchs-Legates wind-loss correction

IR quality control module

- “fixes” for periodic GOES-W cooling issues and other known IR artifacts
- introduced mid-stream in V06

Raise cap on precip rates to 200 mm/hour

- in V06 120, 50 mm/hour, respectively, for PMW, IR

Include PMW estimates over frozen surface

- but given a lower certainty
- V07 is fully global except some boxes near the poles

Satellite Precipitation Estimate Error Detector (SPEEDe)

- quality control for (very) occasional anomalous PMW orbits
- convolutional autoencoder scheme

What Works and What Doesn't?

Better captured

- oceanic rain [finer-resolution, polarimetric low+high-freq. channels]

Less well captured

- coast [finer resolution, algorithms]
- orographic [radar, algorithms]
- snowy/icy-surface [algorithms?]
- high-latitude [synthesis of previous 3]
- short-lived events [more-frequent PMW observations]

Challenges/Opportunities

Challenges

- almost-good-enough next-generation sensors
- cope with spatial resolution and bias differences
  - between sensors
  - across swaths
- balance use of model data to aid in retrievals against diluting observations
- RFI trashing channels

Opportunities

- next-generation sensors with "good" resolution, channel selection, calibration
  - both active and passive
- use disparate channels from multiple sensors
  - flying in formation
  - from both LEO and GEO
- design in subchannels for better RFI resilience
- stable, uniformly (re)processed, long-term multi-channel datasets (PMW, GEO, radar, …)

Critical observation needs – observation interval

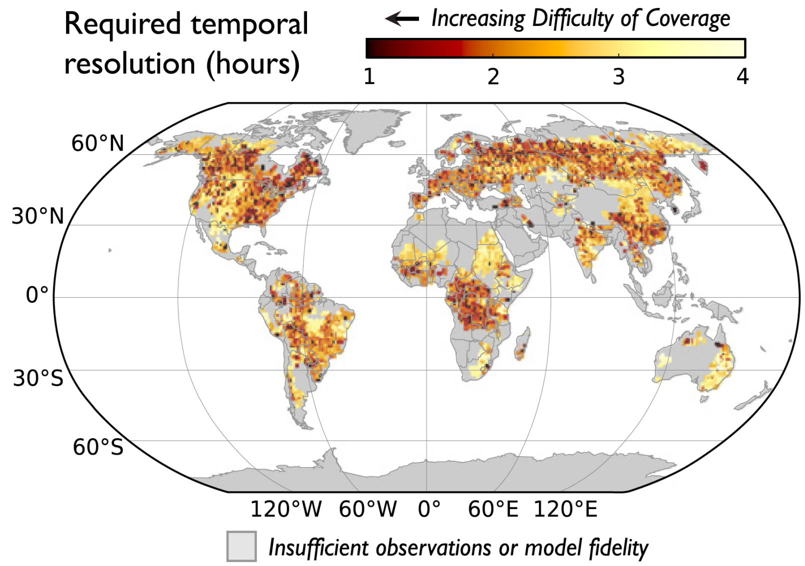


Fig. 1 in Patrick M Reed *et al.* 2015 *Environ. Res. Lett.* **10** 024010**DOI** doi:10.1088/1748-9326/10/2/024010 (under the terms of the Creative Commons Attribution 3.0 license)

Hydrological Analysis

Flash flood analysis is challenging and important

- few-km-scale detail matters
  - the corresponding time scale is order(1hr)

Reed et al. (2015) ran a large modeling study

- temporal resolution required for satellite precip to maintain acceptable model flood predictions
- how quickly do predictions of surface water runoff degrade as the satellite temporal resolution degrades?
- most areas require < 3 hr

Extreme Events

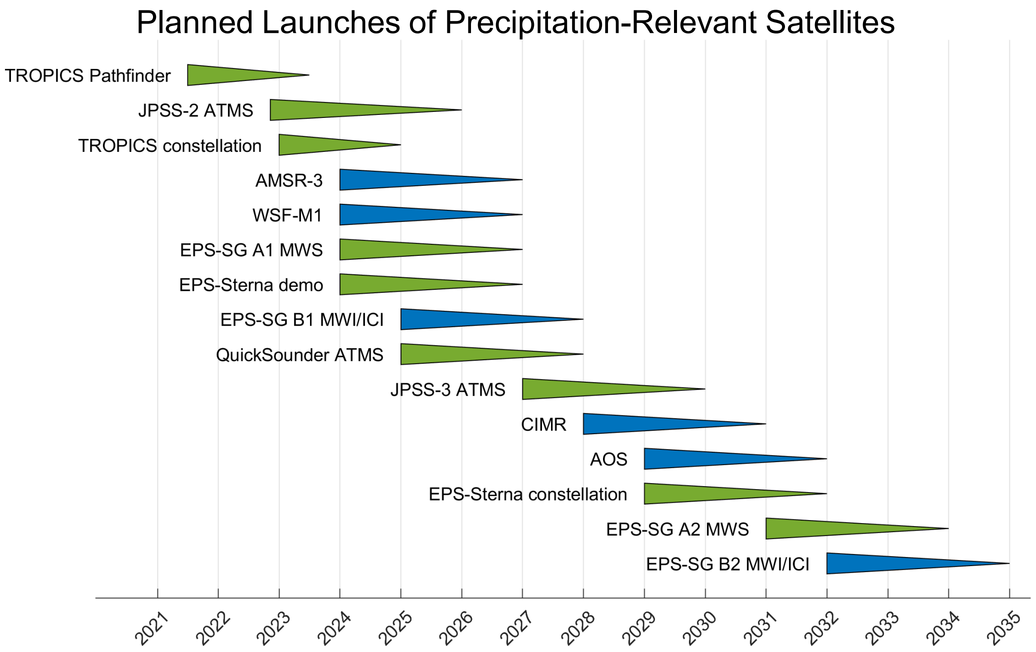
Extreme events are loosely defined

- extremes can be defined at any time scale, but weather and climate studies tend to focus on daily
  - this scale of accumulation requires few-hour snapshots to catch the short events
- the long time record of extremes is very important in global change science

Critical observation needs – gaps in planned launches

In recent years, the notional goal of PMW sampling intervals < 3 hours is satisfied > 90% of the time

- lack of coordination between programs and satellite drift create time-varying overlaps and gaps in time, coverage
  - requires "extra" satellites for coverage
  - perennial gap for the 12/24 slot, except from precessing satellites
- decrease in planned launches foretells longer data gaps
  - demise of ADEOS2, MADRAS, DMSP-F19 demonstrate that assets can end early



Sarah Ringerud (GSFC)