IMERG Multi-Satellite Products Across Two Decades

George J. Huffman(1), David T. Bolvin(1,2),
Dan Braithwaite(3), Kuolin Hsu(3), Robert Joyce(4,5),
Christopher Kidd(1,6), Eric Nelkin(1,2), Soroosh Sorooshian(3),
Jackson Tan(1,7), Pingping Xie(5)

(1) NASA/GSFC Earth Sciences Division – Atmospheres
(2) Science Systems and Applications, Inc.
(3) Univ. of California Irvine
(4) Innovim
(5) NOAA/NWS Climate Prediction Center
(6) Univ. of Maryland / ESSIC
(7) Univ. Space Res. Assoc.

george.j.huffman@nasa.gov

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Liquid Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour

Frozen Precipitation Rate
0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50
mm/hour

E

See https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4285

1. IMERG – Quick Description

IMERG is a single integrated code system for near-real and post-real time

- "Early" – 4 hr (flash flooding)
- "Late" – 14 hr (crop forecasting)
- "Final" – 3 months (research)
- half-hourly and monthly (Final only)
- 0.1º global CED grid
  - morphed precip, 60º N-S in V05, 90º N-S in V06

Combined product (calibrator) adjusted to GPCP V2.3 seasonal climatology zonally for reasonable bias

- see S2

	Half-hourly data file (Early, Late, Final)
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*
	Monthly data file (Final)
1	*[sat.-gauge] precipitation*
2	*[sat.-gauge precip] randomError*
3	GaugeRelativeWeighting
4	*probabilityLiquidPrecipitation [phase]*
5	*precipitationQualityIndex*

see S3

1. IMERG – V06 Upgrades

Morphing vector source switched to MERRA-2/GEOS FP

Morphed precip extended from 60º N-S (V05 and earlier) to 90º N-S, *but*

- masked out for icy/snowy surfaces

Extension to TRMM era

- currently to June 2000, planning January 1998
- compute calibrations for older satellites against TRMM
  - compute TRMM-era microwave calibrations in the band 33ºN-S and
  - blend with adjusted monthly climatological GPM-era microwave calibrations over 25º-90º N,S

Half-hourly Quality Index modified (see S4)

- t=0 values estimated (set to 1 in V05)
- shifted to 0.1º grid (0.25º in V05)

Full intercalibration to Combined Radar-Radiometer Algorithm (CORRA)

- V05 took shortcuts

Revisions to internals raises the maximum precip rate from 50 to 120 mm/hr and no longer discrete

- files bigger due to less compressibility
- allows really tiny numbers

1. IMERG – V06 Roll-Out

Began Version 06 IMERG Retrospective Processing (RP) on 13 March 2019

- the GPM era was launched first, Final Run first
  - Initial Processing (IP) for V06 Early and Late Runs started at the same time
  - errors in RP and IP required re-doing some data records
- the TRMM era Final Run RP came next
  - 4 km merged global IR data files continue to be delayed for January 1998-January 2000
    - we built up the requisite 3 months of calibration data starting from February 2000
    - the first month of data is thus June 2000
    - the initial 29 months of data will be incorporated when feasible
- Early and Late Run RP uses Final RP intermediate files, so they come after Final RP
  - Final is always ~3.5 months behind, so the Early and Late RP had to wait on Final IP to fill in the last 3 months before May 2019
- Final RP finished 3 July 2019, Early and Late RP finished 20 August 2019

TMPA research and real-time products ended with end of 2019 (with a 4.5 month advance notice)

Version 07 release should be in about 2 years (early 2022?)

2. Early Results – Ocean (50ºN-S) Precip Timeseries (1/2)

V06 Final Run starts June 2000

V06 is higher than 3B43 (TMPA) and GPCP over ocean

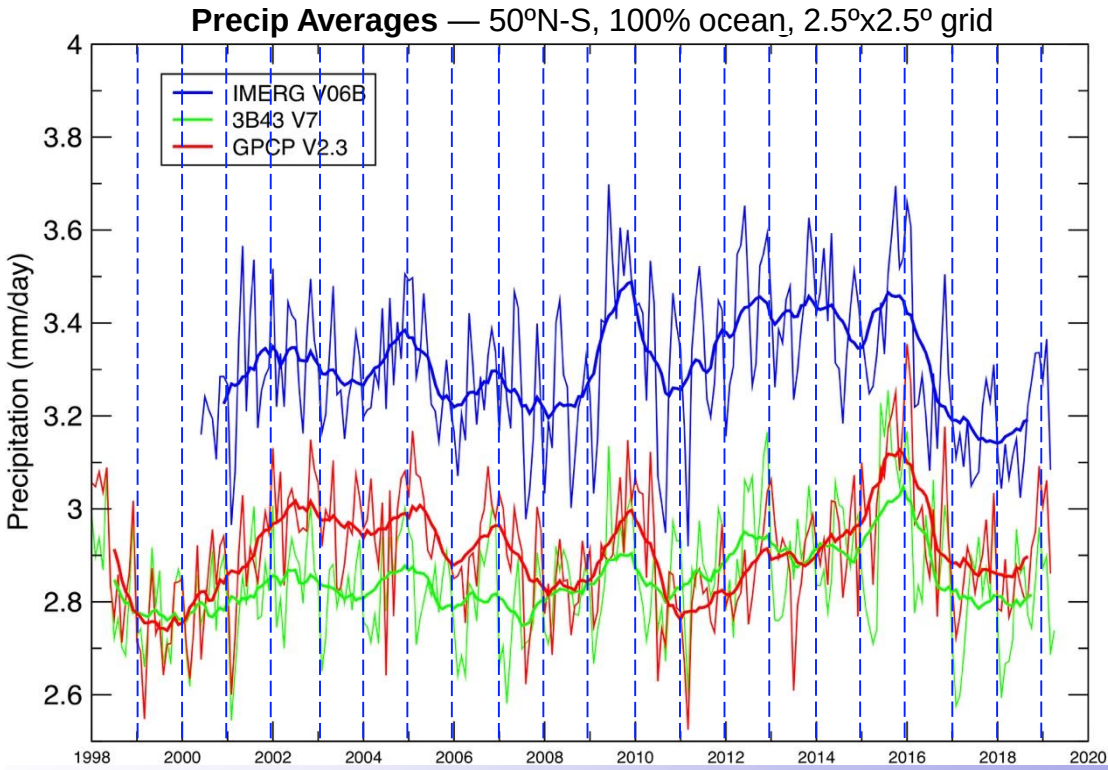
- reason for this is under study

TRMM-era IMERG has a strong semi-annual signal

- GPM-era IMERG and 3B43 dominated by the annual cycle

Interannual variation

- has similar peaks/troughs for all datasets
- GPCP (passive microwave calibration) lags phase of 3B43 (through 2013), IMERG (both PMW/radar calibration)
- after September 2014, 3B43 (PMW calibration) matches GPCP phase

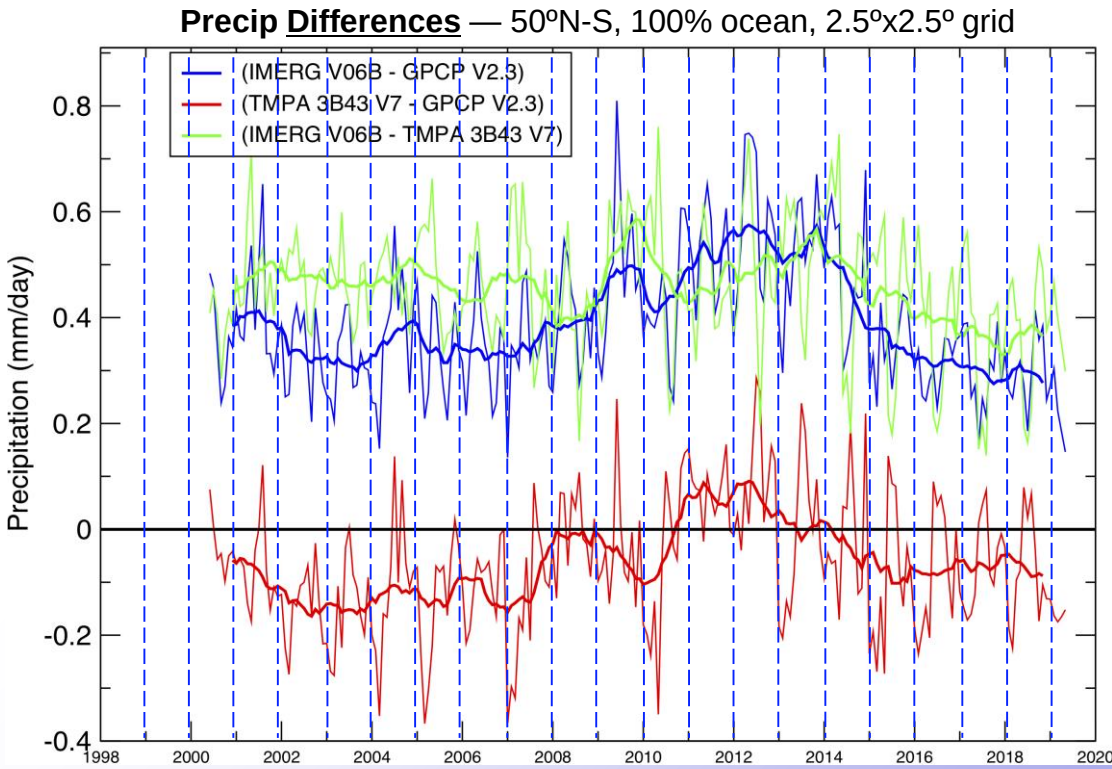


E. Nelkin (SSAI; GSFC)

2. Early Results – Ocean (50ºN-S) Precip Timeseries (2/2)

Additional multi-year variations

- IMERG and 3B43 are High Resolution Precipitation Products, not CDRs
- difference plots tend to emphasize multi-year variations
  - IMERG and 3B43 resemble each other more than GPCP (green line flatter)
- the interannual variations tend to be similar
- phasing differences and differences in amplitude of interannual variation have similar magnitudes



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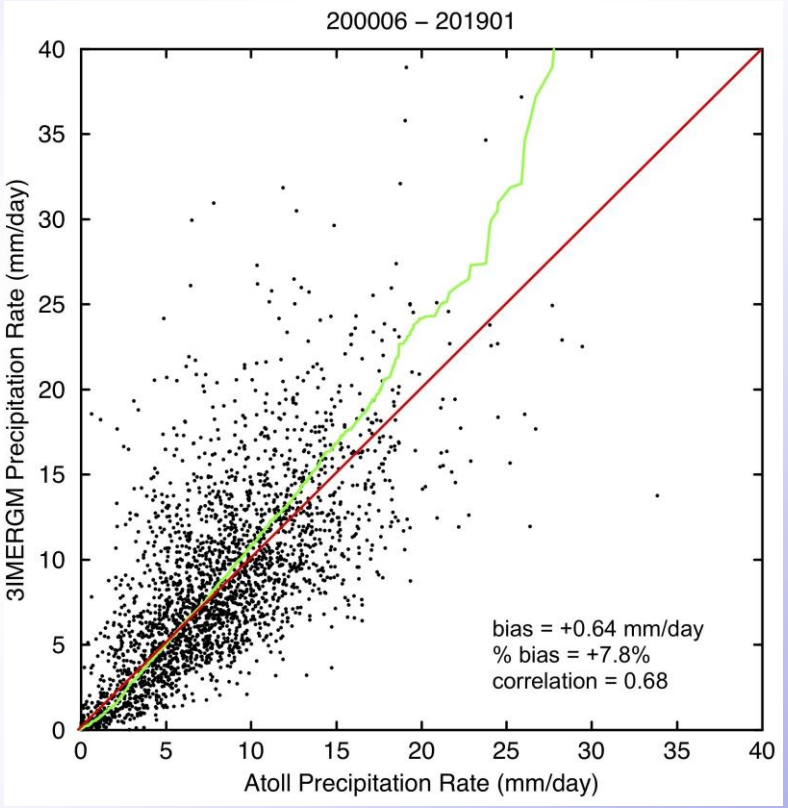
2. Early Results – IMERG Final, Monthly for Atolls

Monthly accumulations for tropical Pacific atolls

- Pacific Rainfall Database (PACRAIN)
- match of gauge to encompassing 0.1º grid box
- all useful months
  - stations have various periods of record (potentially changing the regions sampled)
  - 38 “good” atolls, averaging ~11/month
- bias varies with precip rate
  - IMERG under-(over-)estimates at low(high) rates
  - atoll gauges lack undercatch correction
    - likely ~5-10%, so overall IMERG bias is (amazingly) good, but rate biases remain

See S4 for a land case (Hurricane Harvey)



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2. Early Results – Tropical Ocean (20ºN-S) Monthly Precip Histogram Timeseries

Histogram of Final Run monthly tropical oceanic precip on 0.1º grid, 20º N-S (top)

- log(counts) to help draw out small values

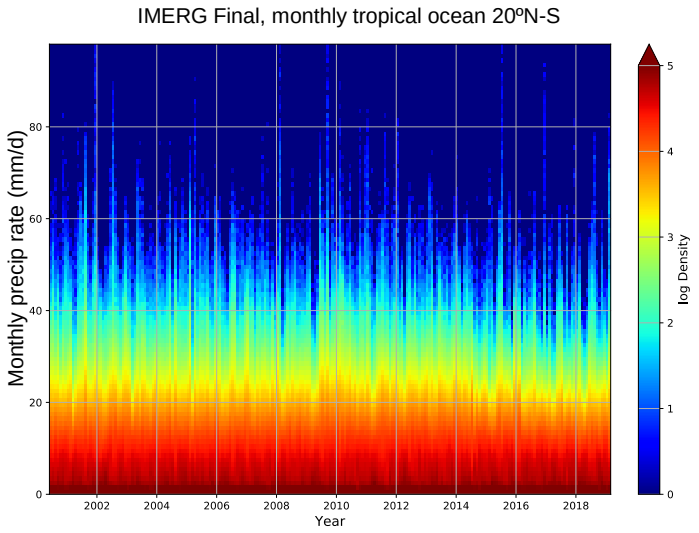
Anomaly (bottom) helps guide interpretation

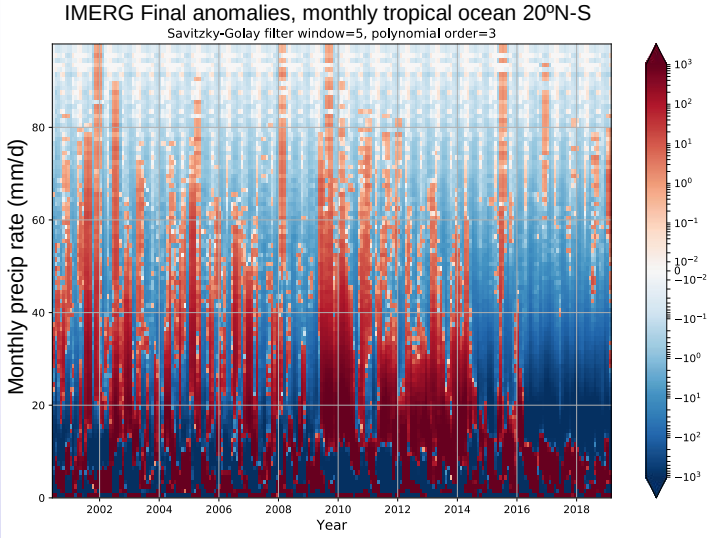
- log scale in both directions from zero
- filtered in time to emphasize main features

Initial impressions

- mid-to-high rates sometimes (2009-10) vary together, but not always (2006-07)
- lower rates tend to vary in the opposite direction
- start of GPM calibration (June 2014) seems to shift the PDF to lower rates
- persistent mid-range positive anomalies in 2009-14 remain to be explained

This discussion will help determine reliability for trend analysis





G. Potter (USRA; GSFC)

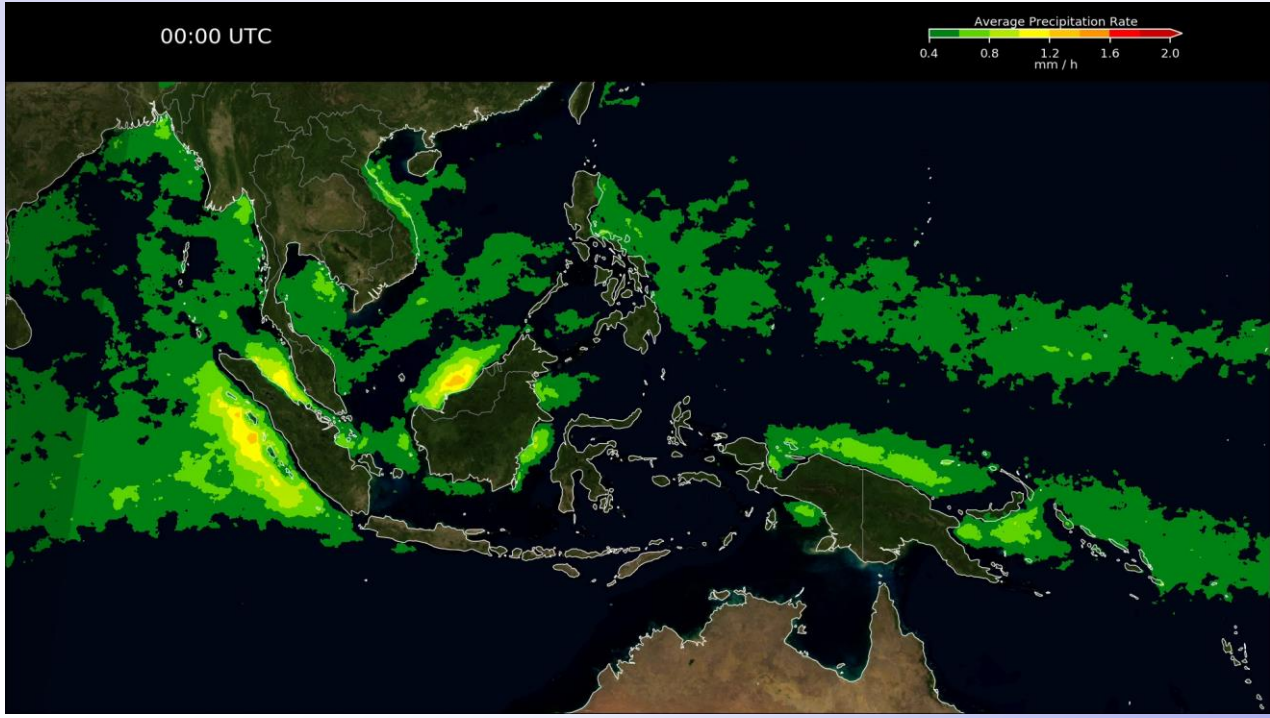
2. Early Results – Final Run, September-November Diurnal Cycle, Maritime Continent

Average September-November for 2001 to 2018, Final Run

- day/night shading
- Blue Marble land
- smoothed in space and time
  - even 18 years of seasonal data still has lumps

Reminiscent of IMERG V05, but

- less “flashing” due to inter-satellite differences and morphing
- better data coverage at higher latitudes (not seen here)



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Reminiscent of TMPA, but

- more detailed, broader spatial coverage
- no interpolations between the 3-hourly times
- less IR-based precip used (which tends to have a phase lag)

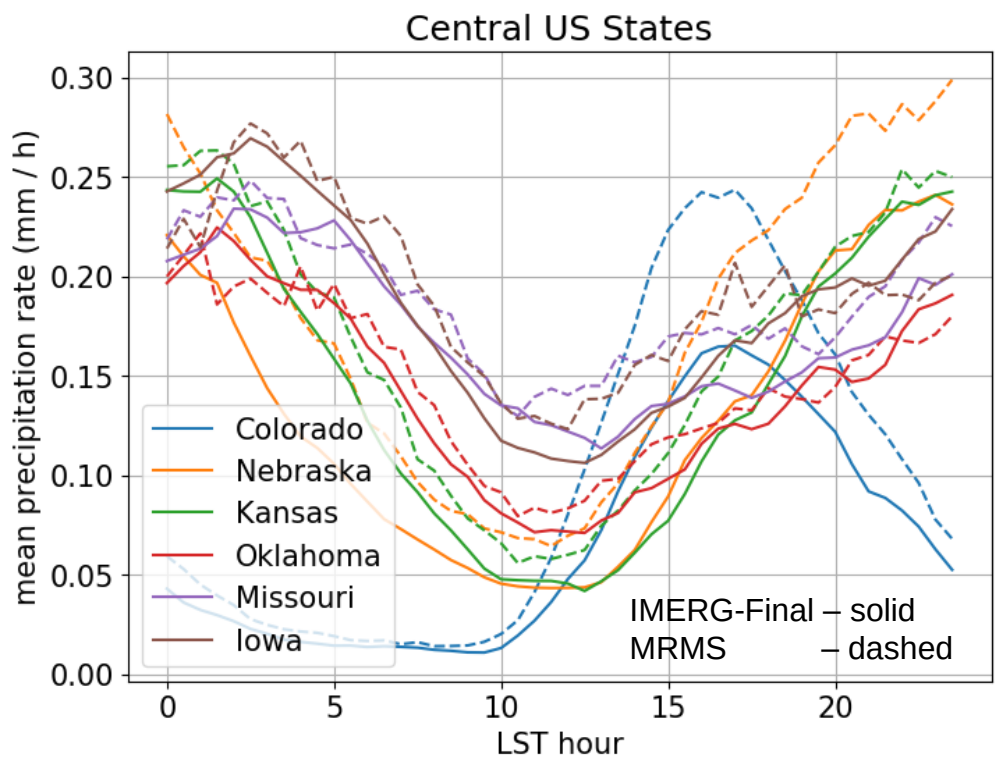
2. Early Results – Final Run, June-August Diurnal Cycle in Central U.S. (GPM Era)

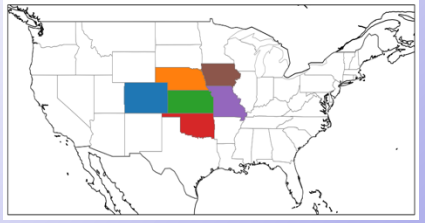
Average June-August for 2014 to 2018 (5 summers) for 6 states, Final Run

Compared to Multi-Radar Multi-Sensor (MRMS, dashed), Final (solid) shows:

- lower averages (despite use of gauge data)
- lower amplitude cycle in Colorado
- higher amplitude cycle in Iowa
- very similar curve shapes, peak times

This version of MRMS only starts in 2014, so an extended comparison requires different data





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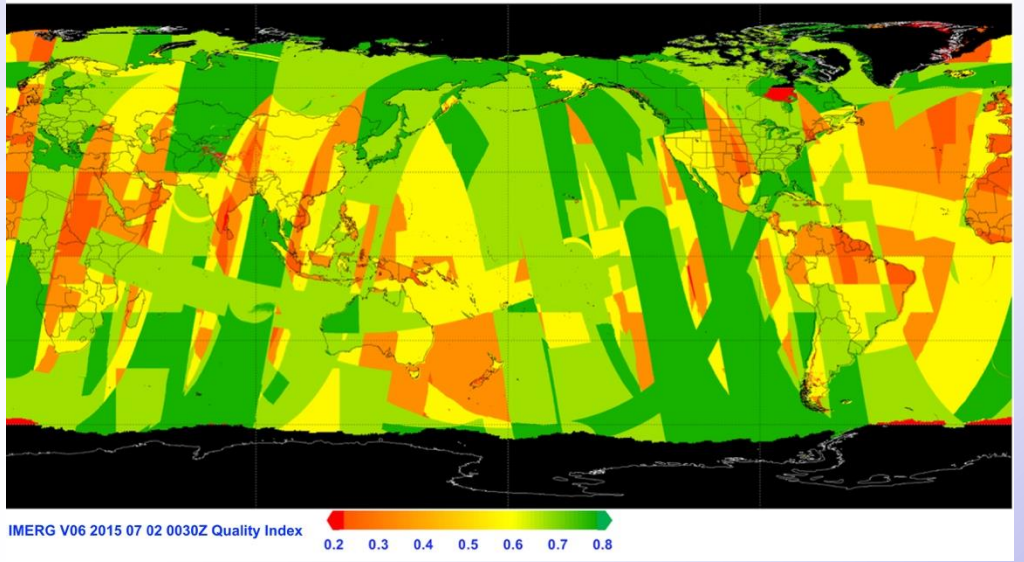
2. Early Results – Half-hourly Quality Index (1/2)

Revised in V06

- approx. Kalman Filter correlation
  - based on
    - times to 2 nearest PMWs (only 1 for Early) for morphed data
    - IR at/near time (when used)

$$QI_h = tanh\left(\sqrt{\sum arctanh^2(r_i)}\right)$$

  - where *r* is correlation, and the *i*'s are for forward propagation, backward propagation, and IR
  - or, an approximate at-overpass correlation when a PMW is used for that half hour
- revised to 0.1º grid (0.25º in V05)
- thin strips due to inter-swath gaps
- blocks due to regional variations
- snow/ice masking will drop out microwave values



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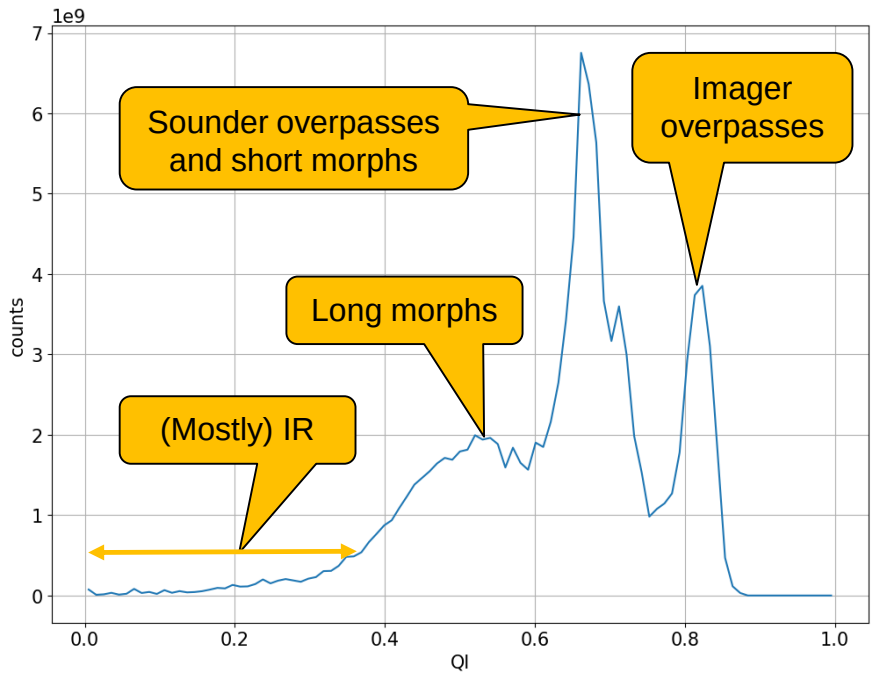
The goal is a simple "stoplight" index

- ranges of QI will be assigned
  - good 0.6-1
  - use with caution 0.4-0.6
  - questionable 0-0.4
  - is this a useful parameter?

2. Early Results – Half-hourly Quality Index (2/2)

IMERG-Final QI Histogram Jun 2014 – May 2015



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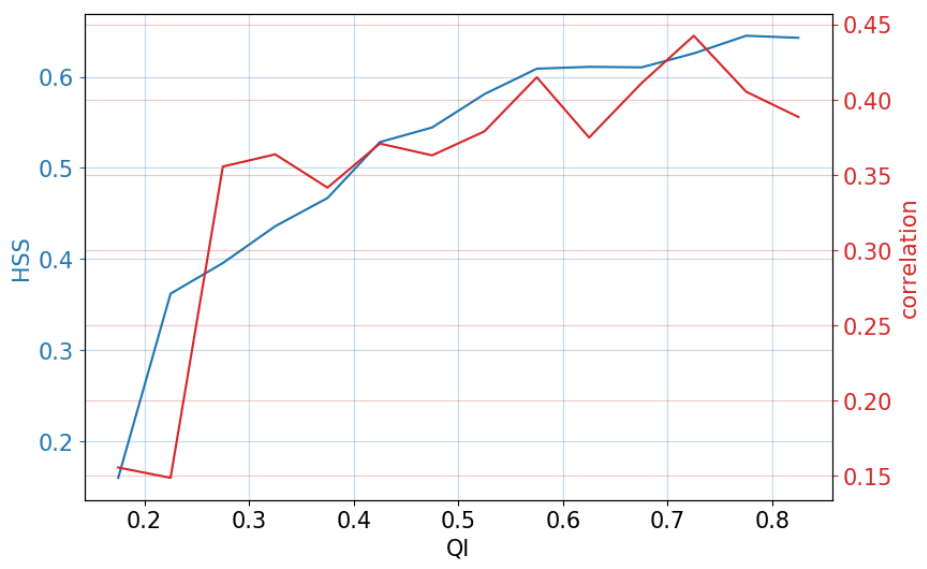
IMERG-Final Heidke Score and Correlation against MRMS over CONUS as a Function of QI
Jun 2014 – May 2015



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3. Development Work for V07

Multi-satellite issues

- address shifts in PDF between overpass and morphed estimates
  - work toward a cloud development component in the morphing system
- address apparent persistent biases
- improve motion vectors near topography
- improve error estimation (as possible)
- develop additional data sets based on observation-model combinations (as possible)

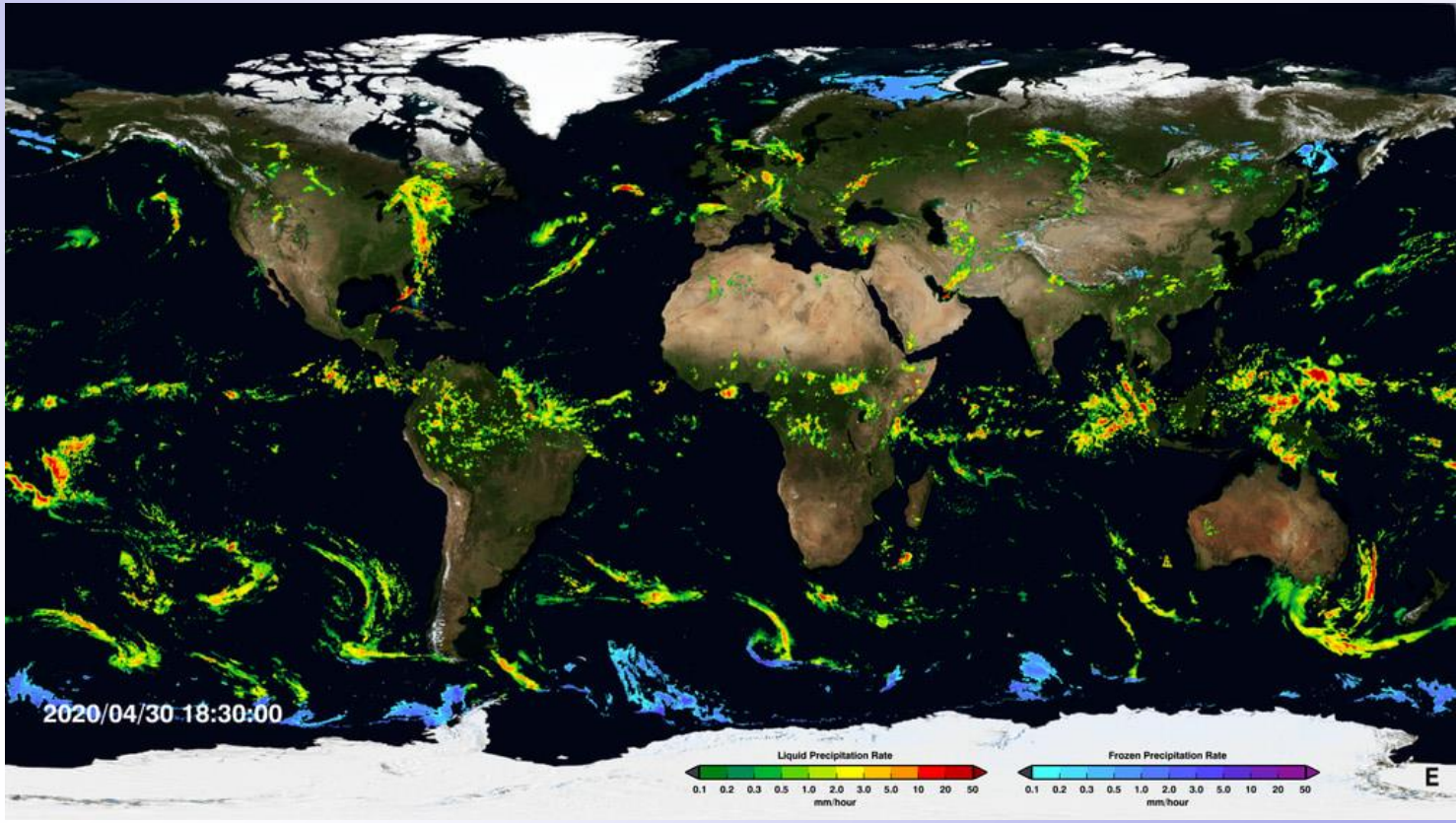
General precipitation algorithmic issues

- more-advanced IR algorithm
- work toward PMW retrievals (i.e., GPROF) that work better over snow/ice
- evaluate ancillary data sources and algorithm for Prob. of Liq. Precip. Phase
- introduce alternative/additional satellites at high latitudes (TOVS, AIRS, AVHRR, etc.)
- work toward improved wind-loss correction to gauge data

4. Final Remarks

IMERG is now V06B

- the product structure remains the same
  - Early, Late, Final
  - 0.1ºx0.1º half-hourly (and monthly in Final)
- new source for morphing vectors
- higher-latitude coverage
- extension back to 2000 (and eventually 1998)
- improved Quality Index
- TMPA ends with December 2019



See https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4285

Supplemental Slides

S1. Introduction – The Constellation

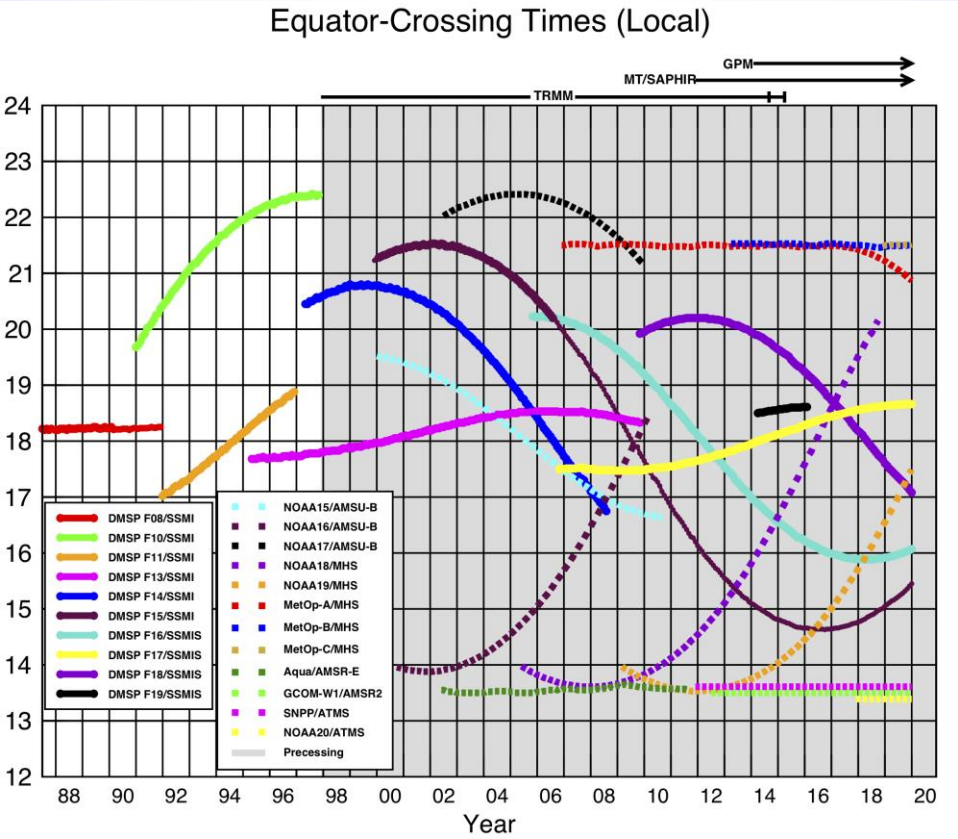
Presently 3-hourly observations >90% of the time, globally

The current GPM constellation includes:

- 5 polar-orbit passive microwave imagers
- 5 polar-orbit passive microwave sounders
- input precip estimates
  - GPROF (LEO PMW) + PRPS (SAPHIR)
  - PERSIANN-CCS (GEO IR)
  - CORRA (combined PMW-Ku radar)
  - GPCP SG (monthly satellite-gauge)

The constellation is evolving

- launch manifests are assured for sounders, sparse for imagers

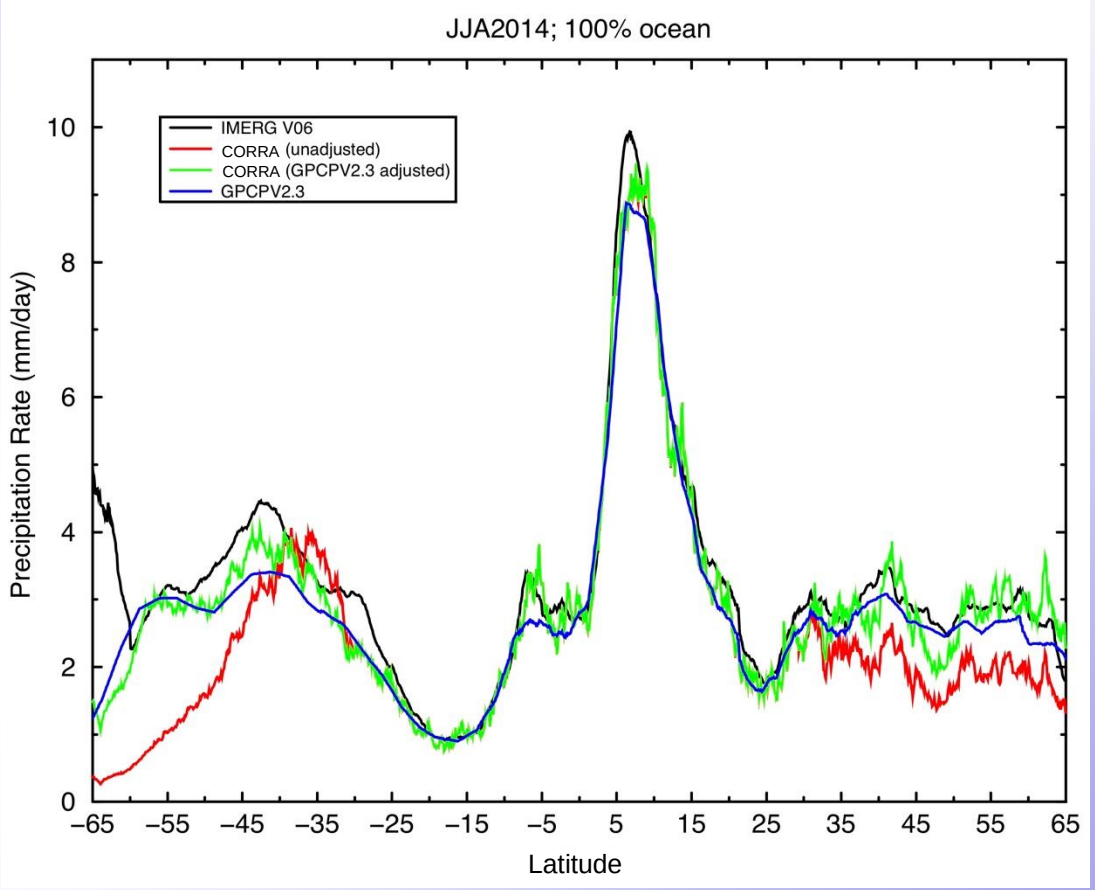


Ascending passes (F08 descending); satellites depicted above graph precess throughout the day.
Image by Eric Nelkin (SSAI), 14 February 2020, NASA/Goddard Space Flight Center, Greenbelt, MD.

S2. Early Results – Calibration (1/2)

Combined product (calibrator) adjusted to GPCP V2.3 seasonal climatology zonally for reasonable bias

- GPM core products have similar bias (by design)
  - these profiles are systematically low in the extratropical oceans vs.
    - GPCP V2.3 SG product
    - Behrangi Multi-satellite CloudSat, TRMM, Aqua (MCTA) product
- over land GPCP adjustment provides a first cut at the adjustment to gauges used in the Final



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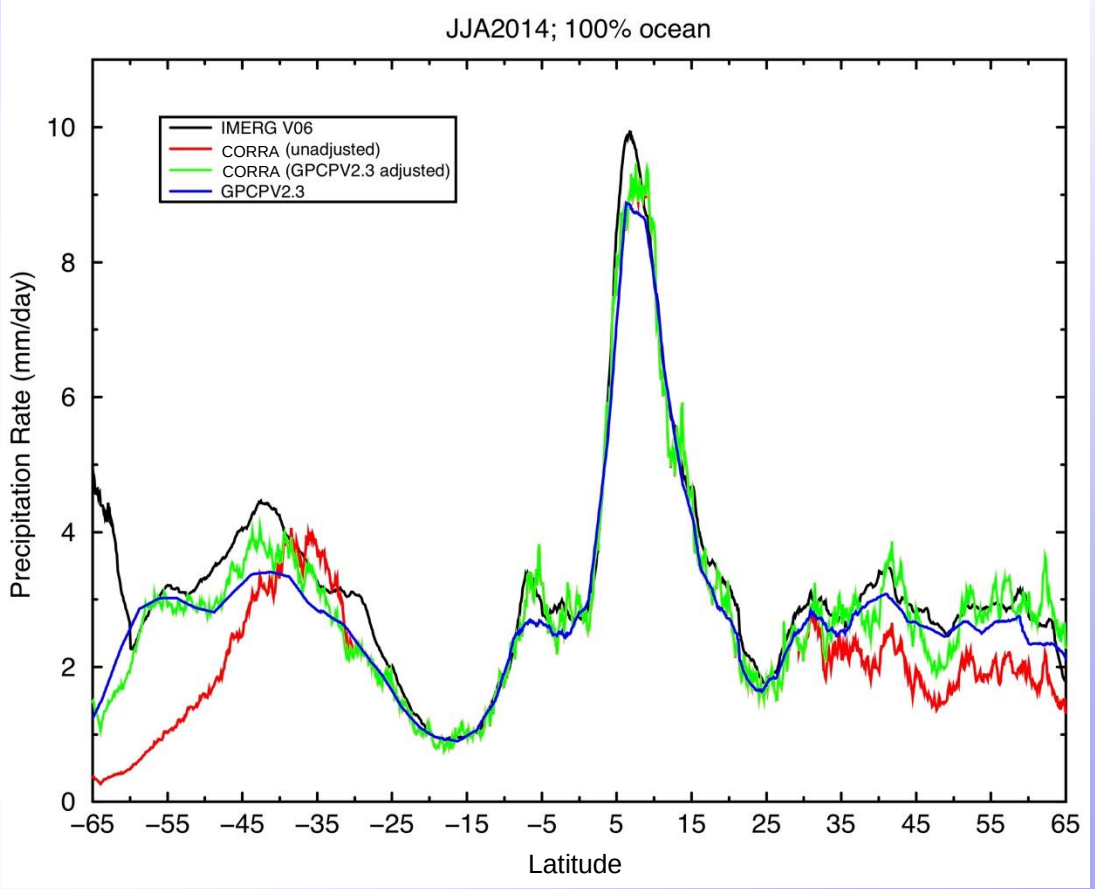
S2. Early Results – Calibration (2/2)

Calibration sequence is

- CORRA climatologically calibrated to GPCP over ocean outside 30ºN-S
- GMI calibrated to monthly CORRA
- GPM constellation climatologically calibrated to GMI

Adjustments working roughly as intended

- CORRA is low at higher latitudes
- adjustments in Southern Ocean are large and need analysis
  - IMERG subsetted to coincidence with CORRA is much closer to (adjusted) CORRA



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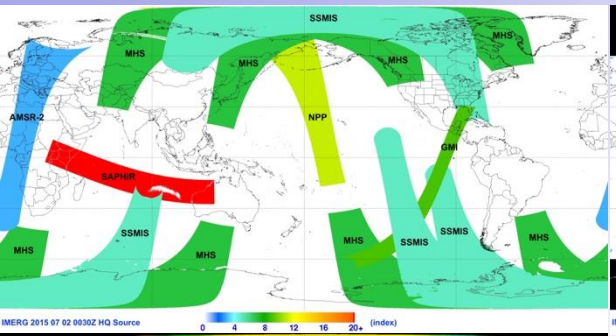
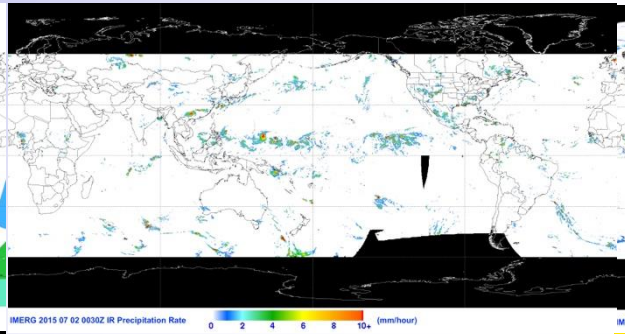
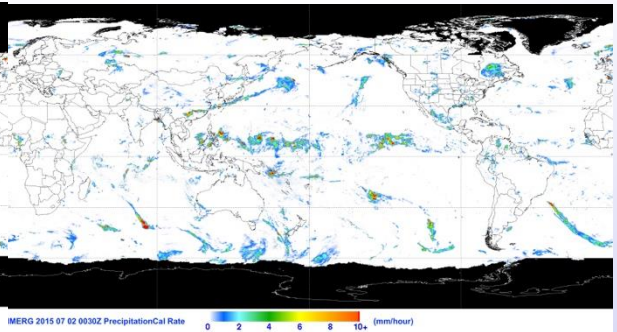
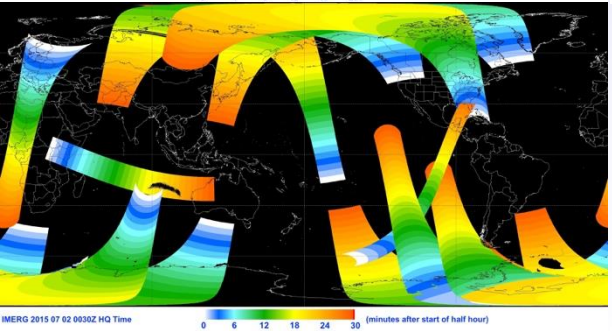
S3. IMERG – Examples of Data Fields





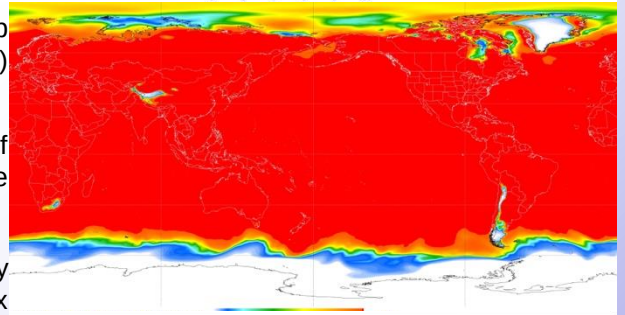




PMW sensor

IR precip

cal precip (uncal precip)



PMW time into half hour

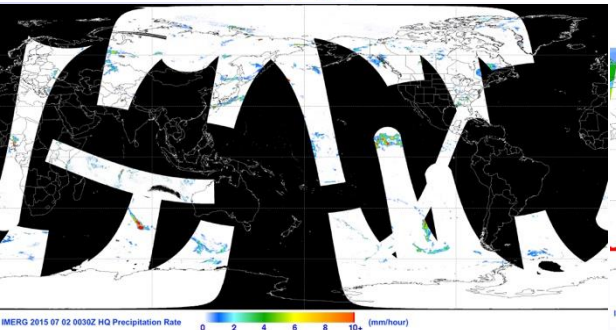
2 July 2015 0030 UTC

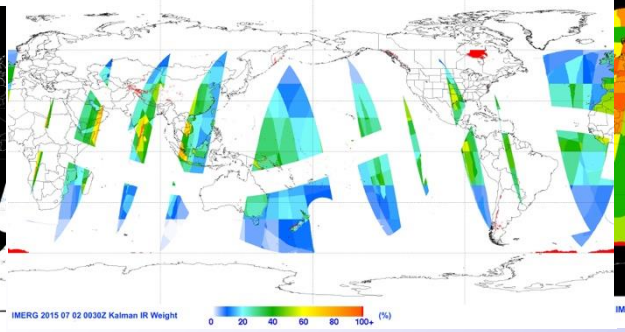
probability of liquid phase

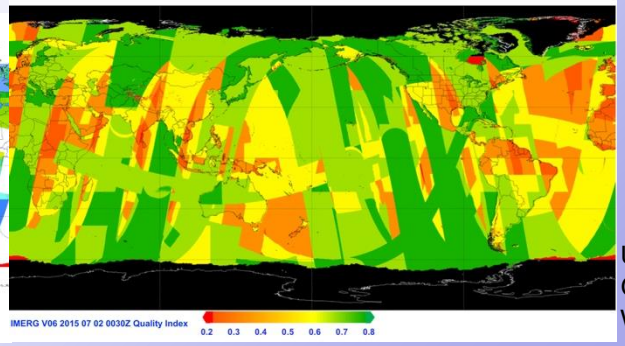
PMW precip

IR weight

Quality Index



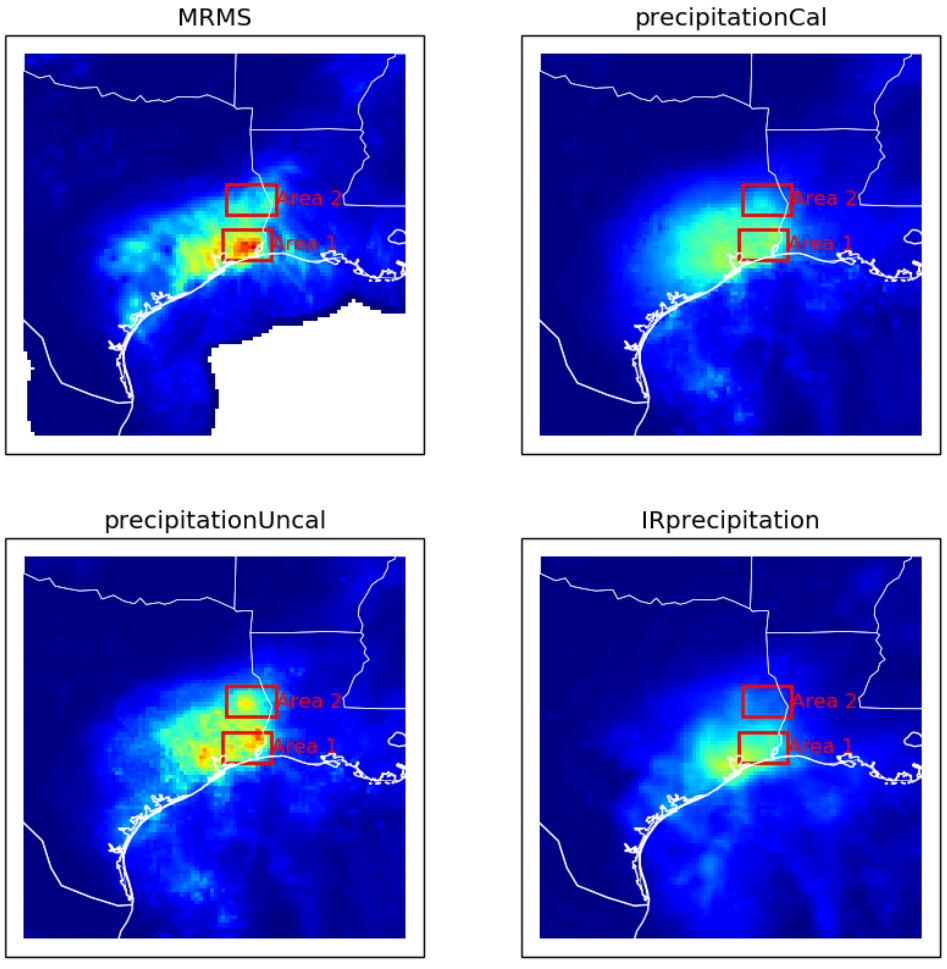




S4. Early Results – Hurricane Harvey, 25-31 August 2017, IMERG and MRMS (1/2)

Harvey loitered over southeast Texas for a week

- MRMS considered the best estimate
  - some questions about the details of the gauge calibration of the radar estimate
  - over land
- Uncal (just the intercalibrated satellite estimates) under(over)-estimated in Area 1(2)
  - should be similar to Late Run
- Cal (with gauge adjustment) pulls both areas down
- microwave-adjusted PERSIANN-CCS IR has the focus too far southwest



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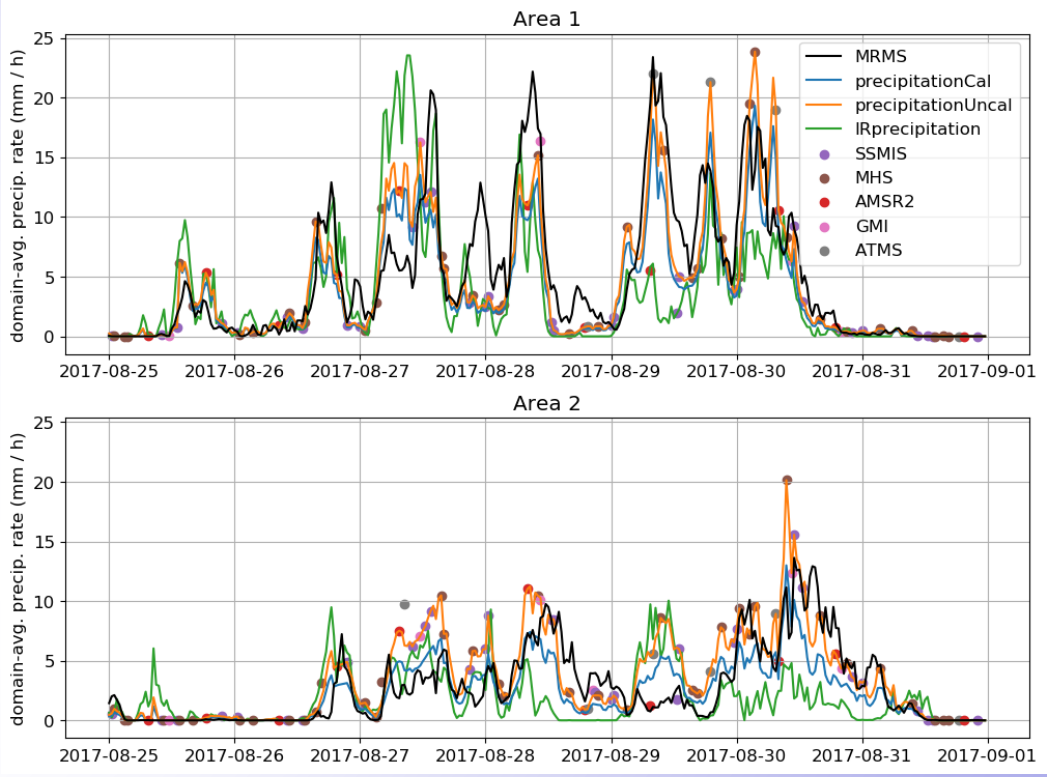
S4. Early Results – Hurricane Harvey, 25-31 August 2017, IMERG and MRMS (2/2)

IMERG largely driven by microwave overpasses (dots)

- except duplicate times
- not just time interpolation
  - systems move into / out of the box between overpasses
- satellites show coherent differences from MRMS
  - microwave only "sees" the solid hydrometeors (scattering channels), since over land
  - IR looks at Tb within "clustered" data
  - both are calibrated to statistics of time/space cubes of data
    - Cal is basically *(Uncal x factor)*
  - short-interval differences show some cancellation over the whole event
    - but several-hour differences can be dramatic



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