Status and Examples for the Version 06 IMERG Multi-Satellite Products

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

1. Introduction – The Constellation

We want 3-hourly observations, globally

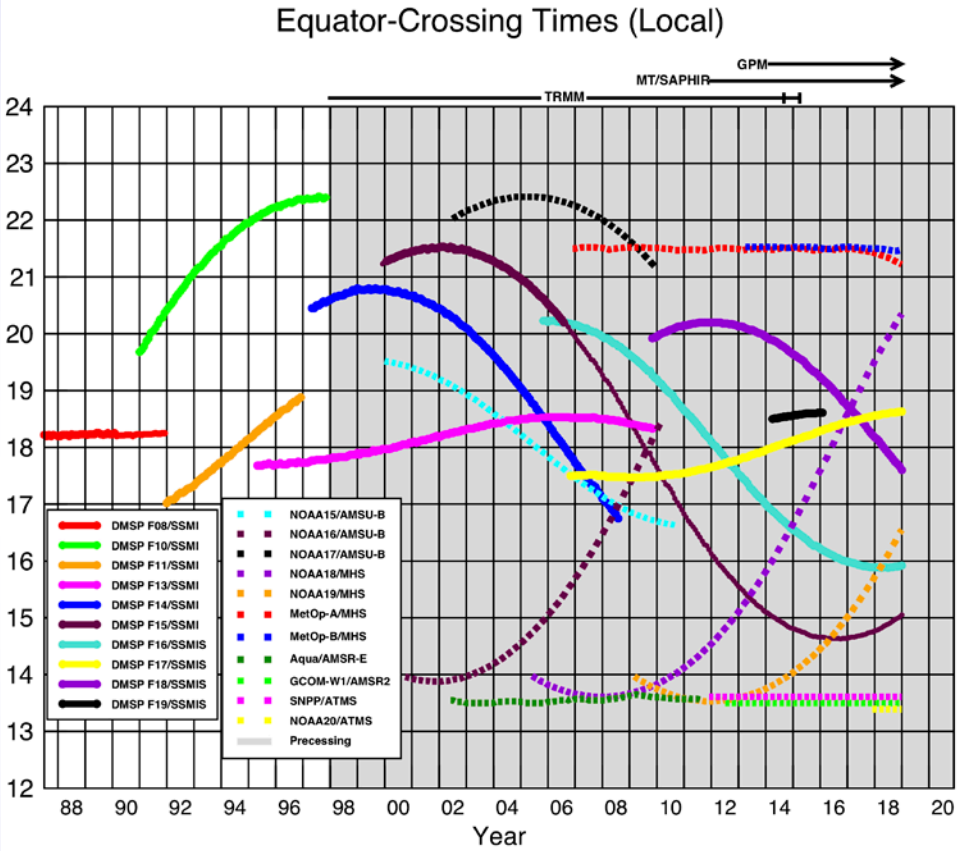
- sampling the diurnal cycle
- morphed microwave loses skill outside ±90 min

The current GPM constellation includes:

- 5 polar-orbit passive microwave imagers
  - 3 SSMIS, AMSR-2, GMI
- 7 polar-orbit passive microwave sounders
  - 4 MHS, 2 ATMS, SAPHIR
- input precip estimates
  - GPROF (LEO PMW)
  - PERSIANN-CCS (GEO IR)
  - 2BCMB (combined PMW-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), 30 January 2019, NASA/Goddard Space Flight Center, Greenbelt, MD.

2. IMERG – Quick Description (1/2)

IMERG is a unified U.S. algorithm based on

- Kalman Filter CMORPH – NOAA/CPC
- PERSIANN CCS – U.C. Irvine
- TMPA – GSFC
- PPS (GSFC) processing environment

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

- multiple runs for 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)
- 0.1º global CED grid
  - morphed precip, 60º N-S in V05, 90º N-S in V06
  - IR covers 60º N-S

	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*

2. IMERG – Quick Description (2/2)

IMERG is adjusted to GPCP monthly climatology zonally to achieve a bias profile that we consider reasonable

- GPM Version 04, 05, 06 core products have similar zonal profiles (by design)
  - these profiles are systematically low in the extratropical oceans compared to
    - GPCP monthly Satellite-Gauge product
    - Behrangi Multi-satellite CloudSat, TRMM, Aqua (MCTA) product
- over land GPCP adjustment provides a first cut at the adjustment to gauges that the final calibration in IMERG enforces
- similar bias concerns apply during TRMM

	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*
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	Monthly data file (Final)
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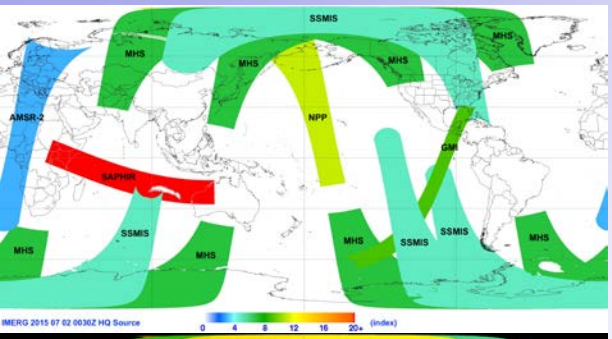
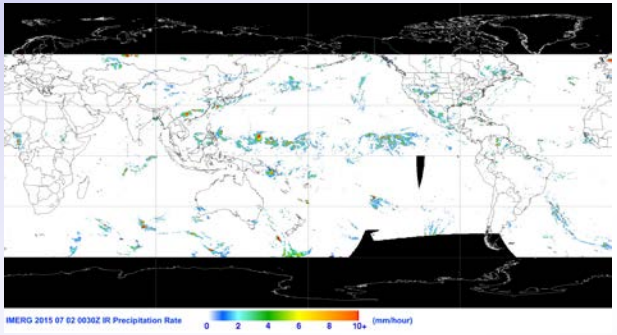
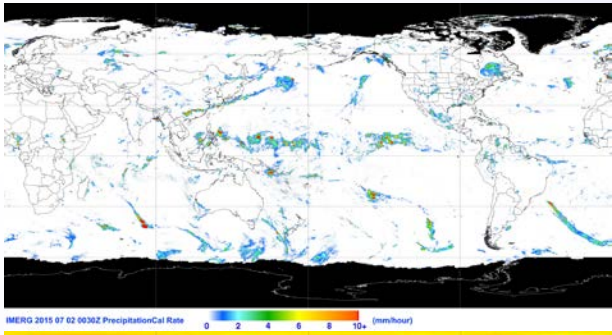
3	GaugeRelativeWeighting
4	*probabilityLiquidPrecipitation [phase]*
5	*precipitationQualityIndex*

2. IMERG – Examples of Data Fields



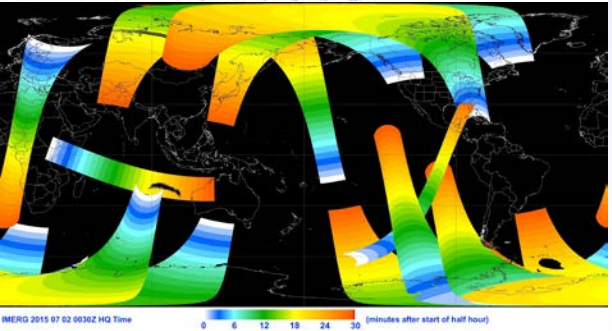




PMW sensor

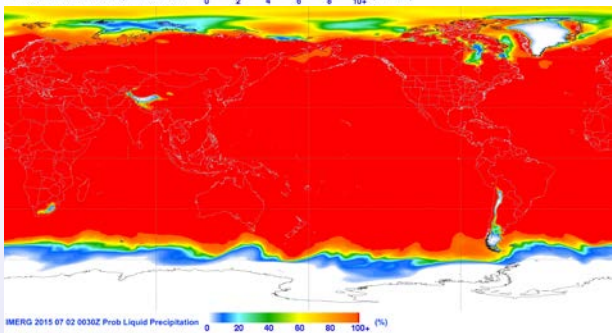
IR precip

cal precip

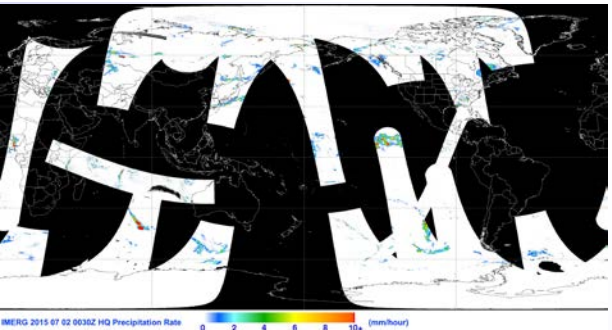


PMW time into half hour

2 July 2015 0030 UTC

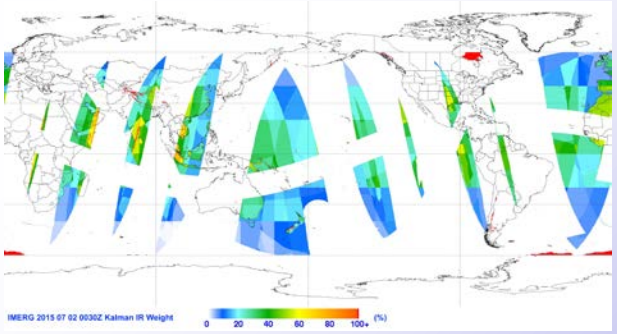


probability of liquid phase

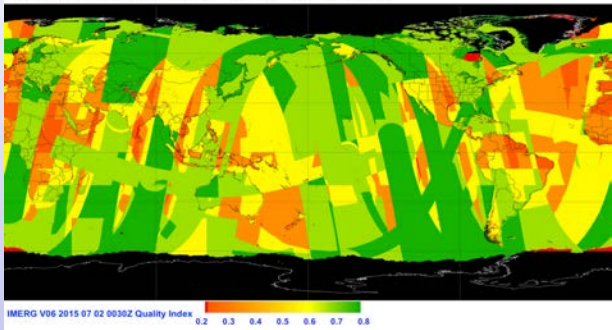


PMW precip

IR weight



Quality Index



2. 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

Half-hourly Quality Index modified

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

Full intercalibration to 2BCMB

- V05 took shortcuts

Modifications for TRMM era

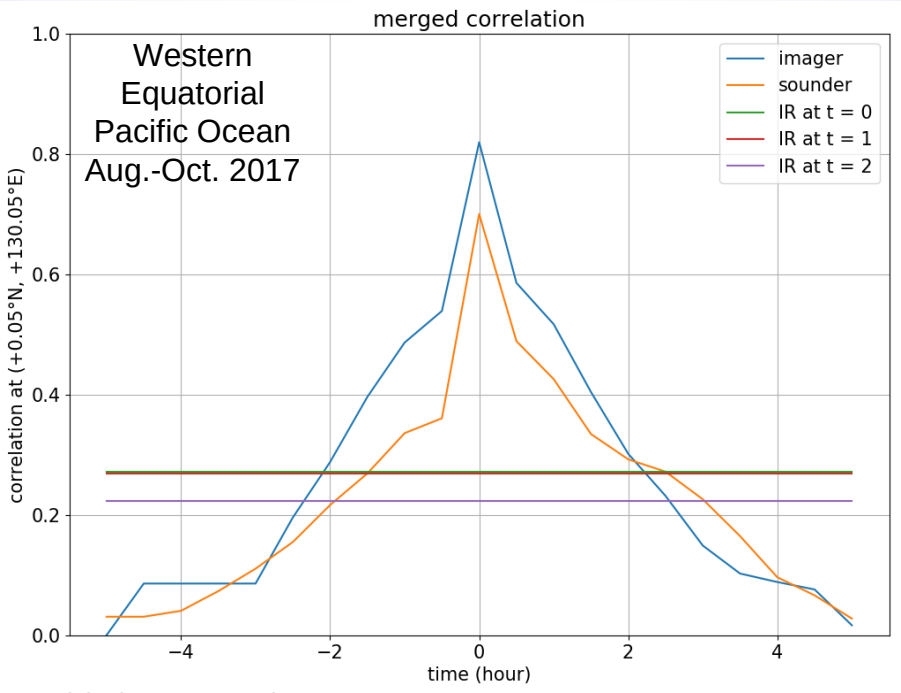
- compute calibrations for older satellites against TRMM
- estimate the microwave calibration based on GPM-era 2BCMB for the band 35º-65º in both hemispheres

Revisions to internals raises the maximum precip rate from 50 to 200 mm/hr and no longer discrete

3. Some Details – Key Points in Morphing (1/2)

Following the CMORPH approach

- for a given time offset from a microwave overpass
- compute the (smoothed) average correlation between
  - morphed microwave overpasses and microwave overpasses at that time offset, and
  - IR precip estimates and microwave overpasses at that time offset and IR at 1 and 2 half hours after that time offset
  - for conical-scan (imager) and cross-track-scan (sounder) instruments separately
- the microwave correlations drop off from t=0, dropping below the IR correlation within a few hours (2 hours in the Western Equatorial Pacific)



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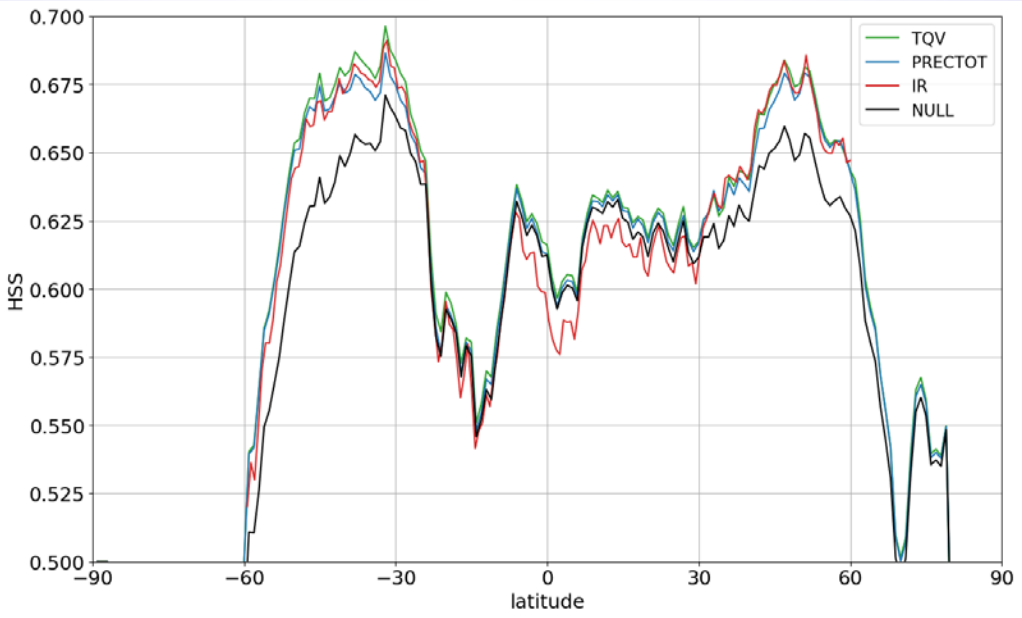
3. Some Details – Key Points in Morphing (2/2)

Tested vectors computed on a 5ºx5º template every 2.5º, interpolated to 0.1ºx0.1º based on

- MERRA2 TQV (vertically integrated vapor)
- MERRA2 PRECTOT (precip)
- CPC 4-km merged IR Tb (as in V05 IMERG)
- NULL (no motion)

On a zonal-average basis, compute the Heidke Skill Score for

- merged GPROF precip (HQ) propagated for 30 min.
- compared to HQ precip observed in the following 30 min.
- TQV is consistently at/near the top
- further research is expected for V07



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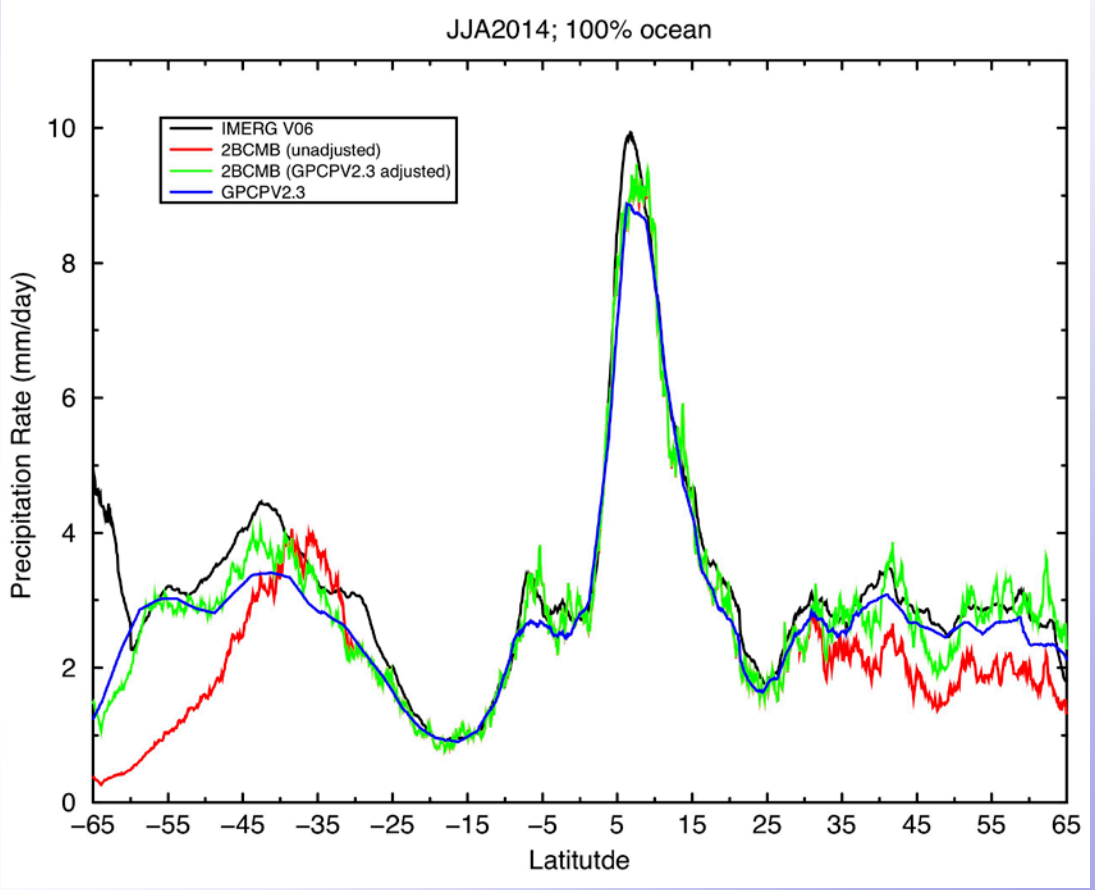
4. Early Results – Calibration

Calibration sequence is

- 2BCMB calibrated to GPCP over ocean outside 30ºN-S
- GPM constellation calibrated to 2BCMB

Adjustments working roughly as intended

- 2BCMB Is low at higher latitudes
- adjustments in Southern Ocean are large and need analysis



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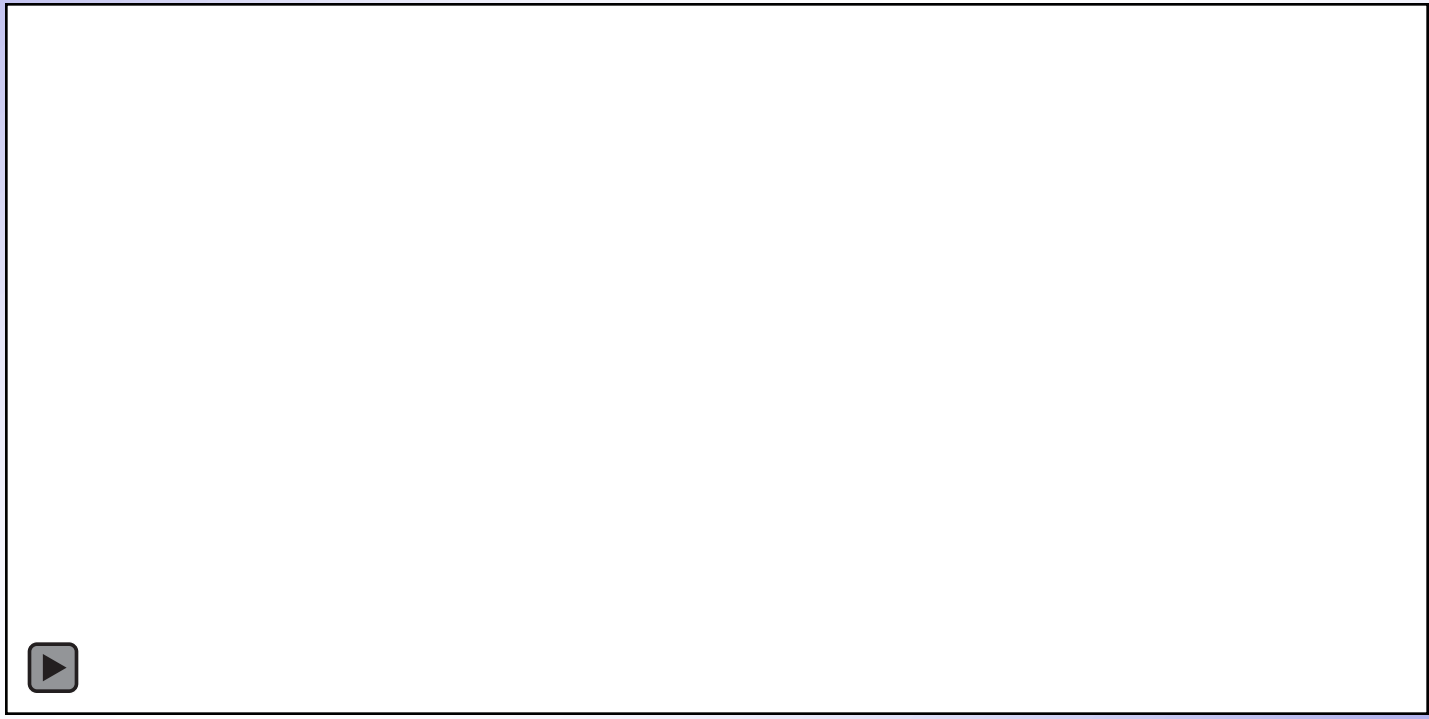
4. Early Results – JJA Diurnal Cycle (GPM Era)

Average June-July-August from June 2014 to November 2018

- data re-sorted to give the same LST over the whole globe
- surface cycles between Blue Marble and Night Lights
- adding the TRMM era will smooth out the results



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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)

Reminiscent of IMERG V05, but

- better data coverage at higher latitudes
- less “flashing” due to inter-satellite differences and morphing
- and still have artifacts along ice edges

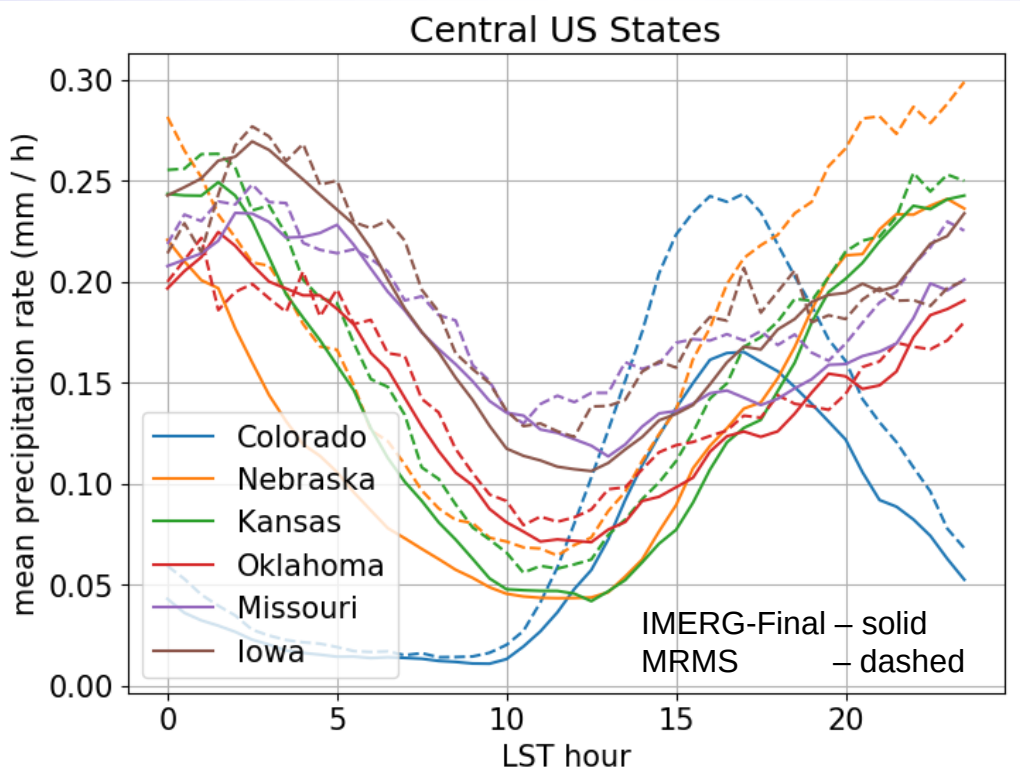
4. Early Results – JJA Diurnal Cycle in Central U.S. (GPM Era)

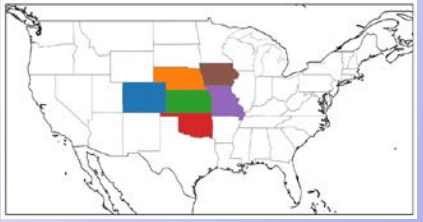
Average June-July-August from June 2014 to November 2018 (5 summers) for 6 states

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

- lower averages
- 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 would have to use different data





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5. Schedule and Final Remarks (2/3)

Early March 2019: began IMERG Retrospective Processing

- the GPM era was la… Fin… R…
- the TRMM era Fin… proces… way
  - complete data will take about …
  - 4 km merged global IR data files continue to be delayed for January 1998-January 2000
    - the run will build up the requisite 3 months of calibration data starting from February 2000
    - the first month of data will be for June 2000
    - the initial 29 months of data will be incorporated when feasible
- Early and Late Run Retrospective Processing uses Final intermediate files, so they come after Final
  - Final is always ~3.5 months behind, so the Early and Late retrospective processing have to wait on Final Initial Processing to fill in the last … months before May 2019
- Early and Late Run Initial Processi… May

done

underway

coming

5. Schedule and Final Remarks (2/3)

Development Work for V07

- multi-satellite issues
  - improve error estimation
  - develop additional data sets based on observation-model combinations
  - work toward a cloud development component in the morphing system
- general precipitation algorithmic issues
  - introduce alternative/additional satellites at high latitudes (TOVS, AIRS, AVHRR, etc.)
  - evaluate ancillary data sources and algorithm for Prob. of Liq. Precip. Phase
  - work toward using PMW retrievals over snow/ice
  - work toward improved wind-loss correction to gauge data

Version 07 release should be in about 2 years (2021?)

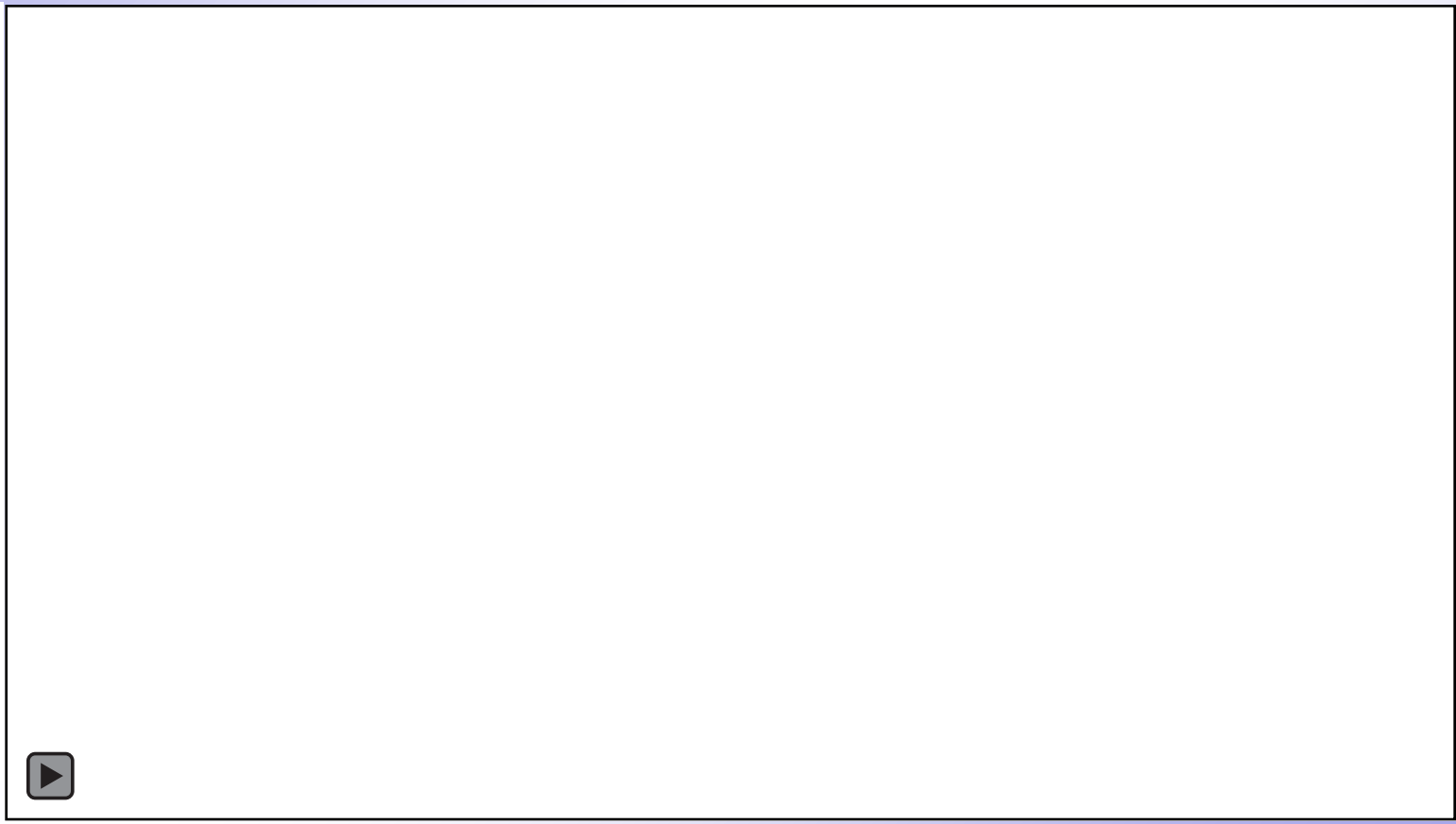
5. Schedule and Final Remarks (3/3)

Come by the Hyperwall

Wednesday, 6 p.m.

IMERG is being upgraded to V06 in Spring 2019

- 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



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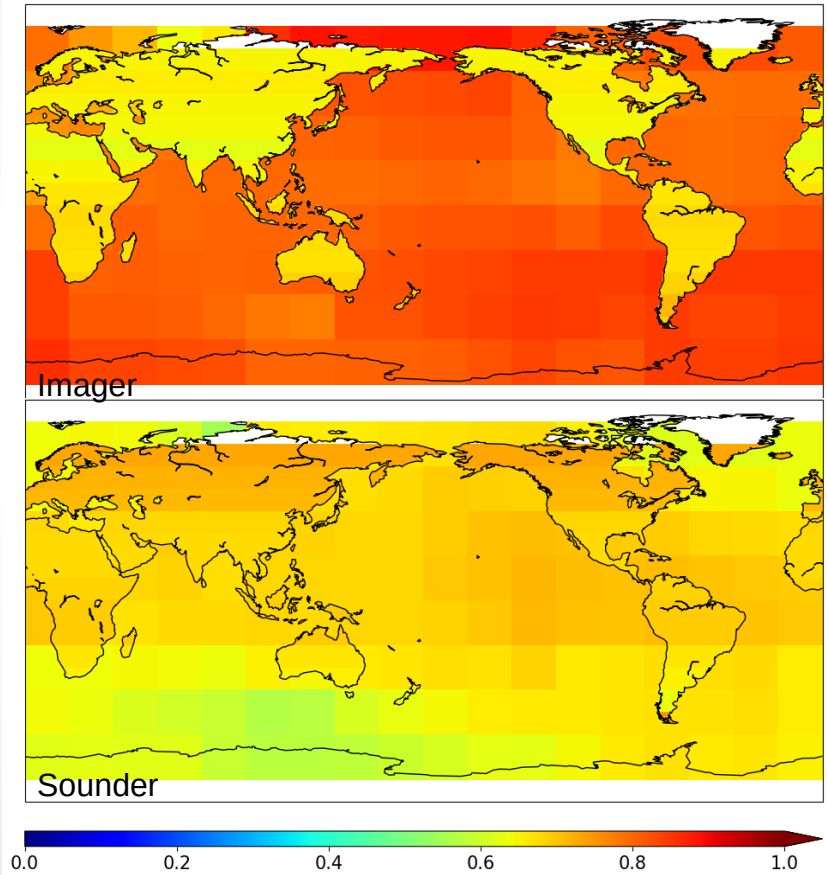
  - for conical-scan (imager) and cross-track-scan (sounder) instruments separately
- the microwave correlations drop off from there, dropping below the IR correlation within a few hours (2 hours in the Western Equatorial Pacific)
- at t=0 (no offset), imagers are better over oceans, sounders are better or competitive over land



L2 correlation at t=0 Aug.-Oct. 2017

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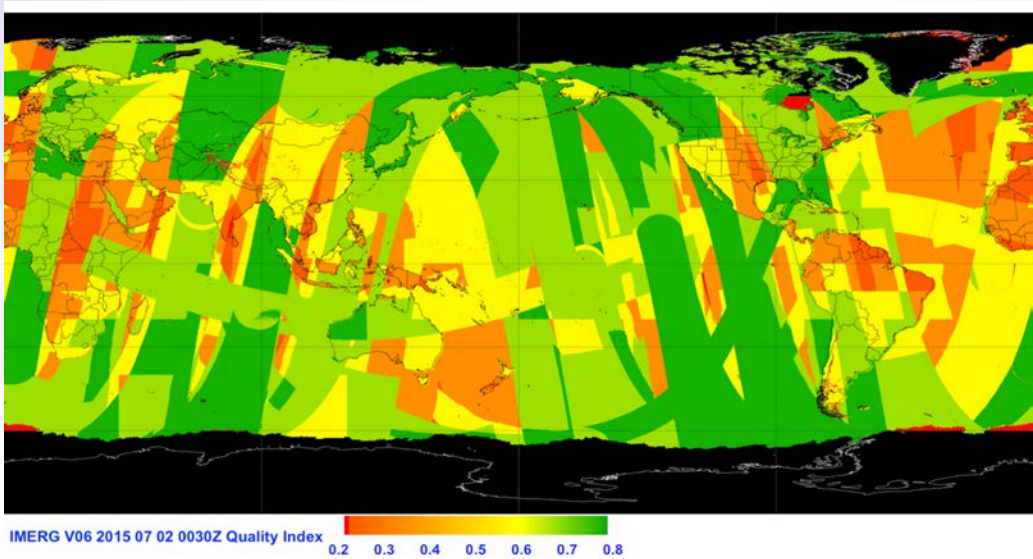
3. Some Details – Quality Index (1/2)

Half-hourly QI (revised)

- approx. Kalman Filter correlation
  - based on
    - times to 2 nearest PMWs (only 1 for Early)
    - IR at 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
  - approximate *r* when a PMW is used for just that satellite
- 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
  - use with caution
  - questionable
- is this a useful parameter?

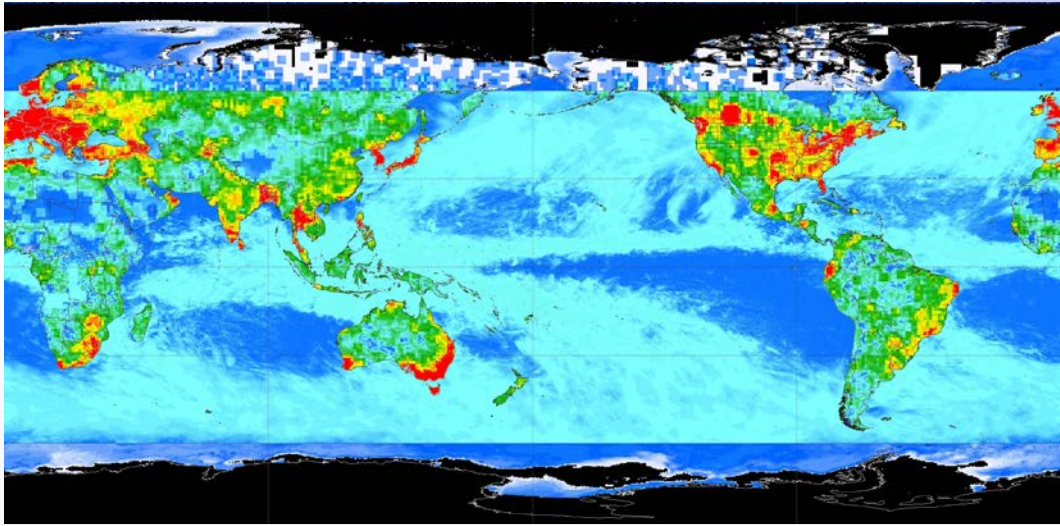
3. Some Details – Quality Index (2/2)

Monthly QI (unchanged)

- Equivalent Gauge (Huffman et al. 1997) in gauges / 2.5ºx2.5º

$$QI_m = (S + r) * H * (1 + 10 * r^2)/e^2$$

  - where r is precip rate, e is random error, and H and S are source-specific error constants
- invert random error equation
- largely tames the non-linearity in random error due to rain amount
- some residual issues at high values
- doesn't account for bias
- $QI_m \geq 4$ is "good"
- $2 \leq QI_m < 4$ is "use with caution"
- $QI_m < 2$ is "questionable"



Month Qual. Index Dec 2016

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0 4 8 12 16 20+