Title: Utilizing TRMM Precipitation Products in Operational Hydrology through Multi-Satellite and Multi-Sensor Quantitative Precipitation Estimation (QPE)

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Type of Report: Year 2 Progress Report

PI: Robert J. Kuligowski

Collaborators: David Kitzmiller, Dong-Jun Seo, Yu Zhang

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Institution: NOAA/NESDIS Center for Satellite Applications and Research
E/RA2 RM 712 WWBG
Camp Springs, MD 20746-4304
Voice: 301-763-8251x192
Email: Bob.Kuligowski@noaa.gov

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Overall Project Objective
Assess and demonstrate the value of TRMM/GPM precipitation products for quantitative hydrologic forecasting in NOAA/NWS by infusing these data into an integrated framework of multi-satellite and muti-sensor precipitation estimation and hydrologic validation.

Overall Project Methodology
To meet the overall project objective, this project was divided into three stages:
Stage 1: Integrate TRMM data into a multi-satellite framework to provide satellite-derived rainfall estimates at the high temporal resolution required for hydrologic forecasting.

Stage 2: Integrate the multi-satellite rainfall estimates into a multi-sensor framework to optimally merge data from satellites, radars, and rain gauges.

Stage 3: Evaluate the impact of the resulting multi-satellite, multi-sensor rainfall estimates and their components by evaluating their impact on hydrologic model simulations.

Original Annual Milestones
The original annual milestones for all three stages are:

Stage 1: Integrate TRMM data into a multi-satellite framework

1. Year 1: (NESDIS/STAR) Accumulate real-time and archive TRMM data and SCaMPR input data (geostationary and microwave satellite data) dating back to 2002.
2. Year 1: (NESDIS/STAR) Evaluate the impact of both TMI and TRMM PR data on SCaMPR performance via data withholding experiments. Evaluate the relative impact of

these data at full resolution versus spatially aggregating them to the 15-km footprint of the SSM/I and AMSU-B input data.

Stage 2: Integrate the multi-satellite rainfall estimates into a multi-sensor framework

1. Year 1: (NWS/OHD) Collect hourly and daily co-operative rain gauge data dating back to 2002 for MPE evaluation. Also collect hourly operational rain gauge data and DPA from WSR-88D for the study period for multi-sensor precipitation estimation.
2. Year 2: (NWS/OHD) Incorporate the SCaMPR products into the satellite-radar-rain gauge multi-sensor framework and perform data denial experiments over the WGRFC region.
3. Year 2: (NWS/OHD) Generate the MPE product suite and carry out validation using rain gauge data.

Stage 3: Evaluate the impact

1. Year 3: (NWS/OHD) Design hydrologic model experiments with various QPE forcings.
2. Year 3: (NWS/OHD) Assess parametric uncertainties in the hydrologic models.
3. Year 3: (NWS/OHD) Adopt/Adapt/Develop a post-processing framework to reduce hydrologic model uncertainty.
4. Year 3: (NWS/OHD) Carry out hydrologic validation experiments and generate results.

Actual Accomplishments for Year 2

Stage 1: Integrate TRMM data into a multi-satellite framework

As mentioned in the Year 1 report, it took longer than anticipated to determine the optimal framework for incorporating TRMM data into the satellite rainfall algorithm, and the impact has been les than expected. Additional delays resulted from unanticipated bug fixes and limitations in the computing resources available for processing long periods of SCaMPR data. As of this date the SCaMPR control and TRMM-version data have been delivered to OHD for the periods 2001-2004 and 2006-2007. The data from 2005 should be delivered by the end of June; the data from 2000 (note that the beginning of the analysis period was moved back from 2002 to 2000) should be delivered by the end of August, depending on the processing efficiency of the CLASS archive from which we are ordering GOES data for the retrospective SCaMPR runs.

As mentioned in the Year 1 report, the final configuration used TRMM data in SCaMPR in two ways:

1. Using the TMI data to bias-adjust the target SSM/I and AMSU data prior to calibration by matching their histograms. The anticipated benefit would be to reduce the bias in SCaMPR by reducing the bias in the target rainfall data.
2. Aggregating the TMI and PR data to the spatial resolution of the SSM/I and AMSU rain rates (for consistency) and adding them to the target data set.

The final impact of the TRMM data on the July 2007 test data set when comparing to Stage IV radar / gauge data was to reduce the wet bias in SCaMPR; however, the impact on the correlation with these data was negligible. More details on the performance of SCaMPR with and without TRMM are given below.

Stage 2: Integrate the multi-satellite rainfall estimates into a multi-sensor framework
This stage is on schedule and has met all Year 1 Milestones. Daily and hourly gauge data (HADS, ASOS and COOP) were retrieved for all of Texas covering the period 2000-2007, and quality assurance was performed on all of these data using corresponding Stage III / MPE data and neighboring gauges. The final data set contains ~1.5 million daily records (of which ~360,000 are nonzero) and ~11.5 million valid hourly records (of which ~570,000 are nonzero). In addition, OHD also obtained a set of rain gauge records from Lower Colorado River Authority (LCRA) to be used as independent ground validation data.

The year 2 Milestones were only partially accomplished due to aforementioned delays in Stage 1. The accomplished tasks include the following. First, OHD configured the multi-sensor precipitation estimator (MPE) to allow ingest of SCaMPR products, and processed the gauge and digital precipitation array (DPA) data needed for multi-sensor merging. OHD performed limited validation of SCaMPR data (with and without TRMM ingest) against the rain gauge data and provided feedback to NESDIS. OHD subsequently performed multi-sensor experiments using existing SCaMPR data (for 2000, 2004-7), and obtained locally bias-adjusted SCaMPR data which were evaluated using LCRA gauge data that were not included in the multi-sensor merging. Evaluation of satellite-radar-gauge merged products and data blocking experiments are delayed to Year 3 due to an error in the DPA database.

An analysis of the SCaMPR 1-hour totals against the LCRA gauge data for the year 2007 is shown in Table 1, including a comparison against the River Forecast Center Multisensor Precipitation Estimator (RFC-MPE), the current operational Hydro-Estimator (HE) satellite rainfall algorithm, the control version of SCaMPR, SCaMPR with TRMM added (SCaMPR-TRMM), and SCaMPR-TRMM with the locally bias-adjusted version of SCaMPR mentioned previously (LSAT-TRMM). It shows that from the perspective of overall volume bias and correlation coefficient, SCaMPR represents an improvement over the Hydro-Estimator, though as expected it does not perform nearly as well as the combined radar-gauge RFC-MPE product. Adding the TRMM data to SCaMPR has a negligible effect on the correlation coefficient but does reduce the dry bias of SCaMPR by roughly one third. The local gauge bias correction further reduces the SCaMPR dry bias and has a slight positive impact on the correlation.

Table 1. *Volume bias and correlation coefficient against hourly rain gauges for the RFC-MPE and four different satellite algorithms for all of 2007.*

Rainfall Estimate	Volume Bias Ratio	Correlation Coefficient
RFC-MPE	0.93	0.87
HE	0.75	0.30
SCaMPR	0.81	0.32
SCaMPR-TRMM	0.87	0.32
LSAT-TRMM	0.92	0.33

Figure 1 illustrates the bias performance of the rainfall estimates by comparing their amount fractiles to those of the LRCA hourly gauges: values above the 1:1 line indicate a wet bias, while

values below indicate a dry bias. As expected, RFC-MPE is nearly unbiased; unfortunately, SCaMPR exhibits a strong conditional dry bias that is only partially alleviated by the addition of TRMM data. The local bias correction further alleviates this conditional dry bias (and also reduces a slight wet bias for SCaMPR for extremely light rainfall amounts), but does not remove it completely.

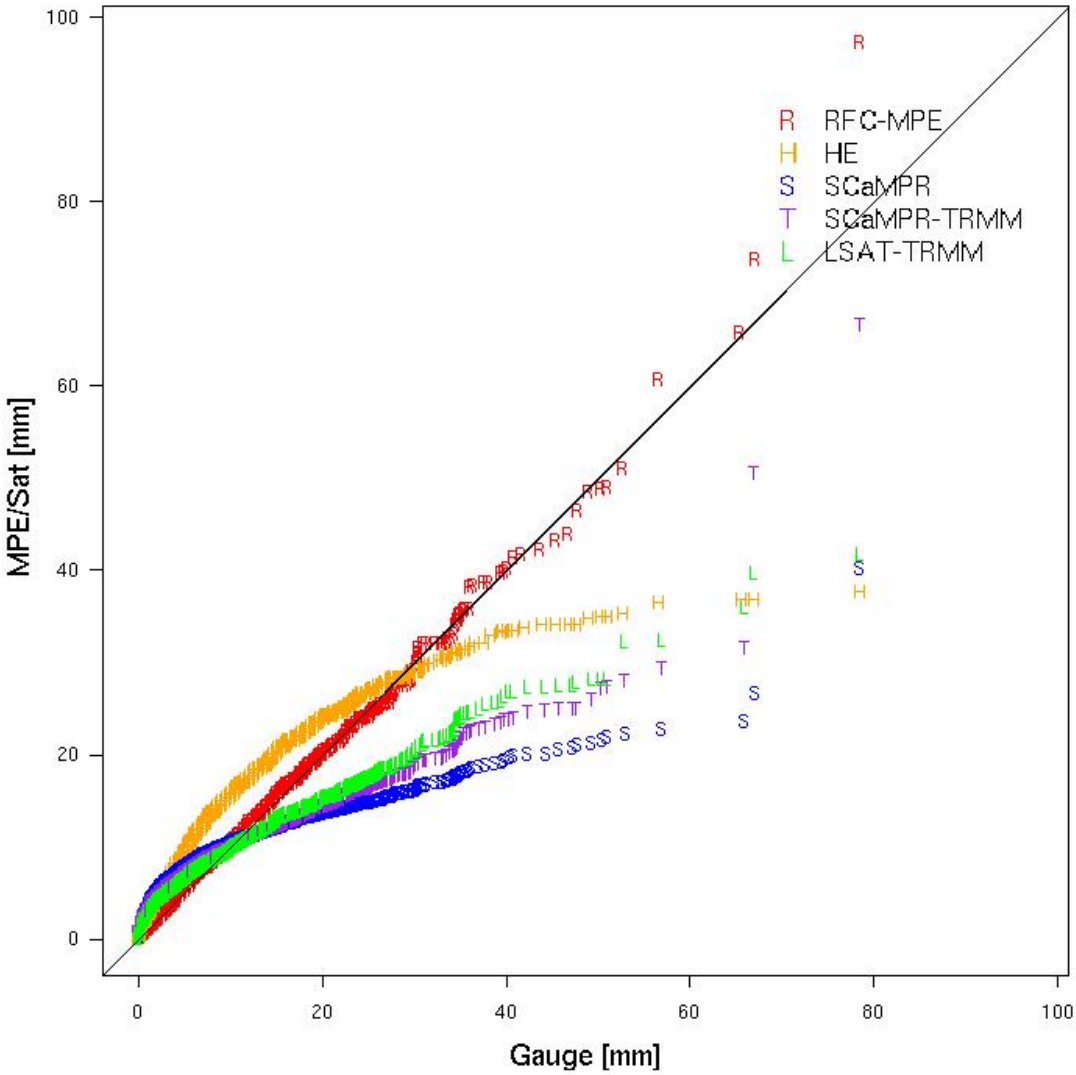

Figure 1. *Quartile plot of rainfall estimates versus hourly rain gauges for all of 2007: values in the upper left indicate a wet bias, while values in the lower right indicate a dry bias.*

Expected Accomplishments for Year 3

The project is approximately six month behind schedule at this point; however, the funding received should be sufficient to complete the work. Therefore, it is anticipated that the original year 2 Milestones will be completed during the first half of Year 3, and that the Year 3

milestones will be completed during the remainder of Year 3 and during a 6-month period afterward that again is not anticipated to entail any additional costs.

PMM Working Groups
In addition to performing the duties outlined in the proposed work plan, the PI also participated in the Hydrologic Science and Applications Working Group and has become a member of the Multi-Satellite Analysis Working Group.

Conference Presentations
Bob Kuligowski presented a poster entitled "Evaluating the Potential use of TRMM Precipitation Products in Operational Hydrology through Multi-Satellite and Multi-Sensor Quantitative Precipitation Estimation (QPE)" at the PMM Science Team Meeting in Ft. Collins, CO on August 4-7, 2008.

Budget

Year 1

Subcontracts/Subawards	**Budget**	**Actual**
STAR Contractor	$75 K	$75 K
OHD Contractor (see Attachment)	$ 9 K	$9 K
Travel		
2007 PMM Science Team Meeting, Atlanta	$ 2 K	$2 K
Facilities and Administrative	$8 K	$8 K
Total Estimated Costs	**$94 K**	**$94 K**

Year 2

Subcontracts/Subawards	**Budget**	**Actual**
OHD Contractor	$43 K	$43 K
UCAR scientists	$24 K	$24 K
2008 PMM Science Team Meeting, Fort Collins	$2 K	$2 K
Other		
Page charges: SCaMPR paper	$2 K	$0 K
Facilities and Administrative	$22 K	$20 K
Total Estimated Costs	**$93 K**	**$91 K**

Year 3

Subcontracts/Subawards	**Budget**	**Actual**
OHD Contractor	$9 K	
UCAR scientists	$80 K	
2009PMM Science Team Meeting, Salt Lake City	$2 K	
Other		
Page charges: multi-sensor paper	$2 K	
Page charges: hydrologic validation	$2 K	
Facilities and Administrative	$29 K	
Total Estimated Costs	**$124 K**	