THE GOES-R RAINRALL RATE PRODUCT: STATUS AND PLANS

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Algorithm Description

Rainfall Rate Algorithm Background

- Requirements: instantaneous rain rates every 15 min over the full disk at full infrared (IR) spatial resolution with latency of 4 min, 26 sec.
- Rain rates are more strongly related to microwave (MW) brightness temperatures than to IR brightness temperatures but cannot meet the latency requirement, so an IR algorithm is calibrated against MW rain rates.
- The selected algorithm is SCaMPR = Self-Calibrating Multivariate Precipitation Retrieval (Kuligowski 2010; Kuligowski et al. 2016).

Algorithm Calibration

- Calibrated against the NWS/CPC combined microwave (MWCOMB) (Joyce et al. 2004), which mosaics all available MW rain rates and bias-adjusts them against GMI.
- MWCOMB rain rates are matched with IR brightness temperatures aggregated to the 8-km MWCOMB grid.
- Separate calibrations for 3 different cloud types that have significantly different relationships between $T_{11.2}$ and MWCOMB rain rate:
  - "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": $T_{7.34}\geq T_{11.2}$
- Separate calibrations for 30° latitude bands to account for variability in rainfall climatology.
- A set of 8 predictors was selected empirically from all possible IR channels and channel differences; each is regressed against MW rain rates in log-log space to produce eight additional nonlinearly transformed predictors.

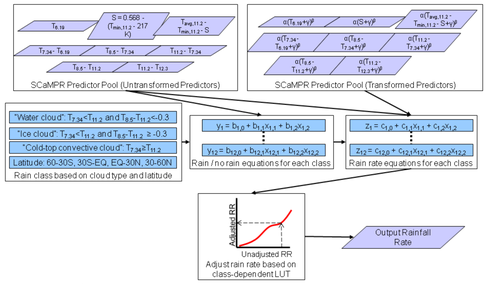

Figure 1. GOES-R Rainfall Rate processing diagram.

Algorithm Calibration (cont.)

- Three calibration steps (Fig. 1):
  - Discriminant analysis selects 2 of the 8 available linear predictors and calibrates rain / no rain discrimination.
  - Stepwise forward linear regression on the raining MW pixels selects 2 of the 16 available predictors (including nonlinear) and calibrates rain rate retrieval.
  - Histogram matching adjusts the distribution of the retrieved rain rates to match MWCOMB.
- Calibration should be updated hourly but fixed calibration is used in operations.

Results of Operational Algorithm Validation

Validation Period, Data Sets, Measures

- Validation period: 1 March – 30 June 2017 (4 months)
- Two ground validation data sets:
  - Global Precipitation Measurement (GPM) Dual-Polarization Radar (DPR) rain rates (Ku band only) over the full disk
  - Multi-Radar Multi-Sensor (MRMS) gauge-adjusted instantaneous rain rate fields over the CONUS
- Primary goal is to evaluate performance against spec:
  - Accuracy=absolute mean bias in mm/h. Requirement is 6 mm/h for rates of 10 mm/h, so values are computed only using pixels with GOES-16 rain rates between 9.5 and 10.5 mm/h.
  - Precision=68th percentile of absolute error in mm/h. Requirement is 9 mm/h for rates of 10 mm/h, so values are computed using only pixels with GOES-16 rain rates of 9.5-10.5 mm/h.
  - Spatial displacements cause significant errors at pixel scale, so, the closest value of the validation data within a 15-km radius is matched to the GOES-16 rain rate pixel.

Validation Findings

- The Rainfall Rate product does not meet spec when validated against either gauge-adjusted MRMS or DPR (Table 1).
- Performance varies with geographic location, and is spec is generally met at lower latitudes and not in higher latitudes (Figs. 2 and 3).

	Spec	vs. MRMS	vs. DPR
Accuracy (mm/h)	6.00	6.84	7.83
Precision (mm/h)	9.00	9.58	9.73

Table 1. Accuracy and precision at 10 mm/h for the operational GOES-16 rain rates vs. MRMS and DPR for 1 March-30 June 2017 compared to spec.

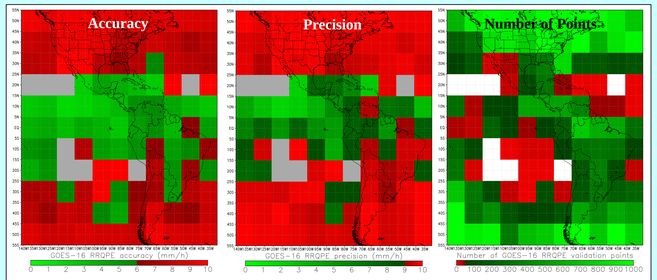

Figure 2. Accuracy (left), precision (center) at 10 mm/h and number of contributing data points (right) for the operational GOES-16 rain rates vs. DPR for 1 March-30 June 2017 for 10x10° lat/lon boxes. Accuracy and precision boxes meeting spec are green and boxes not meeting spec are red. Red boxes on the right had fewer than 50 data points for the calculation; white boxes had no data.

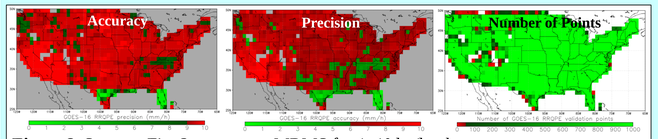

Figure 3. Same as Fig. 2, except vs. MRMS for 1x1° lat/lon boxes.

Causes and Remediation Strategy

Causes

- The original GOES-R Rainfall Rate algorithm was developed using METEOSAT-8 Spinning Enhanced Visible Infra-Red Imager (SEVIRI) data as a proxy for the ABI and thus had to be validated over the SEVIRI coverage area.
- Since the accuracy and precision requirements are for instantaneous rates, the primary validation data set was the Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR), against which it met spec.
- TRMM PR covers only 35°S to 35°N. NIMROD radar composites over Western Europe were also used for validation and though the GOES-R rain rates did not meet spec, it was presumed to be because of known quality issues with the radar data.
- However, GOES-16 rainfall product often shows significant false rainfall at higher latitudes (Fig. 4).
  - This was caused largely by cold IR brightness temperatures in clear air that were exacerbated by the limb cooling rather than clouds (note that Lakes Winnipegosis and Winnipeg affect the rain rates in Fig. 4 so they cannot be obscured by clouds).
  - These represent the vast majority of retrieved rain rates of 9.5-10.5 mm/h and thus dominate the calculations of accuracy and precision.
  - This was not a significant problem when evaluating over Western Europe; however, the evaluation version updated its calibration every hour while the operational version uses fixed calibration coefficients which may exacerbate the problem.

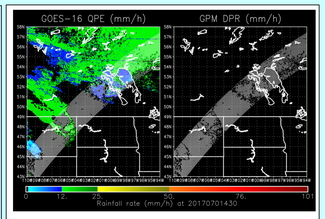

Figure 4. Operational GOES-16 rain rates (left) compared to GPM DPR rain rates (right) at 1430 UTC 11 March 2017.

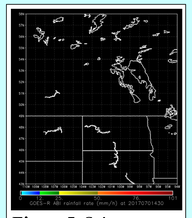

Figure 5. Science Code rain rates from GOES-13/15 at 1430 UTC 11 March 2017.

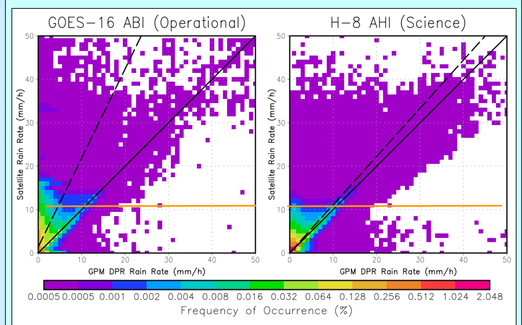

Figure 6. Scatterplots of satellite vs. DPR rain rates for the operational algorithm on the ABI (left) and the science algorithm on the AHI (right) for March-June 2017. Horizontal orange lines indicate the rain rates used to compute the performance statistics; solid black line is 1:1 and dashed black line is best regression fit.

Remediation

- The operational algorithm was coded using an Algorithm Theoretical Basis Document from 2010.
- Significant improvements have been made since then (Kuligowski et al. 2016):
  - Reducing the size of the calibration regions from 30° latitude bands to 15x15° lat/lon boxes improves calibration consistency and reduces limb effects;
  - Removing false / excessive rainfall based on the mean-layer relative humidity (RH) from the Global Forecast System (GFS);
  - Adjusting for parallax using the GFS temperature-height profiles to convert IR temperatures to cloud-top heights.
  - As a result, the science version run on GOES-13/15 does not have the false high-latitude rainfall from Fig. 4 even though it uses only 2 IR bands (Fig. 5).
- This improved algorithm meets spec when applied to Himawari-8 Advanced Himawari Imager (AHI) data and validated against DPR; for the same 4-month period the accuracy of the AHI retrievals was 4.55 mm/h (vs. 6 mm/h); precision was 8.07 mm/h (9 mm/h). The difference in performance is illustrated in Fig. 6.
- Validation of this algorithm for GOES-16 is ongoing but similar results are anticipated.

Remediation (cont.)

- Because of these issues, at the Peer-Stakeholder Product Validation Review (PS-PVR) on 23 May 2017, the Rainfall Rate / QPE algorithm was declared "Provisional Beta" rather than fully Beta until remediation steps could be identified.
- In response, the original code is being modified and re-run for a one –month period (June 2017) to determine the impacts of the individual modifications on algorithm performance:
  - Dynamic calibration, updated weekly and daily
  - RH adjustment
  - Reduction of size of calibration regions to 15x15° lat/lon
- These findings will be used to prioritize modifications to the algorithm processing to meet spec prior to the Provisional PS-PVR in late 2017.

References

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