Operational Transition to the Enterprise GOES-R Rainfall Rate Algorithm

Robert J. Kuligowski, Center for Satellite Applications and Research, College Park MD
Yaping Li, I.M. Systems Group, Rockville, MD

What Does the GOES-R Rainfall Rate Provide?

- Retrievals of instantaneous rain rates..
  - …over the ABI full disk (but only validated for satellite zenith angle < 70°, latitude < 60 °)
  - …at a spatial resolution of the ABI IR bands (2 km at nadir)
  - …updated every 10 minutes (Mode 6) or 15 min (GOES-17 Mode 3)
  - …with a production delay of less than 4.5 minutes.
- Rain rates are derived from IR water vapor (WV) and window bands using relationships that are based on calibration against microwave rain rates
- The current operational algorithm will be replaced with an improved "Enterprise" version (currently expected in November 2020).

What Will Change with the Enterprise Version?

Current Operational Version (Kuligowski 2010)	Enterprise Version
Calibrated one time against NWS/CPC combined microwave (MWCOMB) data set (Joyce et al. 2004): • Discriminant analysis to select predictors and coefficients for rain / no rain discrimination. • Stepwise forward linear regression on the raining MW pixels to choose predictors and coefficients for rain rate retrieval. • Histogram matching adjusts the distribution of the retrieved rain rates to match MWCOMB	Same calibration procedure, but updated hourly to capture time variations in the relationships between the predictors and MW rain rates.
Three cloud types, based on brightness temperature differences (BTDs) between IR bands: • "Water cloud": $T_{7.34}<T_{11.2}$ and $T_{8.5}-T_{11.2}<-0.3$ K • "Ice cloud": $T_{7.34}<T_{11.2}$ and $T_{8.5}-T_{11.2}\geq-0.3$ K • "Cold-top convective cloud": $T_{7.34}\geq T_{11.2}$	Fourth cloud type added for when the GOES-17 ABI Focal Plane Module (FPM) heats up. For this "type", only band 14 (11.2 µm) and derived parameters is used. The reason: BTDs from the GOES-17 ABI are very noisy even when the FPM is relatively cool.
Separate calibrations for 30° latitude bands to account for spatial variability in rainfall climatology.	Smaller 15x15° lat / lon calibration regions better account for spatial variability in rainfall climatology. (Kuligowski et al. 2016)
Eight possible predictors, selected empirically from all possible ABI IR channels and channel differences; each predictor regressed against MW rain rates in log-log space to produce eight additional nonlinearly transformed predictors.	Added band 14 and its nonlinear transformation to the predictor list for all classes.
No adjustment evaporation of precipitation below cloud bottom.	Adjusts for evaporation of precipitation below cloud bottom using relative humidity (RH) values from the GFS. (Kuligowski et al. 2016)
No parallax adjustment.	Adjusts for parallax based on cloud-top heights derived by comparing limb-adjusted band 14 brightness temperatures to GFS temperature-height profiles.

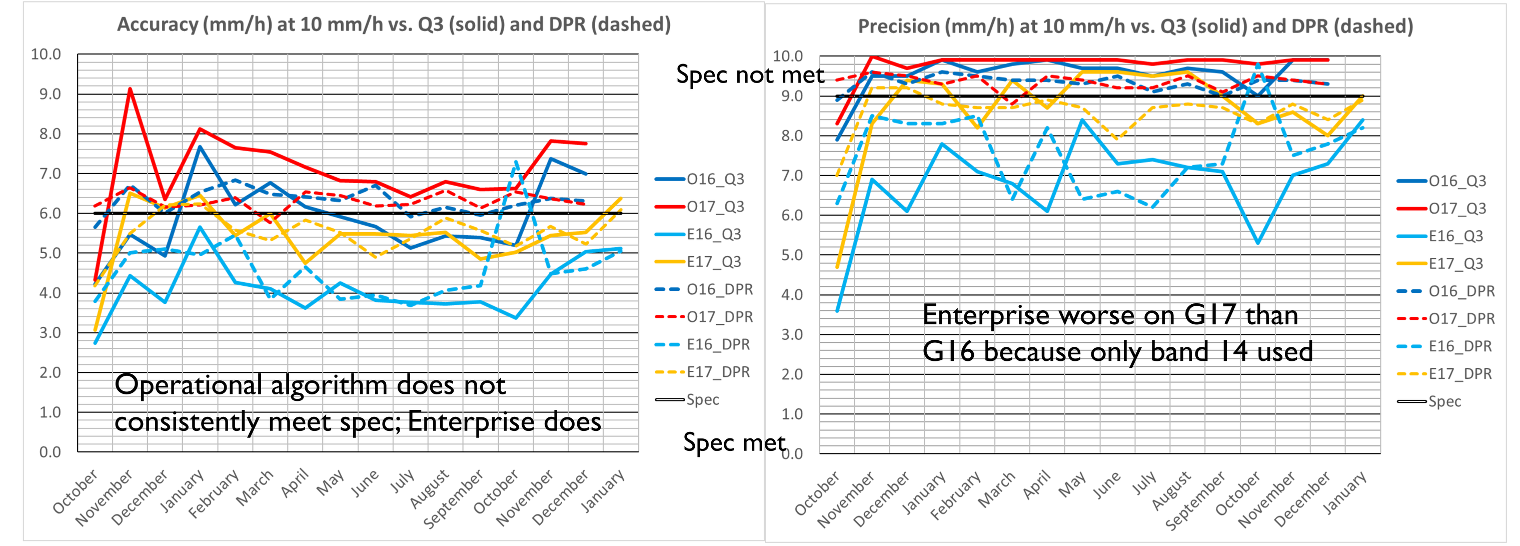

Figure 1. Monthly time series of performance vs. spec for the operational ("O", dark shades) and Enterprise ("E", light shades) rain rates vs. MRMS Q3 (solid lines) and GPM DPR (dashed lines) for GOES-16 and -17 from October 2018 – January 2020. Accuracy is mean error for retrieved rates of 10 mm/h; precision is 68th percentile of error for retrieved rates of 10 mm/h.

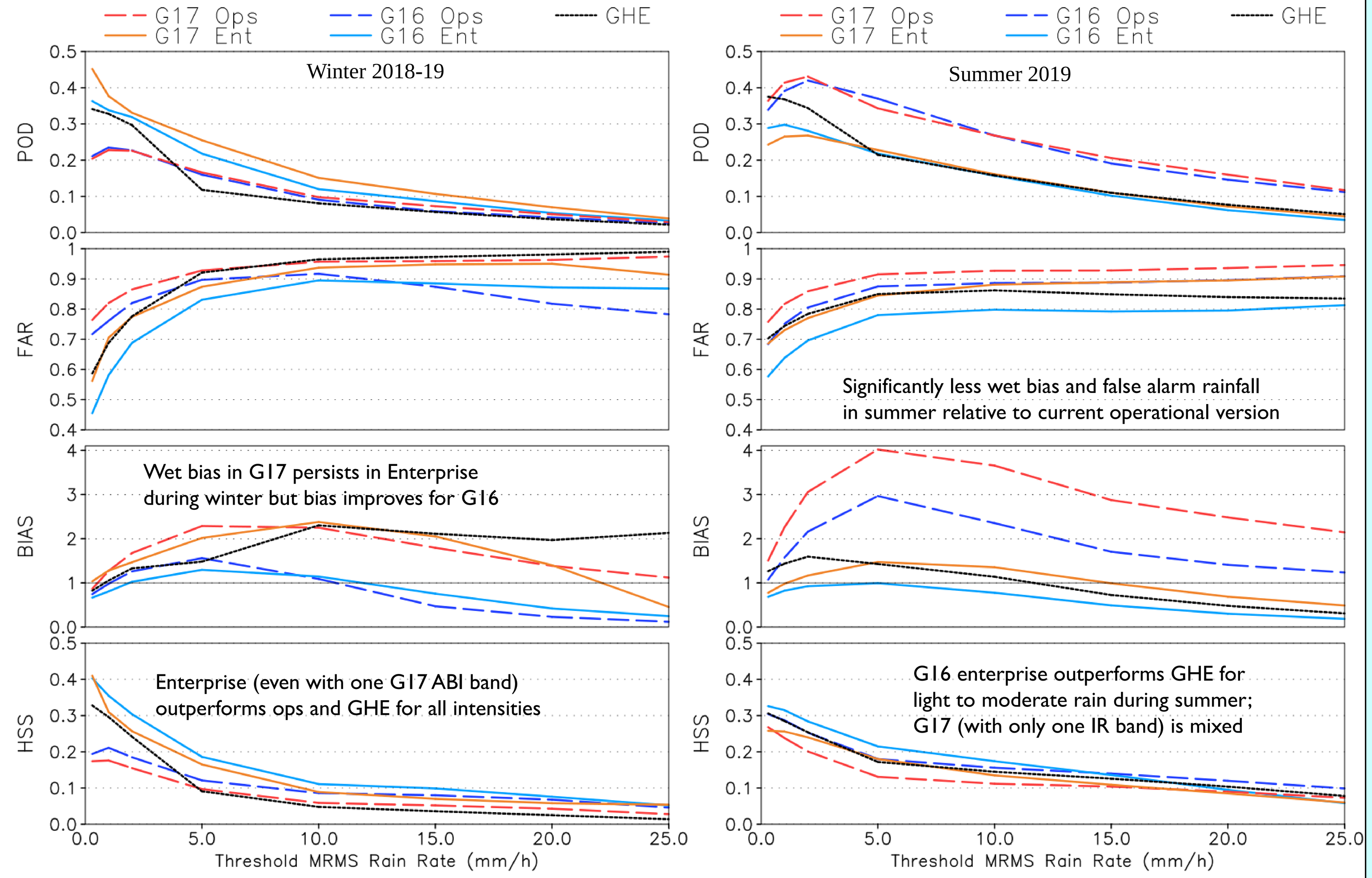

Figure 2. Probability of Detection (POD), False Alarm Rate (FAR), area bias ratio (BIAS), and Heidke Skill Score (HSS) vs. MRMS Q3 for the operational ("Ops") and Enterprise ("Ent") versions of the algorithm compared to the current operational Global Hydro-Estimator ("GHE") for DJF 2018-19 (left) and JJA (right) 2019.

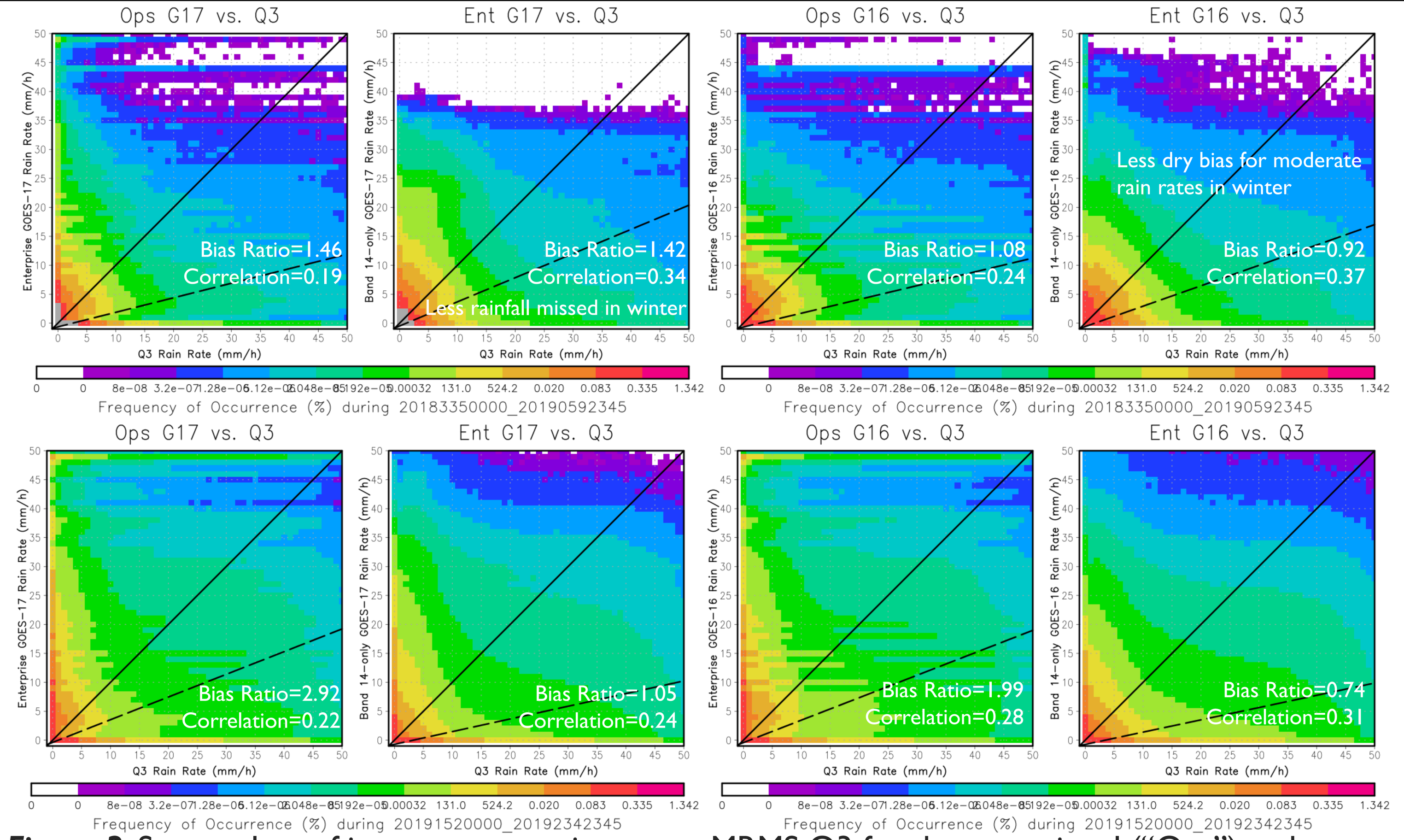

Figure 3. Scatterplots of instantaneous rain rate vs. MRMS Q3 for the operational ("Ops") and Enterprise ("Ent") rain rates for GOES-17 (left) and GOES-16 (right) for DJF 2018-19 and JJA 2019 (bottom). The dashed line is the best-fit regression line; the solid line is the 1:1 line.

Is the Enterprise Version Better?

- The algorithms are being validated against gauge-adjusted Multi-Radar Multi-Sensor (MRMS) Q3 over the CONUS and against Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar (DPR) over the full disk.
- The operational algorithm does not meet spec, but the Enterprise version consistently does for GOES-16 and mostly does for GOES-17 despite using only band 14 (Fig. 1).
- The Enterprise algorithm improves over the current operational version and the previous-generation Global Hydro-Estimator (GHE), particularly during the cool season (Fig. 2) and especially for GOES-16.
- Using only band 14 on GOES-17 degrades performance somewhat relative to GOES-16, particularly in the form of a strong wet bias for moderate to heavy precipitation during the cool season (Fig. 2).
- Rain rates from the Enterprise algorithm have better correlation and generally less bias than the current operational version (Fig. 3).

What Happens Next?

- Lightning (GLM) data will be added to improve the depiction of convective cores that are obscured by cirrus anvils.
- The matches between the IR and MW rain rates will be improved by using individual MW rain rate swaths in place of MWCOMB, which will allow the MW rain rates to be adjusted for parallax and allow closer matches in time with ABI IR.
- The RH adjustment will be improved--it currently reduces moderate to heavy rain rates too much (Figs. 2 and 3).
- The algorithm may start using at lease some fixed, AI-based calibration if it significantly outperforms the current calibration(see poster #8 next door)
- Will continue trying to develop / incorporate an adjustment with orography. However, existing schemes generally degrade skill because the enhanced / reduced rain rates are in the wrong places when validated at fine scales.

Who Paid for All This?

This work was supported by the GOES-R Program Office.

Whose Work Did We Cite Here?

Joyce, R. J. et al., 2004: CMORPH: A method that produces global precipitation estimates from passive microwave and infrared data at high spatial and temporal resolution. *J. Hydrometeor.*, **5**, 487-503.

Kuligowski, R. J., 2010: *GOES-R Advanced Baseline Imager (ABI) Algorithm Theoretical Basis Document for Rainfall Rate (QPE).* Available at https://www.star.nesdis.noaa.gov/goesr/documents/ATBDs/Baseline/ATBD_GOES-R_Rainrate_v2.6_Oct2013.pdf

-----, Y. Li, Y. Hao, and Y. Zhang, 2016: Improvements to the GOES-R Rainfall Rate algorithm. *J. Hydrometeor.*, **17**, 1693-1704.