

Improvements to the GOES-R Rainfall Rate Algorithm

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- GOES-R Rainfall Rate Algorithm Description
- Recent Improvements and Impacts
- Future Work



GOES-R Background

- GOES-R begins the next generation of NOAA geostationary satellites
- Launch currently scheduled for early 2016
- Advanced Baseline Imager (ABI) with enhanced imaging capability compared to current GOES:
 - 16 spectral bands instead of 5
 - Spatial resolution of 0.5-2 km instead of 1-4 km
 - Full-disk scan in 5 min instead of 30
- Also will carry an 8-km optical Geostationary Lightning Mapper (GLM)



Rain Rate Algorithm Background

- Estimates instantaneous rain rate every 15 min on the ABI full disk at the IR pixel resolution (~ 2 km) with a latency of <5 min from image time.
 - Primary focus: operational flash flood forecast support
- Retrieves rain rates from the ABI IR bands, calibrated against rain rates from MW.
- Allows the rapid refresh / high spatial resolution of IR data from GEO while attempting to capture the accuracy of MW rain rates from LEO.



Calibration: Matched MW-IR Data

- GOES IR calibration uses on a rolling-value matched MW-IR dataset of 15,000 pixels with rates ≥2.5 mm/h, which is updated whenever new MW rain rates become available.
 - MW rain rates are from the CPC combined MW (MWCOMB) dataset





Calibration: Cloud Types

- Divide pixels into three types:
 - » Type 1 ("water cloud"): $T_{7.34}$ < $T_{11.2}$ and $T_{8.5}$ - $T_{11.2}$ <-0.3 K
 - » Type 2 ("ice cloud"): T_{7.34}<T_{11.2} and T_{8.5}-T_{11.2}≥-0.3 K
 - » Type 3 ("cold-top convective cloud"): T_{7.34}≥T_{11.2}
- Divide pixels by latitude (60-30°S, 30°S-EQ, EQ-30°N, 30-60°N).
- Maintain separate matched data sets and calibration equations for each class (3 cloud types x 4 latitude bands = 12 classes)



Calibration: GOES Predictors

 Use data from 5 ABI bands (6.19, 7.34, 8.5, 11.2, and 12.3 µm) to create a total of 8 predictors:

T _{6.19}	T _{8.5} - T _{7.34}
S = 0.568*(T _{min,11.2} -217 K)	T _{11.2} - T _{7.34}
T _{avg,11.2} - T _{min,11.2} - S	T _{8.5} - T _{11.2}
T _{7.34} - T _{6.19}	T _{11.2} - T _{12.3}

» (Note that these predictors were selected from a much larger initial set)



Calibration: Nonlinear Predictor Transformation

 Since the relationship between the IR predictors and rain rates are nonlinear, separately regress each of the 8 predictors against the rainfall rates in log-log space to produce 8 additional nonlinear rain rate predictors; i.e.,

$$x_N = \boldsymbol{a} (x + \boldsymbol{g})^b$$

(the intercept γ is determined via "brute force")



Two Calibration Steps

- Rain / no rain calibration using discriminant analysis and only linear predictors
 - » Optimize Heidke Skill Score (with bias constraint) for up to 2 predictors
- Rain rate calibration using stepwise forward linear regression on all predictors (raining MW pixels only)
 - » Optimize correlation coefficient for up to 2 predictors



Calibration: Distribution Adjustment

- After calibration, match the CDF of the retrieved rain rates against the CDF of the target MW rain rates
- Use the result to adjust the retrieved rain rates to match the target rain rate distribution.





Current-GOES Version

- The current GOES imager has no 8.5 μ m-band, so there are 2 cloud types instead of 3, discriminated using T_{6.7}-T_{11.2}.
- Only four of the original 8 predictors are used since the other four require bands not currently available:

∓ _{6.19} T _{6.7}	
S = 0.568*(T _{min,11.2} -217 K)	∓ _{11.2} ∓ _{7.34} T _{11.2} -T _{6.7}
T _{avg,11.2} - T _{min,11.2} - S	

Running in real time since August 2011.



Current-GOES Version





Significant Issues and Recent Changes

- Problem: Significant amounts of false alarm rainfall
- Cause: No accounting for subcloud evaporation
- Solution: Develop a RH correction by relating the bias in MWCOMB (vs. Stage IV) to RH



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Impact of RH Correction

False Alarms / Observed Rainfall Missed Rainfall / Observed Rainfall 10.0 10.0 9.0 9.0 8.0 8.0 7.0 7.0 6.0 6.0 5.0 5.0 4.0 4.03.0 3.0 2.0 2.0 1.0 1.0 0.0 0.0 GHE GHE SCaMPR SCaMPR-RH SCaMPR SCaMPR-RH

 Impact: False alarms greatly reduced, but some additional missed rainfall



Impact of RH Correction

Correlation Coefficient at 1 h, 4 km



Impact: Improved correlation, much less wet bias



Significant Issues and Major Changes

- Additional problems:
 - 1. Inconsistency between GOES-East and –West rain rates
 - 2. Occasional inconsistency in rain rates from the <u>same</u> GOES from one period to the next
 - 3. Occasional inconsistency in rain rates between deep convective and non-deep-convective clouds
- Causes:
 - » Limb cooling (for #1)
 - » Calibration regions are too large



Significant Issues and Major Changes

- Calibration region size details:
 - » The regression portion of SCaMPR preserves location information, but the distribution adjustment via CDF matching does not.
 - » Consequently, MW rain rates may be matched with SCaMPR rain rates from storms 1000s of km away!

Solution:

- » Reduce the size of the calibration regions from 30° latitude x 120° longitude to 5x5° lat / lon
 - Allowed relaxation of training requirement from 15,000 to 10,000 pixels ≥2.5 mm/h

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Impact of Smaller Calibration Regions (1 of 3)

 Improved consistency between GOES-West and -East
 GOES-East Original



Comparison at 2345 UTC 25 July 2013





Impact of Smaller Calibration Regions (2 of 3)

2. Improved consistency in rain rates from one period to the next

Original Calibration Regions

5x5° Calibration Regions





1445 UTC

1515 UTC



Impact of Smaller Calibration Regions (3 of 3)

3. Improved consistency in rain rates between deep convective and non-deep-convective rainfall





Future Plans

- Currently experimenting with using Q3 as calibration standard over the CONUS instead of / in addition to MWCOMB to improve accuracy.
- Re-calibrate RH correction against Q3 instead of Stage IV (reduces uncertainty from comparing instantaneous MWCOMB with 1-h Stage IV).
- Include rain rates derived from GOES cloud property information and evaluate impact on warm-cloud light rain which IR and MW typically have difficulty detecting.



Summary

- The GOES-R Rainfall Rate algorithm will estimate instantaneous rain rate at the full ABI IR pixel resolution (~2 km) with a latency <5 min from image time, using MW rain rates as a calibration standard.
 Recent improvements include a RH correction to remove spurious rainfall in dry regions and reducing in the size of the calibration regions to make the calibration more consistent.
- Additional improvements are being investigated and will be incorporated into the algorithm code as results warrant it.



Questions?