Multi-Sensor Data Fusion for High-Resolution QPE Products Over the CONUS

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INTRODUCTION

Quantifying accurate high-resolution (H-R) *instantaneous precipitation intensities* is important for many applications. For example, hydrological applications such as flood forecasting, runoff accommodation, erosion prediction, and urban hydrological studies depend on an accurate representation of the rainfall that does not infiltrate the soil, which is controlled by the rain intensities. Systematic shifts in rain-rate probability distribution functions will have a significant impact on surface runoff production.

Having accurate instantaneous precipitation reference products is also very important for verifying precipitation estimates from LEO satellites, which suffer from temporal sampling errors. As part of NASA's Precipitation Measurement Missions, verification of satellite precipitation estimates is conducted by comparing instantaneous precipitation intensity fields at overpass time (snapshot comparisons). Snapshot comparisons avoid satellite temporal sampling errors.

ADJUSTING THE INSTANTANEOUS Q2 PRODUCTS TO THE GAUGES OVER THE ENTIRE CONTINENTAL U.S.

To have accurate reference data for satellite snapshot comparisons, we have developed the first instantaneous gauge-adjusted radar national mosaics. The product is based on adjusting the NEXRAD based-NMQ/Q2 radar-only precipitation rate estimates to the gauges. Pixel-by-pixel hourly adjustment factors are calculated (using the hourly radar gauge-adjusted and the hourly radar-only Q2 products) and applied to the Q2 radar-only instantaneous product. The gauge correction method includes a data quality control procedure.

$$\frac{\text{Q2 hourly gauge adjusted}}{\text{Q2 hourly radar-only}} \quad X \quad \text{Q2 inst. radar-only} \quad = \quad \text{Inst. gauge adjusted}$$

(1) (2)

(1) The NOAA/NSSL QPE H-R (0.01° horizontally , instantaneous) mosaics with updates every 5-min available over the entire CONUS and South Canada (Q2) http://nmq.ou.edu/ Vasiloff et al. (2007), Zhang et al. (2011).

(2) $Q2_{GC}$ -The new H-R (0.01°, instantaneous) gauge-adjusted radar products, generated by applying a gauge correction on the Q2 products (Amitai et al. 2009, 2011, 2012).

The gauge correction method has recently been adopted by NSSL for systematic error modeling of the TRMM PR with Q2 (Kristetter et al. 2012).

These new reference products provide a breakthrough in the accuracy of large-scale H-R surface reference data available for various hydrological applications, and for verification of satellite snapshot observations.

Amitai, E., W. Petersen, X. Llort, and S. Vasiloff, 2012: Multiplatform comparisons of rain intensity for extreme precipitation events. *IEEE Trans. Geosciences and Remote Sensing*, **50(3)**, 675-686. **Article selected for front cover of the March 2012 issue**.

Amitai, E., B. Thill, J. J. Gourley, and S. Vasiloff, 2011: Gauge Adjustment of Instantaneous Radar Fields Over the Entire Continental U.S. *2011 World Environmental & Water Resources Congress (EWRI)*, Palm Springs, Calif.

Amitai E., X. Llort, and D. Sempere-Torres, 2009: Comparison of TRMM radar rainfall estimates with NOAA Next Generation QPE. *Journal of the Meteorological Society of Japan*, **87A**, 109-118 (special issue on 'Precipitation Measurements from Space').

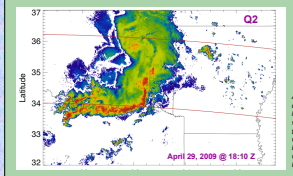
Kirstetter, P.-E., Y. Hong, J. J. Gourley, S. Chen, Z. L. Flamig, J. Zhang, M. Schwaller, W. Petersen, and E. Amitai, 2012: Toward a framework for systematic error modeling of NASA spaceborne radar with NOAA/NSSL ground radar-based National Mosaic QPE. *J. Hydrometeor.*, **13**, 1285-1300.

Vasiloff, S, D. J. Seo, K. W. Howard , 2007: Improving QPE and very short term QPF: An initiative for a community-wide integrated approach. *Bull. Amer. Meteor. Soc.*, **88**, 1899-1911.

Zhang, J., K. Howard, C. Langston, et al., 2011: National Mosaic and multi-sensor QPE (NMQ) system: description, results and future plans. *Bull. Amer. Met. Soc.*, **92**, 1321-1338.

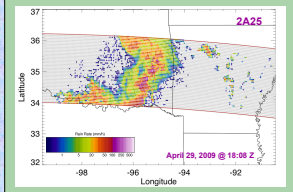
Q2 / $Q2_{GC}$ / TRMM-PR COMPARISONS

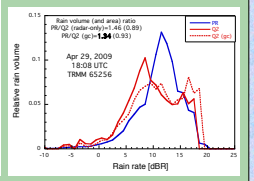
The gauge correction method was first used in comparing Q2/PR snapshots (Amitai et al. 2009). Extensive comparisons during extreme rain events fund that upon the adjustment the rain amount more closely agrees with that of PR (Amitai et al. 2012).



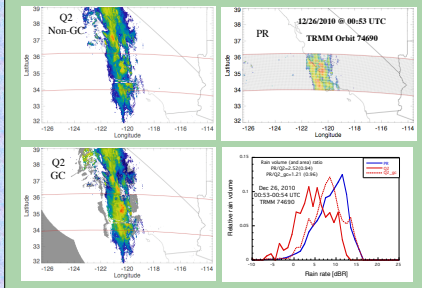
On April 29, 12.89 inches (327 mm) of rain was recorded in Burneyville, OK, the state's highest *daily total* in nearly 36 years. Gov. Brad Henry issued a State of Emergency for nine OK counties impacted by tornadoes, severe storms and flooding...

A driver attempting to turn onto West Lindsay Street had to be extracted from this vehicle during heavy thunderstorms in Norman, OK, on April 29, 2009. Photo: Steve Sisney, The Oklahoman ORG XMIT: KOD





- Topographical features cause some significant discrepancy between PR/Q2
- Upon adjustment of Q2 to the gauges ($Q2_{GC}$) the rain amount more closely agrees with that of PR
- Merging PR, Q2, and $Q2_{GC}$ will improve QPE in mountainous/overshooting regions



Images display original resolution; pdfs are based on data matched to a common grid with 0.04° resolution.

All PR and Q2 rainy values within the PR swath are taken to generate the pdfs regardless of whether both observed rain at the same pixel.

FUTURE PLANS

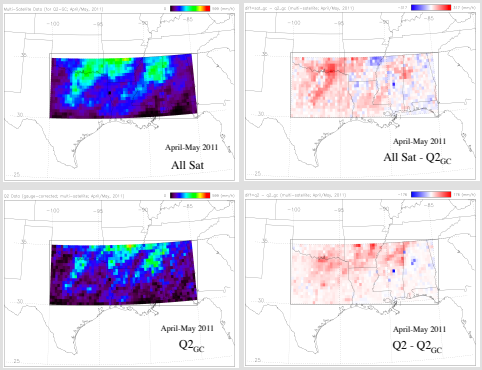
- Assess the conditions under which the very fine-scale Q2 (and $Q2_{GC}$) data can be considered accurate for evaluating satellite precipitation estimates
- Assess/improve the Q2 gauge correction procedure for more accurate reference data for satellite snapshot comparisons. The current adjustment approach assumes a fixed adjustment factor value, valid during the entire hour (although it can change from pixel-to-pixel). We will examine the spatiotemporal behavior of hourly gauge/radar ratios. The adjustment factor for a given instantaneous radar rain-rate pixel will likely change within a given hour; hence, a weighting function for spreading the hourly bias should be considered
- Integrate the TRMM PR data into the Q2 ($Q2_{GC}$) product

SUPPORTING IMERG DEVELOPMENT

The advent of the high-resolution multi-satellite products such as the Integrated Multi-satellitE Retrievals for GPM (IMERG, 0.1°, updated every 30-min) potentially provides very useful products, which require evaluation in support of their development. Evaluation is required not only for the end-user products, but for the individual LEO satellite estimates (PMW imagers and sounders), which will be used to construct GPM multi-satellite products. The evaluation is required at different steps of the multi-satellite product development (pre- and post-calibration). Evaluation is also required for selecting the best IR scheme to be used at times when PMW observations do not exist.

In a pilot study over a selected domain in south-central U.S (30-35°N, 85-100°W) instantaneous *R* fields (snapshots) retrieved from individual PMW satellite sensors, such as these that will be used to construct IMERG, are compared with collocated Q2 instantaneous *R* fields (radar-only and gauge-adjusted) at overpass time. The comparisons are based on a 0.25° match-up resolution.

The figure on the right presents the summation of 1140 snapshots during April-May 2011, based on retrievals from several PMW satellite sensors [upper left panel], and co-located gauge-adjusted Q2 ($Q2_{GC}$) [lower left panel]. The differences in the estimates are presented in the upper right panel (satellite overestimation in red; underestimation in blue). The adjustment to the gauges [lower right panel] reduces the ground reference estimates and increases the Sat/Ground-reference bias.

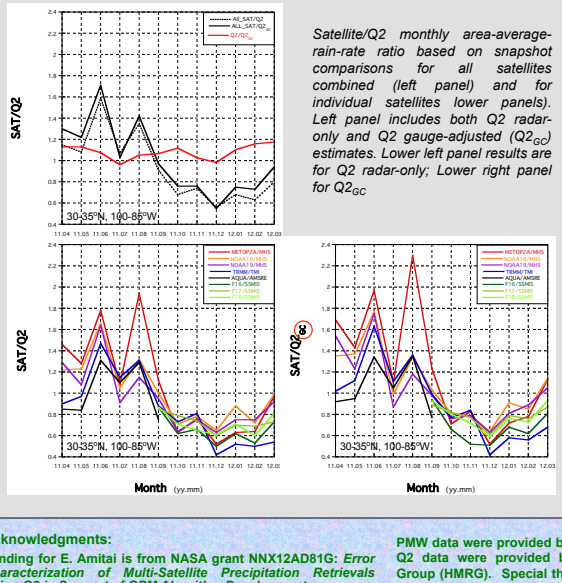


Month-to-month variabilty:
The Satellite/Q2 (and Satellite/$Q2_{GC}$) area-average-rain-rate ratio for all satellites combined and for each sensor for April are similar to these of May. How do the ratios change throughout the year?

Satellite/Q2 Area Average Rain Rate Ratio

		All	METOP2A/MHS	NOAA19/MHS	NOAA18/MHS	TMI	AQUA/AMSRE	NOAA16/AMSUB
$\Sigma R_{SAT}/\Sigma R_{Q2}$	April	1.11	1.46	1.29	1.22	0.90	0.85	0.44
	May	1.08	1.29	1.08	1.23	0.97	0.84	N/A
$\Sigma R_{SAT}/\Sigma R_{Q2_{GC}}$	April	1.26	1.69	1.54	1.35	1.02	0.92	0.50
	May	1.22	1.43	1.23	1.37	1.12	0.95	N/A

Multi-Satellite/Q2 Snapshot Comparisons: Monthly Area Average Rain Rate



Satellite/Q2 monthly area-average-rain-rate ratio based on snapshot comparisons for all satellites combined (left panel) and for individual satellites lower panels). Left panel includes both Q2 radar-only and Q2 gauge-adjusted ($Q2_{GC}$) estimates. Lower left panel results are for Q2 radar-only; Lower right panel for $Q2_{GC}$

The satellites overestimate the precipitation compared to the Q2 (radar-only and gauge-adjusted) during April through August and underestimate from September till March.

The zigzag pattern observed in the summer months in both imager and sounders may suggest issues with the Q2 data (the precipitation retrieval algorithms for the imagers and for the sounders are independent of each other). However, this pattern, which remains upon adjusting the Q2 to the gauges, along with other Q2 evaluation studies increased our confidence in the ground reference estimates. These studies included monthly comparisons with STAGE IV, and additional comparisons with independent gauge data (CoCoRaHS network). More evaluation studies are planned.

How do the ratios change upon IMERG inter-satellite calibration?

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