GOESR3 Periodic Reporting

Reporting Period: January 2018 – June 2019 (2nd half of FY18 funding cycle)

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Project Title: **Probabilistic precipitation rate estimates from GOES-R for hydrologic applications**
Project Number: 424

Executive Summary

The high-resolution and low-latency of GOES-R observations is essential for the monitoring and prediction of floods and flash floods, specifically in the Western United States where the vantage point of space can complement the degraded weather radar coverage of the NEXRAD network. The GOES-R rainfall rate algorithm will yield deterministic quantitative precipitation estimates (QPE). Accounting for inherent uncertainties will further advance the GOES-R QPEs that will be improved through the new bands, higher resolution, and basic algorithmic improvements. With quantifiable error bars, the rainfall estimates can be more readily fused with ground radar products and incorporated into ensemble hydrologic forecast applications. On the ground, the high-resolution NEXRAD-based precipitation products from the Multi-Radar/Multi-Sensor (MRMS) system, which is now operational in the National Weather Service (NWS), provides QPEs suited for flash flood monitoring and forecasting. However, NWS operations are challenged across the intermountain West due to a lack of suitable coverage of operational weather radars over complex terrain. An opportunity exists to combine the observations from GOES-R and MRMS to provide seamless, high-resolution and low-latency precipitation estimates across the CONUS. The goal of this research project is to derive consistent, accurate and fine-resolution precipitation rates with uncertainties over the CONUS. An already created MRMS-based precipitation database will provide an independent and consistent reference to document, analyse and design GOES-R QPE over a broad sample of precipitation situations. GOES-R precipitation estimates will be matched to the MRMS-based rainfall database in order to derive and analyse distributions of QPE uncertainties associated with the GOES-R deterministic retrievals. The probabilistic model mitigates biases compared to the deterministic GOES-R QPE and quantifies the associated uncertainty. It provides the basis for the generation of GOES-R precipitation ensembles suitable to 1) merge with MRMS-based probabilistic QPEs from ground radar-based algorithms already developed to advance multisensor QPE integration (Kirstetter et al. 2015a) and 2) serve as input to a framework being developed in an already funded project for probabilistic flash flood prediction across the U.S. (Gourley et al., 2013, 2016). The product will be further tested in an operational environment in order to improve its use for weather and water forecasting.

Progress toward FY18 Milestones

The fourth half-year of the project has been devoted to investigating probabilistic relations between GOES-16 observations and surface precipitation derived from MRMS in preparation of GOES-16 probabilistic precipitation estimates. The completed milestones are on-track with the project schedule. Note that new efforts not initially planned are underway to improve GOES-16 derived QPE.
A database matching GOES-16 observations and the independent MRMS-based precipitation reference has been used to perform an error budget between SCaMPR and MWCOMB (MWCOMB is the satellite-based precipitation product used to train SCaMPR). SCaMPR and MWCOMB have been analyzed with systematic attention to rainfall detection, and quantification. It was shown that SCaMPR has significant

challenges in detecting precipitation and providing accurate precipitation magnitudes, which is partly traced back to MWCOMB. A paper is in prepratation on this work.
Directions for improvement have been discussed and our effort shifted towards improving GOES-16 derived QPE in collaboration with Dr. Kuligowski. Preliminary probabilistic QPE relations for GOES-16 have been established for rainfall detection and quantification (see Fig. 3). Probabilitic GOES-16 QPE shows improved precipitation estimation performances with respect to SCaMPR and MWCOMB (Table 1).

Plans for Next Reporting Period

During the next period, we will improve the probabilistic retrievals and finalize the derivation of new probabilistic relations conditioned on precipitation types to improve the GOES-16 precipitation retrievals (Figure 3). Current matching is underway between GOES16 ABI observations and MRMS surface precipitation at the actual ABI resolution. Besides invetigating the impact of precipitation types, improvement will also focus on the detection and quantification of precipitation. We started to investigate the benefit of accounting for the GOES16 ABI temporal resolution. Results will be communicated and close coordination with NOAA GOES-16 scientists and collaborators will proceed so that additional factors can be investigated if deemed necessary. This work will be presented at the American Geophysical Union Fall Meeting in December 2019.

Additional Information

1. Interaction with operational partners –

- Exchanges with collaborator R. Kuligowski (NOAA/NESDIS/STAR)
- Telecons with the Hydrology Initiative working group (Ralph Ferraro)
- Discussion with the MRMS team for possible transition to operation.

2. Conference/workshop participation –

- European Geosciences Union General Assembly 2019, Vienna, Austria, Apr. 7-12, 2019.
- 12th International Precipitation Conference - IPC12, Irvine, California, U.S., June 19 - 21, 2019

3. Outside project publicity –

- Hydrology Initiative working group (Ralph Ferraro)
- NCAR.

4. Journal articles –

- Kirstetter, P.E., N. Karbalaee, K. Hsu, Y. Hong, 2018: Probabilistic Precipitation Rate Estimates with Space-based Infrared Sensors. *Quarterly Journal of the Royal Meteorological Society*, 1–15. doi: 10.1002/qj.3243

This paper demonstrates the concept of probabilistic precipitation rate estimates with space-based geostationary infrared sensors similar to GOES-16.

- Upadhyaya, S., P.E. Kirstetter et al.: A Systematic Error Budget on Spaceborne Passive Microwave and Geostationnary Precipitation Estimates. *Journal of Hydrometeorology, in preparation*.

Key Graphics

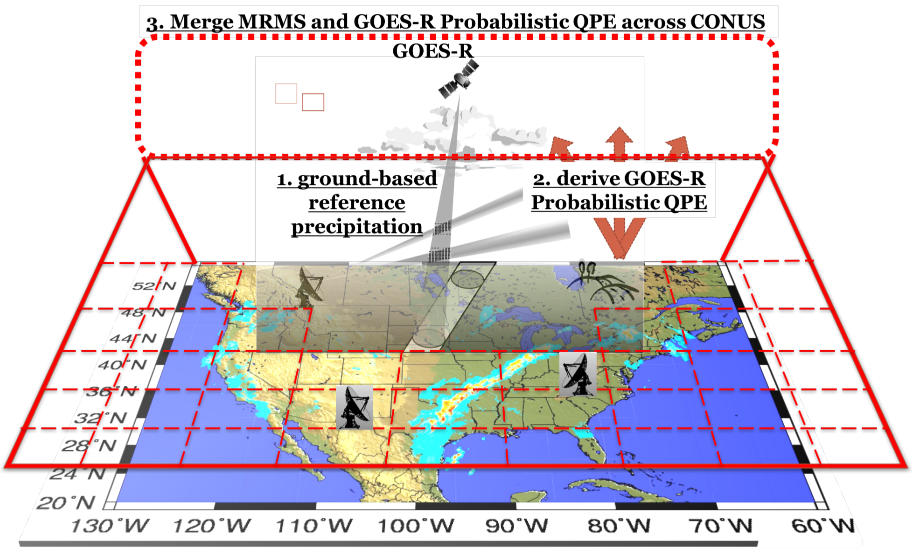

Figure 1: Research framework and overview flowchart of the project.

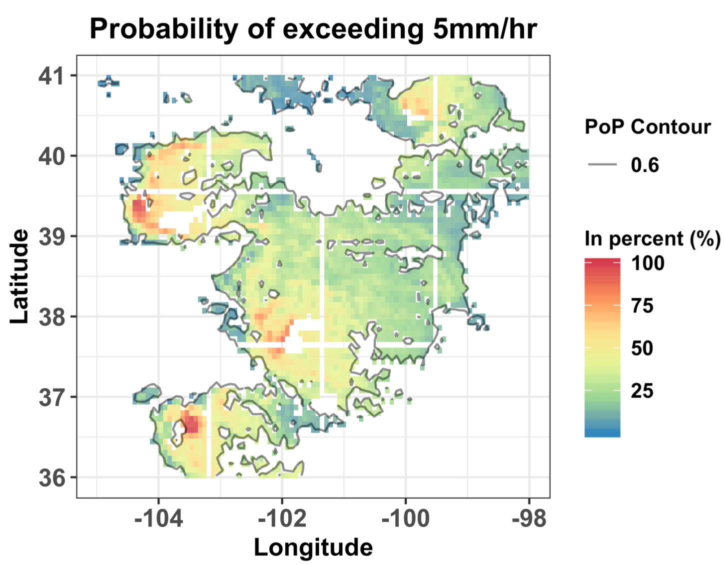

Figure 2: Preliminary GOES-16 probabilistic precipitation retrievals with the probability of exceeding 5 mm/h from GOES-16 observations on 07/30/18 at 2:45pm UTC. The continuous black line shows the Probability of Precipitation (PoP) 0.6 isocontour.

Detection	MWCOMB	SCaMPR	PQPE – GOES16
HSS	0.49	0.35	0.55

Quantification	MWCOMB	SCaMPR	PQPE – GOES16
CC	0.41	0.32	0.49
RMSE (mm/h)	5.63	4.95	4.1
Bias (mm/h)	+1.10	-0.78	+0.12
Mean Relative Error (%)	+41.5	-28.8	+3.6

Table 1: Preliminary quantitative assessment of MWCOMB, SCaMPR, and GOES-16 probabilistic precipitation retrievals with respect to the MRMS-based independent precipitation reference. The best performances are indicated in red. To evaluate detection performances the Heidke Skill Score (HSS) score is used. To assess quantification performances the following scores are used: correlation coefficient (CC), root-mean-square error (RMSE), Bias, and Mean Relative Error.

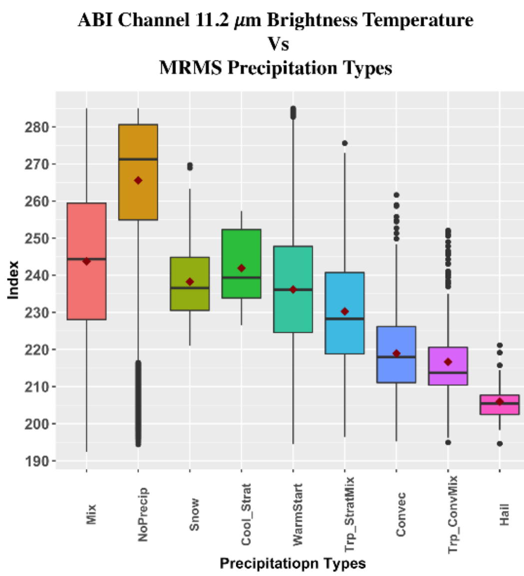

Figure 3: Boxplot analysis of GOES-16 observations at 11.2 μm as a function of MRMS precipitation types. The differences between boxplots for different precipitation types suggests ABI observations can be used to identify precipitation types associated with different microphysics and precipitation rates.