

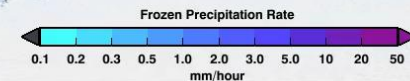
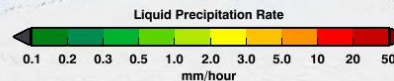
# Connecting Satellite-Based Precipitation Estimates to Users

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1. History
2. Content
3. Dissemination
4. User Support
5. Back to Content
6. Final Comments

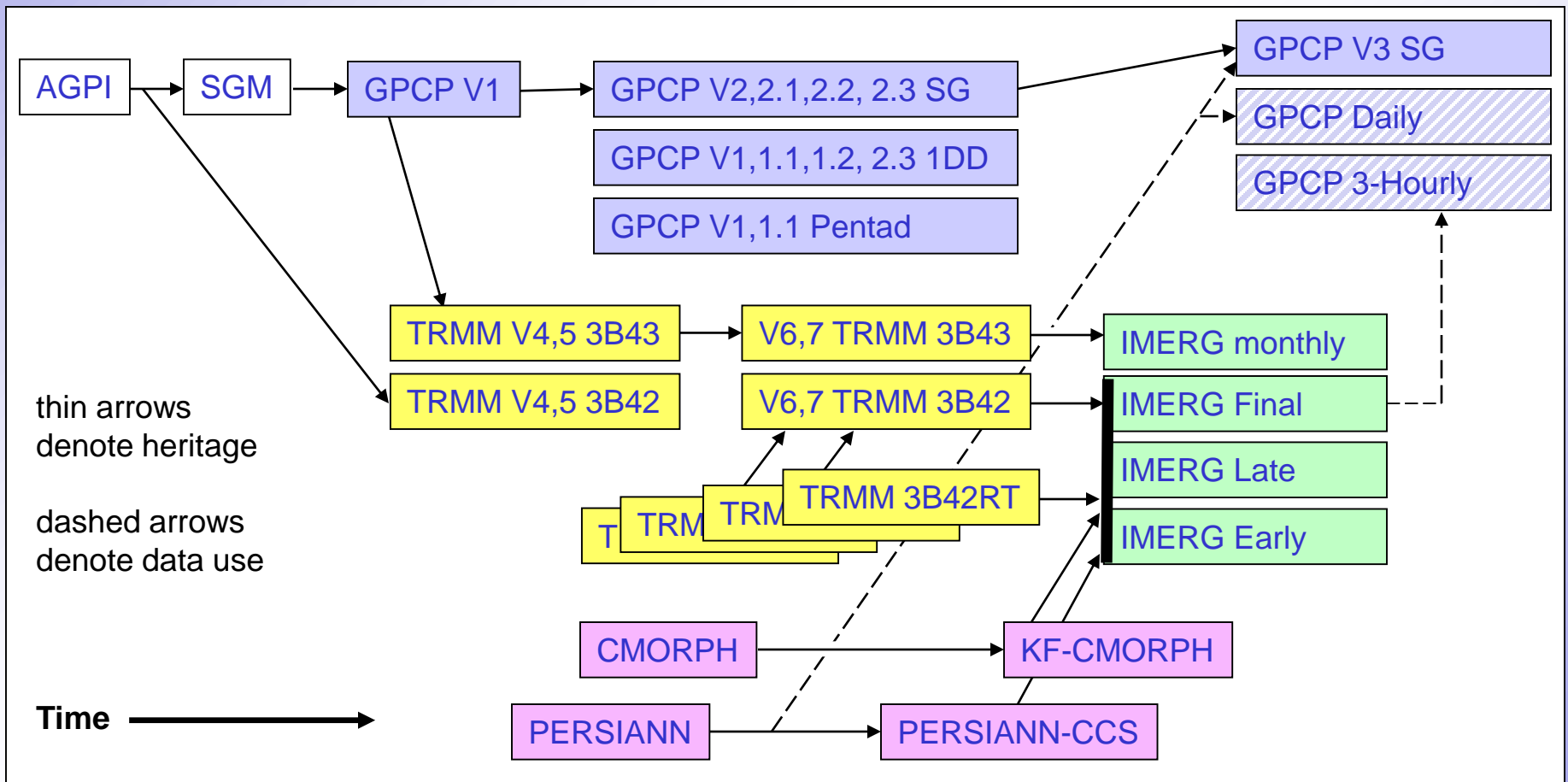
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# 1. HISTORY

Merged Precipitation Group has had a major role in

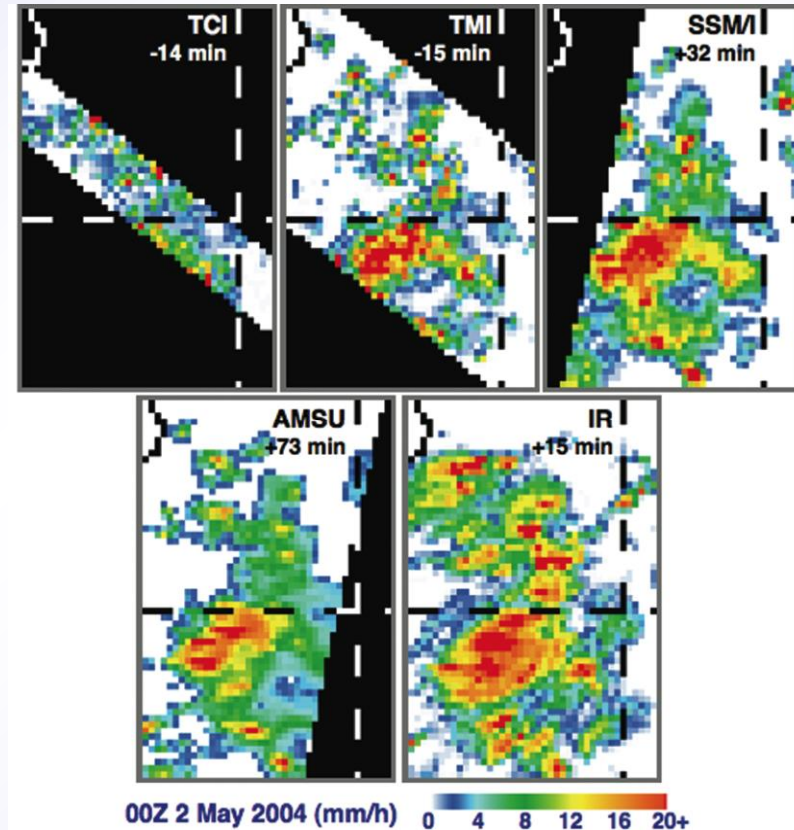
- Global Precipitation Climatology Project (GPCP) – 1995
- TRMM Multi-satellite Precipitation Analysis (TMPA) – 2002
- Integrated Multi-satellitE Precipitation Retrievals for GPM (IMERG) – 2014



## 2. CONTENT

Multi-satellite datasets merge retrievals/analyses of precipitation from individual satellites (and gauges)

- this puts a premium on consistent and accurate retrievals
- intercalibrations are required to improve consistency
- still, different sensors “see” precipitation differently
  - nearly coincident views by 5 sensors southeast of Sri Lanka
  - offset times from 00Z given below the sensor name
- data gaps in the combination process are filled by various interpolations
  - necessarily smoother than in reality
  - need to control effect on fractional coverage



## 2. CONTENT – IMERG Example

The original GPCP dataset included “all” intermediate fields

- assumed that precip experts would want to see these – not true

The original TMPA fell back to just precip and random error

- discovered we needed some fields for diagnosis and development
- some users needed them, too
- re-introduced fields with actual need

IMERG has continued this trend

- introduce ancillary fields at user request
  - **Probability of Liquid Phase Precip**
    - diagnostic, using model data
  - **Quality Index**
    - new, work in progress

### IMERG Data Fields

	<b><i>Half-hourly data file (Early, Late, Final)</i></b>
1	[multi-sat.] precipitationCal
2	[multi-sat.] precipitationUncal
3	[multi-sat. precip] randomError
4	[PMW] HQprecipitation
5	[PMW] HQprecipSource [identifier]
6	[PMW] HQobservationTime
7	IRprecipitation
8	IRkalmanFilterWeight
9	[phase] probabilityLiquidPrecipitation
10	precipitationQualityIndex
	<b><i>Monthly data file (Final)</i></b>
1	[sat.-gauge] precipitation
2	[sat.-gauge precip] randomError
3	GaugeRelativeWeighting
4	probabilityLiquidPrecipitation [phase]
5	precipitationQualityIndex

### 3. DISSEMINATION (1/2)

#### Format

- originally in flat binary, sometimes encoded
- innovation: add an extra row loaded with metadata
- standards have evolved
  - HDF flavors, NetCDF flavors, tending toward interoperability
  - still a work in progress, particularly in dealing with libraries for different versions
- data centers are adding web services, format converters, subsetting by parameter and location, value-added products (shape file averages, accumulations)

#### Time/space interval driven by data availability

- GPCP V1 was  $2.5^\circ$  /monthly, then introduced  $1^\circ$  /daily (for a shorter period)
- TMPA V4 was  $1^\circ$  /monthly and  $1^\circ$  /daily, then went to  $0.25^\circ$  /monthly and  $0.25^\circ$  /3-hourly
- IMERG is  $0.1^\circ$  /monthly and  $0.1^\circ$  /half-hourly

#### Errors are higher for finer-scale estimates

### 3. DISSEMINATION (2/2)

Multiple runs accommodate different user requirements for latency and accuracy

- TMPA backed into handing out near-real-time (~8 hours old) by user request
  - tapped into a strong demand for current data
  - lesson learned: users need a long, consistently processed record for each dataset to support calibration of applications
    - the entire record of all variants has to be upgraded in a version shift
    - “real time” ≠ “disposable” ... this is a paradigm shift for archive operators
- IMERG has 3 “Runs” to support a wider variety of use cases
  - “Early” – 4 hr (flash flooding)
  - “Late” – 12 hr (crop forecasting)
  - “Final” – 3 months (research)
  - waiting longer includes more input data – presumably more accuracy
  - lesson learned: users get confused when confronted with multiple products
    - this is also true across data providers
    - data providers have to do a better job at “suitability for use” information

## 4. USER SUPPORT

User support was originally

- algorithm papers
- e-mail with developers
- text README files
- technical documents

Modern support includes

- mailing list(s)
- web site
  - documents
  - data access hot link(s)
  - Frequently Asked Questions
  - Ask-A-Question hot link
  - Recipes
- social media presence
  - facebook
  - twitter
  - ResearchGate
  - LinkedIn



## 4. USER SUPPORT – PMM Example (1/2)

PMM summarized all data access at Goddard on a single set of pages

- <https://pmm.nasa.gov/data-access>

The screenshot shows the NASA PMM website interface. The main navigation bar includes Home, GPM, TRMM, Science, Applications, Meetings, Data Access, Resources, and Education. The 'Data Access' sidebar lists various options, with 'GPM' selected. The main content area is titled 'GPM Data Downloads' and features three tabs: Level 3, Level 2, and Level 1. The 'Level 3' tab is highlighted with a red box. Below the tabs, there is a red-bordered box containing a paragraph of text describing the algorithm used for IMERG data. Another red-bordered box highlights a 'Documentation:' section with a list of links. A table at the bottom of the page provides details on resolution, regions, latency, format, and source for the data.

Gridded Data

Opens to IMERG by default

Short description

Hot links to documentation

**Level 3**   **Level 2**   **Level 1**

Geophysical parameters that have been spatially and/or temporally resampled from Level 1 or Level 2 data.

IMERG: Rainfall estimates combining data from all passive-microwave instruments in the GPM Constellation

This algorithm is intended to intercalibrate, merge, and interpolate "all" satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales for the TRMM and GPM eras over the entire globe. The system is run several times for each observation time, first giving a quick estimate and successively providing better estimates as more data arrive. The final step uses monthly gauge data to create research-level products.

**Documentation:**

- IMERG Technical Documentation
- IMERG Algorithm Theoretical Basis Document (ATBD)
- IMERG Day 1 Early Run Release Notes
- IMERG Day 1 Final Run Release Notes
- IMERG Day 1 Late Run Release Notes
- IMERG GIS TIFF + Wordfile Documentation
- Transitioning from TMPA (3B42x) to IMERG

Resolution ?	Regions - Dates ?	Latency ?	Format ?	Source ?	DL ?
0.1° - 30	Gridded, 90°N-90°S.	6 hours (NRT)	HDF5	NRT: FTP (RDS)*	



## 4. USER SUPPORT – PMM Example (2/2)

- <https://pmm.nasa.gov/data-access>

Access details

3 runs  
2 NRT,  
1 post-RT

Resolution ?	Regions - Dates ?	Latency ?	Format ?	Source ?	DL ?
0.1° - 30 minute	Gridded, 90°N-90°S, March 2015 to present	6 hours (NRT / early run)	HDF5	NRT: FTP (PPS)*	↓
			GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
			Giovanni	Giovanni	↓
			HDF5	OpenDAP	↓
			HDF5	Mirador	↓
			NETCDF	Simple Subset Wizard	↓
0.1° - 30 minute	Gridded, 90°N-90°S, March 2015 to present	18 hours (NRT / late run)	HDF5	NRT: FTP (PPS)*	↓
			GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
			Giovanni	Giovanni	↓
			HDF5	OpenDAP	↓
			HDF5	Mirador	↓
			NETCDF	Simple Subset Wizard	↓
0.1° - 30 minute	Gridded, 90°N-90°S, March 2014 to present	4 months (Prod / final run)	HDF5	Prod: FTP (PPS)* (/YYYY/MM/DD/imerg/)	↓
			GIS TIFF + Wordfile	Prod: FTP (PPS)* (/YYYY/MM/DD/gis/)	↓
			HDF5	Prod: STORM	↓
			HDF5	Mirador	↓
			Giovanni	Giovanni	↓
			NETCDF	Simple Subset Wizard	↓
0.1° - 3 Hours	Gridded, 90°N-90°S, April 2015 to present	6 hours (NRT / Early Run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
0.1° - 3 Hours	Gridded, 90°N-90°S, April 2015 to present	18 hours (NRT / Late Run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓

• View Frequently Asked Questions

• View the PMM Glossary

• Contact Us



## 4. USER SUPPORT – PMM Example (3/3)

- <https://pmm.nasa.gov/data-access>

0.1° - 1 Day	Gridded, 90°N-90°S, April 2015 to present	6 hours (NRT / early run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
0.1° - 1 Day	Gridded, 90°N-90°S, April 2015 to present	18 hours (NRT / late run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
0.1° - 3 Day	Gridded, 90°N-90°S, April 2015 to present	18 hours (NRT / late run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
0.1° - 7 Day	Gridded, 90°N-90°S, April 2015 to present	18 hours (NRT / late run)	GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
0.1° - Monthly	Gridded, 90°N-90°S, March 2014 to present	4 months (Prod / final run)	HDF5	Prod: FTP (PPS)* <small>(monthly data files are in the folder corresponding to the first day of each month)</small>	↓
			HDF5	Mirador	↓
			Giovanni	Giovanni	↓
			NETCDF	Simple Subset Wizard	↓
IMERG Derived Imagery					
			Video (mp4)	Past 7 Days IMERG Late/Early Run Global Precip. Animation (SVS)	↓
			KML	Google Earth / PMM	↓
▶ 3-CMB: Combined GMI + DPR Rainfall Averages					
▶ 3-DPR: DPR rainfall averages					
▶ 3-GPROF: GMI rainfall averages					

other Level 3 datasets

## 4. USER SUPPORT – But Wait, There's More

GPCP and TMPA reformatted to the Obs4MIPS archive

- CMIP5 standard for model work

Custom product releases to NOAA

- Short-term Prediction Research and Transition (SPoRT) Center

Training Activities

- Applied Remote Sensing Training (ARSET)
- PMM application workshops

Secondary archives outside of Goddard

- typically without coordination with developers

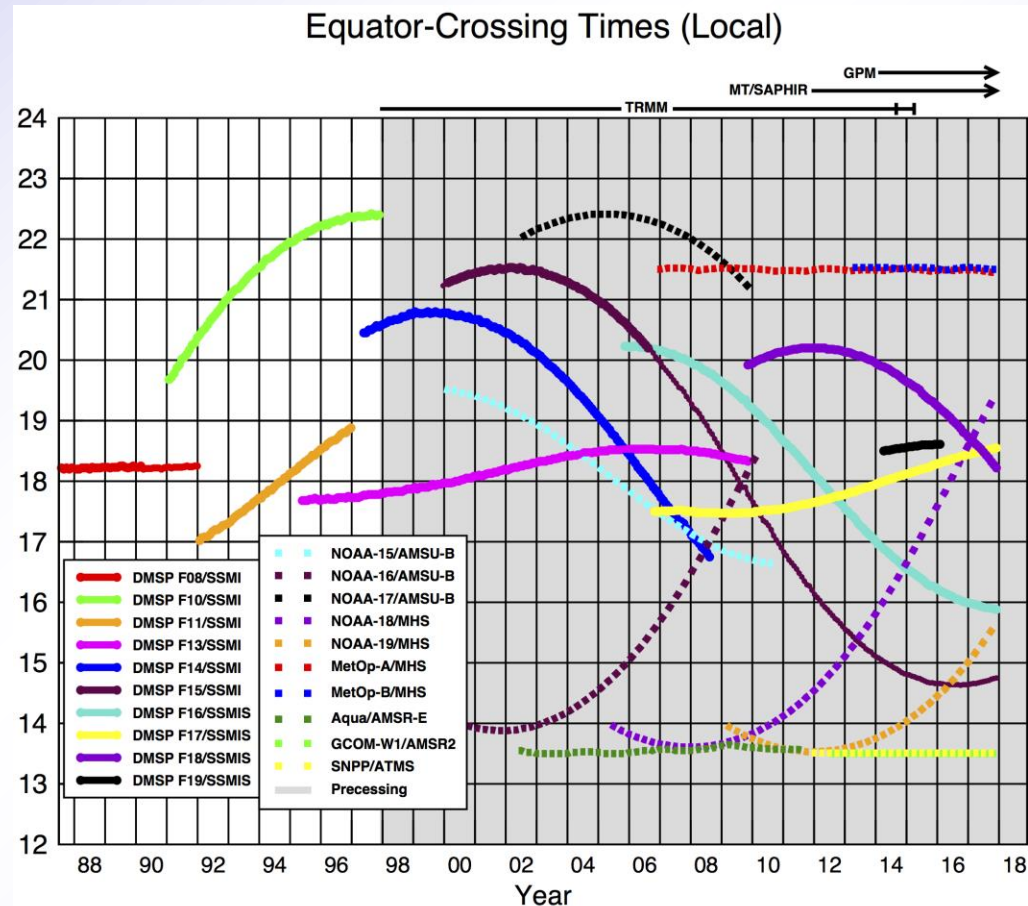
## 5. BACK TO “CONTENT”

Multi-satellite precip datasets have advanced over the last 20 years due to

- improved retrievals from individual satellites
- continued advancement in combination approaches
- increased numbers of microwave sensors
- improved sensors

The launch manifests for the next generation of satellites are sparse

- the user community expects the existing (or better) products in the future
- this requires a steady supply of high-quality satellite observations



Ascending passes (F08 descending); satellites depicted above graph process throughout the day.  
Image by Eric Nelkin (SSAI), 14 December 2017, NASA/Goddard Space Flight Center, Greenbelt, MD.

## 6. FINAL COMMENTS

All of this work has taken sustained commitment of resources

Going into the future the challenges are

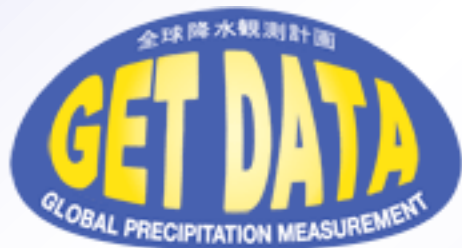
- how do we maintain/augment the observational base (including surface gauges)?
- how do we squeeze additional information out of space-based sensors?
- what are sustainable models for supporting the enormous community of non-expert users?

The climate community has a stake in this discussion

- “extremes” are inherently fine-scale, so the climatology of extremes requires a long record of fine-scale estimates
- even precipitation averages tend to be dominated by a few large events, which are usually fine-scale

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New Users Start Here

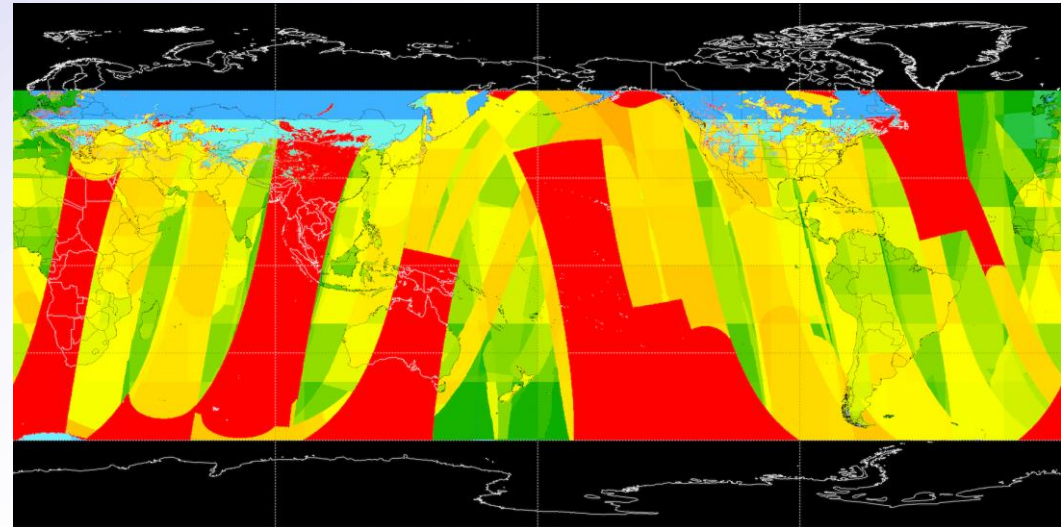
IMERG on the Hyperwall 4 p.m.

**extra slides**

## 4. VERSION 05 IMERG – Quality Index (QI)

### Half-hourly QI

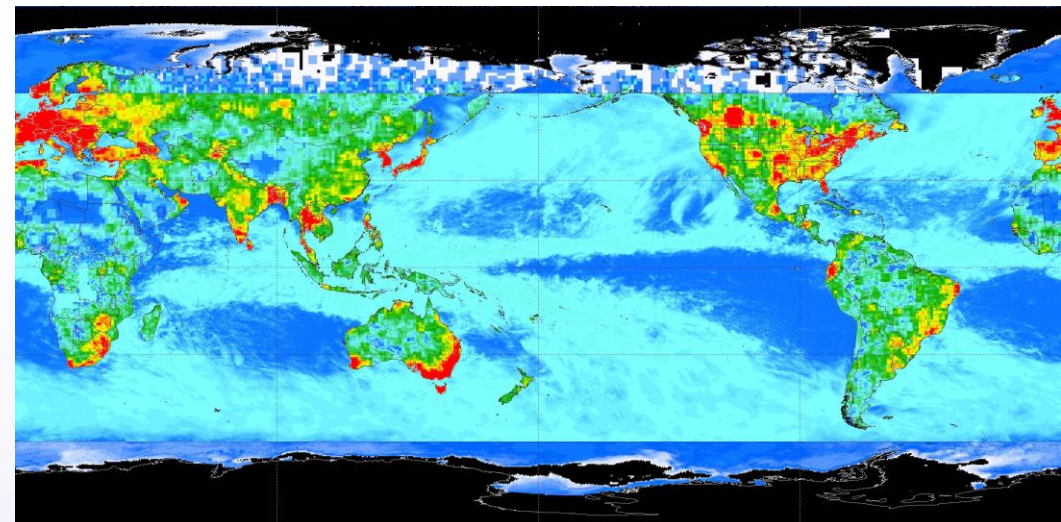
- approx. Kalman Filter correlation
  - time to nearest PMWs
  - IR at time (when used)
  - set to 1 when a PMW is used
- thin strips due to inter-swath gaps
- blocks due to regional variations
- low values at high lat. due to using IR with PMW masked out over snow



Half-Hr Qual. Index 00 UTC 3 Dec 2016

### Monthly QI

- Equivalent Gauge (Huffman et al. 1997) in gauges /  $2.5^\circ \times 2.5^\circ$
- invert random error equation
- largely tames the non-linearity due to rain amount
- some residual issues at high values



Month Qual. Index Dec 2016

D.Bolvin (SSAI; GSFC)

## 2. CONTENT – IMERG Example

Multiple runs accommodate different user requirements for latency and accuracy

- “Early” – 4 hr (flash flooding)
- “Late” – 14 hr (crop forecasting)
- “Final” – 3 months (research)

Time intervals are half-hourly and monthly (Final only)

0.1° global CED grid

- merged PMW precip 90° N-S
- morphed precip 60° N-S for now
- probability of liquid precip 90° N-S

User-oriented services by archive sites

- interactive analysis (Giovanni)
- alternate formats (TIFF files, ...)
- value-added products

	<b><i>Half-hourly data file (Early, Late, Final)</i></b>
1	[multi-sat.] precipitationCal
2	[multi-sat.] precipitationUncal
3	[multi-sat. precip] randomError
4	[PMW] HQprecipitation
5	[PMW] HQprecipSource [identifier]
6	[PMW] HQobservationTime
7	IRprecipitation
8	IRkalmanFilterWeight
9	[phase] probabilityLiquidPrecipitation
10	precipitationQualityIndex
	<b><i>Monthly data file (Final)</i></b>
1	[sat.-gauge] precipitation
2	[sat.-gauge precip] randomError
3	GaugeRelativeWeighting
4	probabilityLiquidPrecipitation [phase]
5	precipitationQualityIndex