NOAA ROSES Semi-Annual Report

Reporting Period: September 2021 – February 2022 (3rd report)

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Project Title: Probabilistic Quantitative Precipitation Estimation with Geostationary Satellites

Executive Summary

Progress in precipitation estimation is critical to advance weather and water budget studies and prediction of natural hazards caused by extreme rainfall events from local to global scales. The low latency and high space/time resolution from geostationary satellites (e.g. GOES-16/17, Himawari-8) are essential for monitoring and predicting precipitation processes occurring over short space and time scales and driving hydrometeorological hazards. Hydrometeorological applications require more than just one deterministic precipitation "best estimate" to adequately cope with the intermittent, highly skewed distribution that characterizes precipitation. As geostationary quantitative precipitation estimation (QPE) is currently deterministic, we propose to advance the interpretation of GOES-16/17 observations for hydrometeorological applications with the use of probability as an integral part of QPE. The overarching goal of this research project is to leverage reliable ground-based radar Multi-Radar/Multi-Sensor (MRMS) quantitative precipitation applications to geostationary missions and synergize CONUS-wide GOES-16/17 precipitation enhancement. We will explore the use of GOES-16/17 ABI multiple spectral bands and high space/time resolution through spatial and temporal textures. Probability distributions of precipitation rates will be established using models quantifying the relation between ABI observations and the corresponding "true" precipitation from MRMS. Probabilistic QPE (PQPE) mitigates systematic biases from deterministic retrievals and quantifies uncertainty for hydrologic applications and advances the monitoring of precipitation extremes with remote sensing. It provides the basis for multisensory integration across GOES-16, GOES-17, and MRMS through quantified uncertainties to optimally merge PQPEs. PQPEs can be more readily fused with MRMS ground radar products for seamless precipitation estimation over CONUS, specifically in the western United States where the vantage point of space can complement the degraded weather radar coverage of the NEXRAD network. It opens perspectives for improved estimation of precipitation at multiple scales, hydrological prediction, and risk monitoring.

Progress toward FY21 Milestones and Relevant Findings

1. Generated and tested probabilistic precipitation retrievals with machine learning techniques using multiple spectral bands and high space/time resolution through spatial and temporal textures (Figure 1).
2. Started testing the precipitation retrieval algorithm in quasi real-time settings to identify a trade-off between model complexity/accuracy and retrieval efficiency. The purpose is to perform a probabilistic retrieval over the CONUS within 5-min. The framework and GOES-

16 data flows (satellite predictors) have been set up. Environmental parameter flows (RAP predictors) are being set up.

3. One manuscript has been conditionally accepted in *Quarterly Journal of the Royal Meteorological Society*: Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, M. Searls, 2021: Towards Improved Precipitation Estimation with the GOES16 Advanced Baseline Imager: Algorithm and Evaluation. Reviewers are positive and stress (1) the retrieval performances (i.e, accuracy) and (2) the improved understanding on the relation between the satellite-based and model-based predictors and the precipitation rate. Another manuscript is submitted to IEEE *Geoscience and Remote Sensing Letters*.
4. A presentation of the project has been made to the MRMS team.
5. GOES-16 – GV-MRMS matchups have been generated at 30-min timescale over Summer 2018 and at 2-min timescale over Summer and Winter 2020; After iterating with collaborator R. Kuligowski, match-ups with GOES-17 observations are not considered at this time.

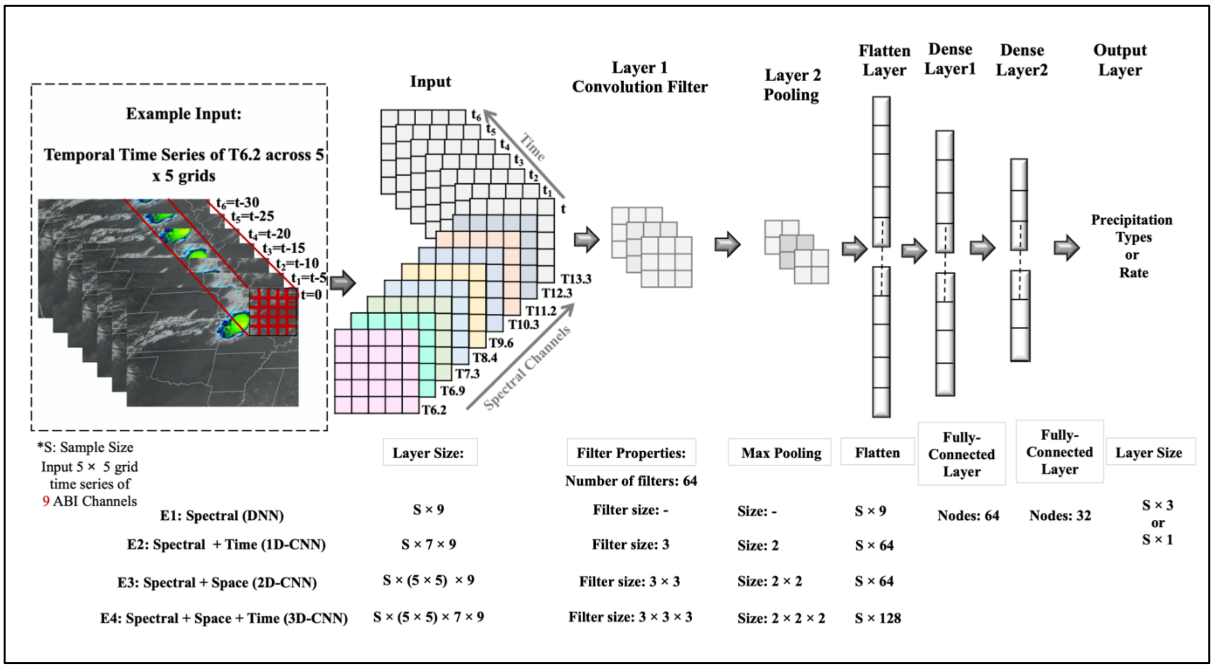

Figure 1. 3D-Convolution Neural Network to utilize high spatial, temporal and spectral resolution observations from the GOES-16 / ABI sensor

The quantification model is based on probabilistic machine learning. An example of PQPE products is shown in Figure 2. Deterministic precipitation estimates such as the PQPE expectation (Figure 2a) can be used along with uncertainty estimates (Figure 2b). Monitoring precipitation extremes with probabilities of exceeding thresholds is enabled with PQPE to address one of the major needs for real-time QPE (Figure 2c and d).

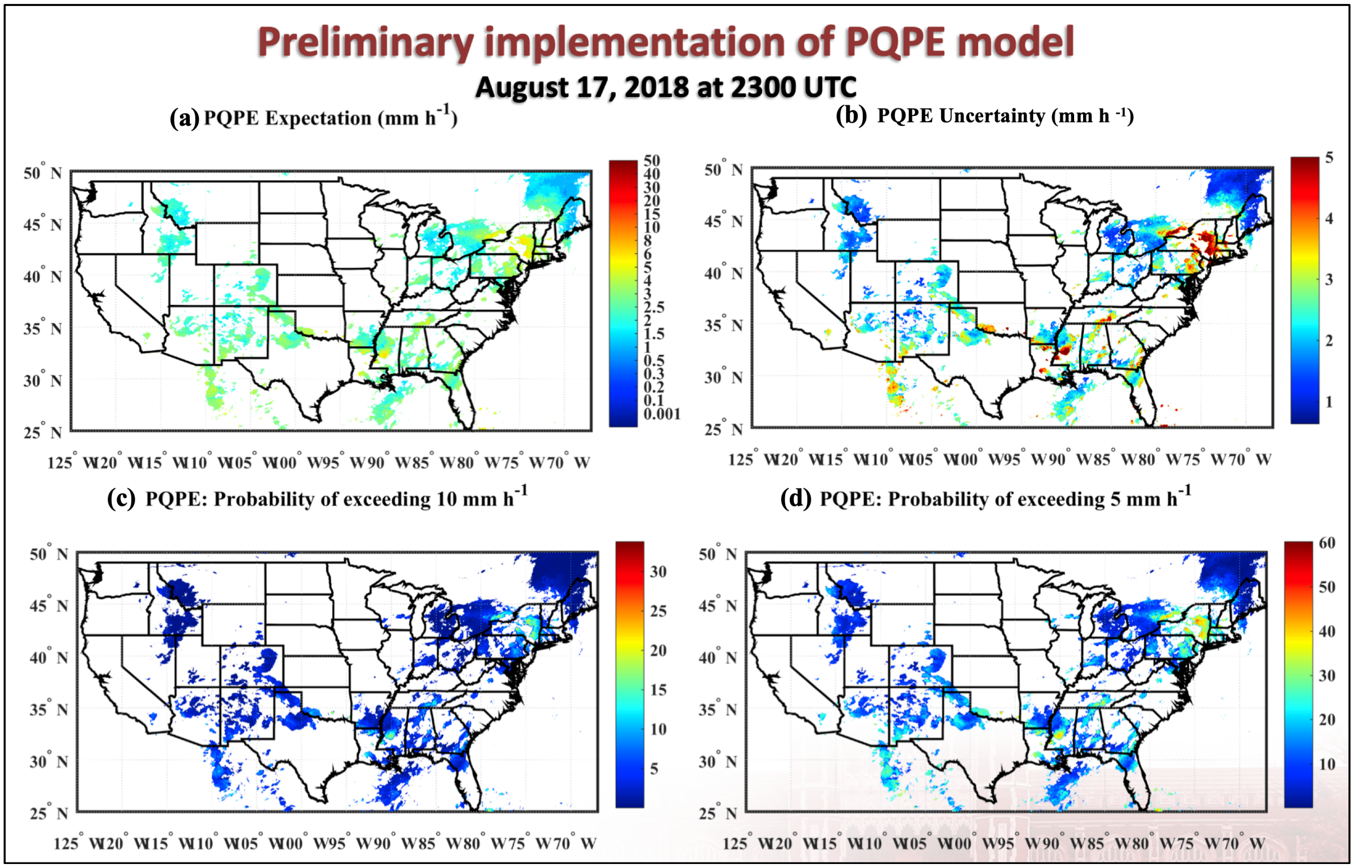

Figure 2. PQPE model products: (a) expectation; (b) uncertainty; (c) probability of exceeding 10 mm.h^{-1}; (c) probability of exceeding 5 mm.h^{-1}.

Manuscript conditionally accepted:

1. Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, M. Searls, 2021: Towards Improved Precipitation Estimation with the GOES16 Advanced Baseline Imager: Algorithm and Evaluation. *Submitted to Quarterly Journal of the Royal Meteorological Society*.

Manuscript Submitted:

1. Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, M. Searls, 2021: Exploring the Value of Temporal Changes for Estimating Precipitation from Space with Convolutional Neural Networks. *Submitted to IEEE Geoscience and Remote Sensing Letters*.

Plans for Next Reporting Period

1. Test real-time precipitation retrievals.
2. Refine probabilistic precipitation retrievals for GOES-16. Focus will be on probabilistic precipitation detection to tackle the most challenging problem of false detections. The retrieval of a Proportion of Precipitation Occurrence (PoP) variable allows to target the rain / no-rain transition.
3. Other AI/ML approaches such as multi-task learning will be explored to develop more computationally efficient PQPE models.