NOAA ROSES Semi-Annual Report

Reporting Period: March 2021 – August 2021 (2nd report)

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Project Title: Probabilistic Quantitative Precipitation Estimation with Geostationary Satellites

Executive Summary (1 paragraph max)

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 FY20 Milestones and Relevant Findings (with any Figs)

1. 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;
2. An interpretable machine learning model has been set up for precipitation type classification. Two manuscripts have been published in *Quarterly Journal of the Royal Meteorological Society*;

3. A Machine Learning model (Random Forest) for quantification with GOES-16 ABI has been developed and compared SCaMPR. A manuscript is finalized for submission;
4. The impact of rapid-refresh GOES-16 observations is explored on QPE. A manuscript is finalized for submission;
5. Started building GV-MRMS-GOES17 matchup datasets;
6. Developed preliminary probabilistic precipitation retrievals for GOES-16 by using predictors identified in previous work.

The quantification model is based on random forest (RF) machine learning. It is compared with SCaMPR (SC) across different U.S. climate regions that are broken down into land vs. coastal areas and into flat vs. complex terrain. An example of comparison in terms of Probability of detection is shown in Figure 1. The degradation of precipitation delineation across the western CONUS is due to the degrading ABI resolution and the complex terrain environment. The impact is higher on SC than on RF.

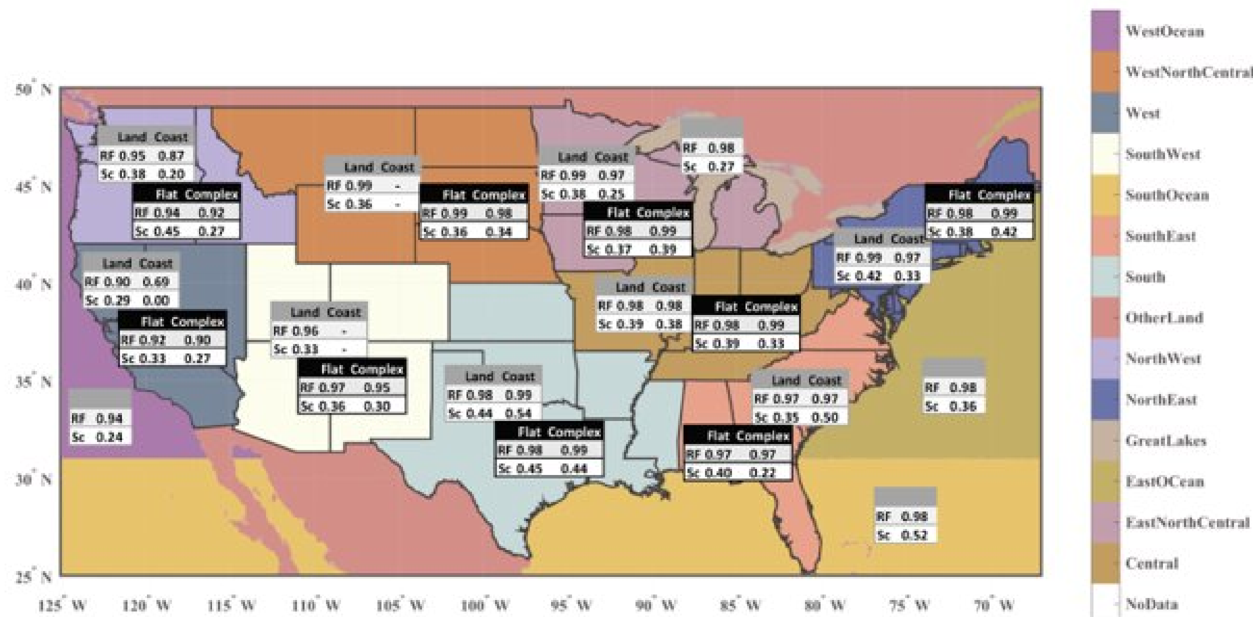

Figure 1. Probability of detection for Random Forest (RF) and SCaMPR(SC) across different climate regions and broken down into land vs. coast areas and flat vs. complex terrain.

While GEO satellites uniquely provide frequent updates, this strength has been underexplored for QPE. Rapid-refresh GOES-16 observations are used to extract relevant information using advanced machine learning techniques for QPE. The developed QPE retrieval shows promising results with improved correlation coefficient (0.41) compared to SC (0.34). Incorporating temporal information better separates rapidly evolving cloud systems that produce heavy rainfall from more uniform stratiform precipitation. This study is significant as it shows how estimates of lower rain rates and the detection of stratiform precipitation can be improved by using the temporal information from GEO sensors.

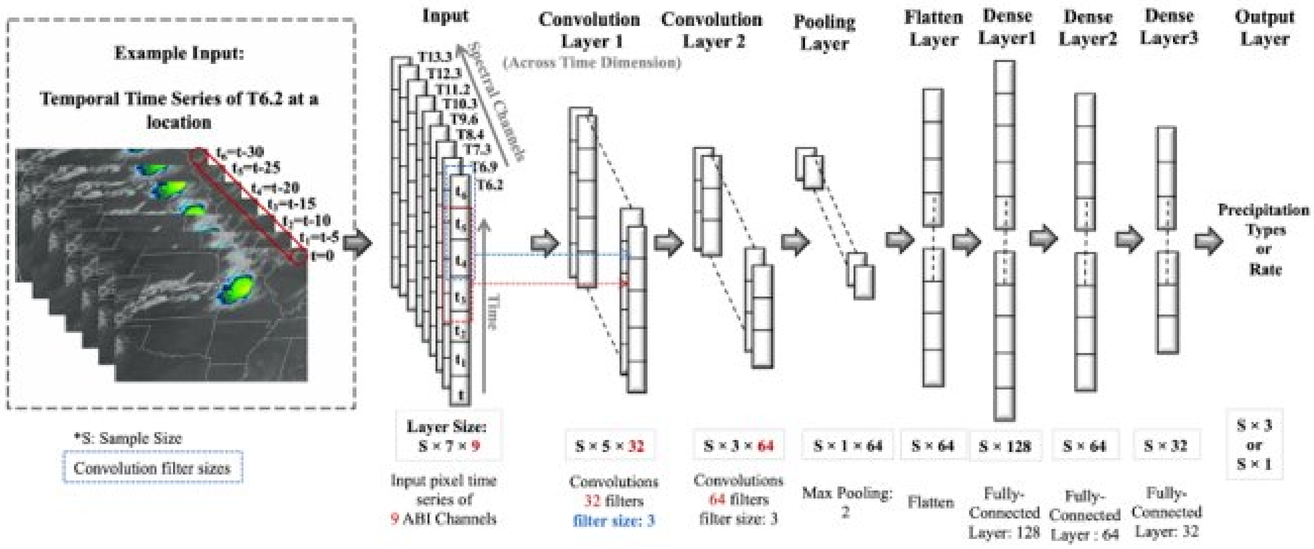

Figure 2. 1Dimensional Convolutional Neural Network Architecture for precipitation type classification and quantification.

Manuscripts published:

1. Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, J. Gourley, H. Grams, 2021: Classifying precipitation from GEO Satellite Observations: Part I- Prognostic Model, *Quarterly Journal of the Royal Meteorological Society*, **147**(739), 3394– 3409. Doi: 10.1002/qj.4134
2. Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, M. Searls, 2021: Classifying precipitation from GEO Satellite Observations: Part II- Diagnostic Model, *Quarterly Journal of the Royal Meteorological Society*, **147**(739), 3318– 3334. Doi: 10.1002/qj.4130

Plans for Next Reporting Period

1. Build GV-MRMS-GOES17 matchup datasets;
2. Refine probabilistic precipitation retrievals for GOES-16;
3. Submit two manuscripts:
    a. Upadhyaya, S., P.E. Kirstetter, R. Kuligowski, M. Searls, 2021: Towards Improved Precipitation Estimation with the GOES16 Advanced Baseline Imager: Algorithm and Evaluation. *To be submitted to QJRMS - Undergoing internal review at NOAA/NESDIS*.
    b. 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. *To be submitted to GRL - Undergoing internal review at NOAA/NESDIS*.