Application of Himawari-8 AHI Data to the GOES-R Rainfall Rate Algorithm

Yaping Li[1], Robert Kuligowski[2] and Yan Hao[1]

1. IMSG at NOAA/NESDIS/STAR
2. NOAA/NESDIS/STAR, College Park, MD

GOES-R Baseline Products

- Aerosol Detection
- Aerosol Optical Depth
- Clear Sky Masks
- Cloud and Moisture Imagery
- Cloud Optical Depth
- Cloud Particle Size Distribution
- Cloud Top Height
- Cloud Top Phase
- Cloud Top Pressure
- Cloud Top Temperature
- Derived Motion Winds
- Derived Stability Indices
- Downward Shortwave Radiation: Surface
- Fire/Hot Spot Characterization
- Hurricane Intensity Estimation
- Land Surface Temperature (Skin)
- Legacy Vertical Moisture Profile
- Legacy Vertical Temperature Profile
- Radiances
- Rainfall Rate / QPE
- Reflected Shortwave Radiation: TOA
- Sea Surface Temperature (Skin)
- Snow Cover
- Total Precipitable Water
- Volcanic Ash: Detection and Height

Outline

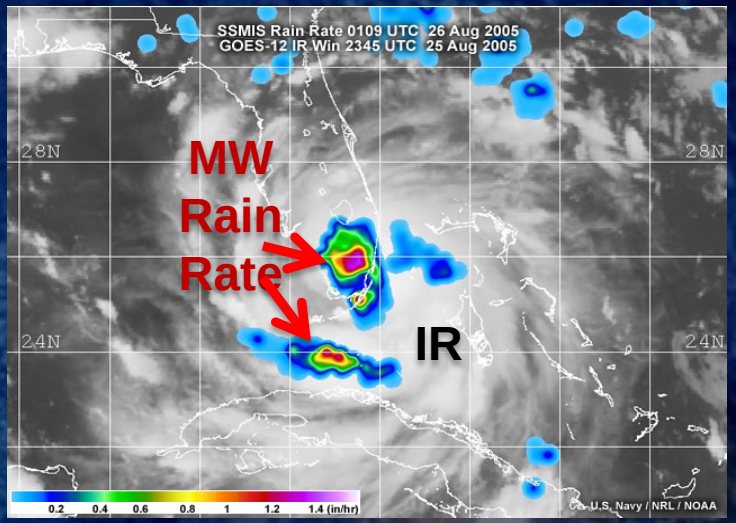
- Introduction of the GOES-R Rainfall Rate Algorithm
- Recent Improvements to the Algorithm
- Preliminary Results of Running the Algorithm on Himawari-8 AHI Data
- Conclusions and Next Step Work

GOES-R Rainfall Rate Algorithm

- GOES-R Rainfall Rate Algorithm estimates *instantaneous* rainfall rate…
  - …every 15 minutes
  - …at the full ABI pixel resolution (2 km at nadir)
  - …with a latency of less than 5 minutes
  - …over the entire full disk

Based on IR and calibrated by MW-derived rain rates

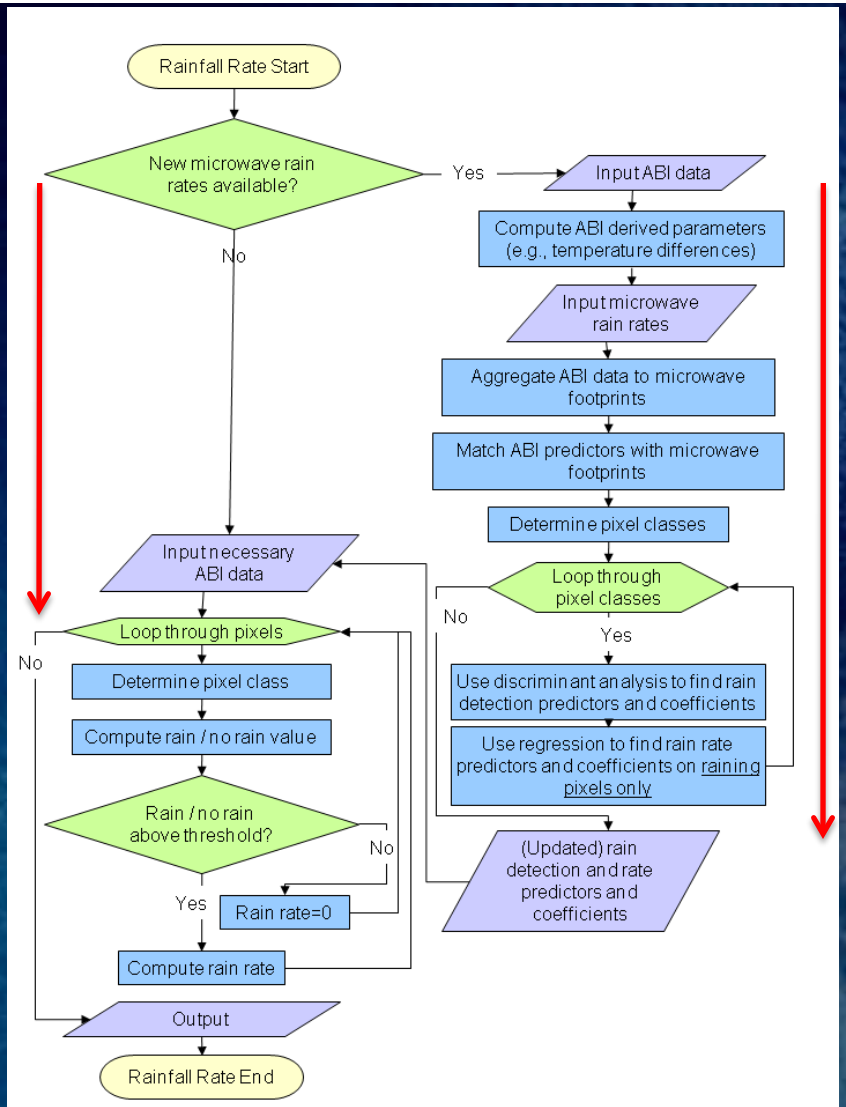
- IR continuously available, but weaker relationship to rain rate
- MW more strongly related to rain rate, but available ~every 3 h
- GOES-R Rainfall Rate Algorithm ***combines these two by using MW-derived rain rates to calibrate IR data to maximize resolution and accuracy***
- Objective: optimal calibration for a particular geographic area, cloud type, and time of year



Algorithm Overview

Apply most recent calibration in between new MW overpasses

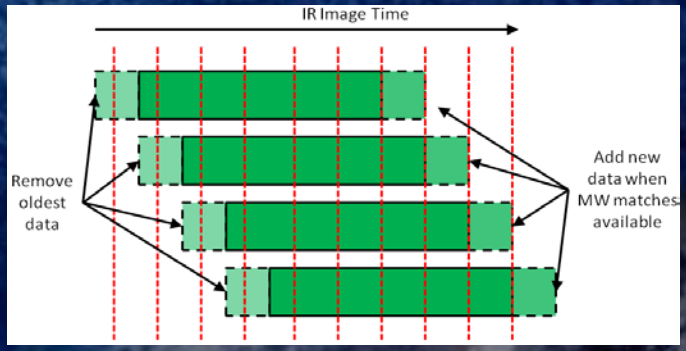
Retrieve rain rates from ABI data



Update calibration when new MW rain rates available

Matched MW-IR Data

- As new MW rainfall rates are received, matched with ABI data (current MW rain rates from the NOAA Climate Prediction Center (CPC) combined microwave (MWCOMB) product that is part of the CPC Morphing (CMORPH) processing)
- The matched data 12 different classes according to:
  - Four latitude regions (60-30^{o}S, 30^{o}S-EQ, EQ-30^{o}N, 30-60^{o}N)
  - Three cloud types:
    - Water-top cloud: $T_{7.34} < T_{11.2}$ and $T_{8.5}-T_{11.2} < -0.3K$;
    - Ice-top cloud: $T_{7.34} < T_{11.2}$ and $T_{8.5}-T_{11.2} >= -0.3K$;
    - Cold-top convective cloud: $T_{7.23} >= T_{11.2}$



- The matched data set is a rolling-value data set—older data are cycled out as newer data are brought in to keep the data set up-to-date. The size of the matched data set is governed by the number of raining pixels.

ABI Predictors

Channel Number	Wavelength (μm)		Resolution (km)	Used in Rain Rate
	ABI	AHI		
8	6.15	6.2	2.0	✓
9	7.0	7.0	2.0	
10	7.4	7.3	2.0	✓
11	8.5	8.6	2.0	✓
12	9.7	9.6	2.0	
13	10.35	10.4	2.0	
14	11.2	11.2	2.0	✓
15	12.3	12.3	2.0	✓
16	13.3	13.3	2.0	

Five ABI bands are used to create predictors

$T_{6.19}$	$T_{8.5} - T_{7.34}$
$S = 0.568-(T_{min,11.2}-217\ K)$	$T_{11.2} - T_{7.34}$
$T_{avg,11.2} - T_{min,11.2} - S$	$T_{8.5} - T_{11.2}$
$T_{7.34} - T_{6.19}$	$T_{11.2} - T_{12.3}$

8 predictors were selected

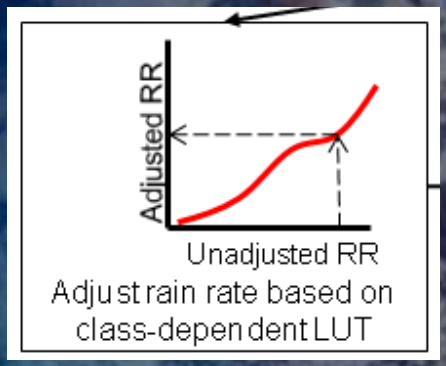
+ 8 additional nonlinear rain rate predictors

Separate rain/no rain and rain rate retrieval Calibration Steps

- discriminant analysis
  → calibrate the rain / no rain discrimination
- stepwise forward regression
  → calibrate the rain rate retrieval
- Histogram matching used to address the inherent strongly skewed distribution of rainfall rates:

Retrieved rain rates —(Map cumulative distribution function (CDF))→ Target MW rain rates → Lookup Tables LUTs

- Use the LUTs to adjust the retrieved rain rates to match the target MW rain rate distribution



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Simplified Current GOES Version

- A simplified version of the Rainfall Rate algorithm has been running on current GOES since August 2011
  - » Coverage: both GOES, 165ºE – 15ºW and 60ºS – 70ºN
- Significantly simplified (only half the predictors)

  (because there are no 8.5 μm and 12.3 μm bands on current GOES)

~~$T_{6.19}$~~ $T_{6.7}$	~~$T_{8.5}$~~ – ~~$T_{7.34}$~~
$S = 0.568-(T_{min,11.2}-217\ K)$	~~$T_{11.2}$~~ – ~~$T_{7.34}$~~ $T_{11.2}$- $T_{6.7}$
$T_{avg,11.2} - T_{min,11.2} - S$	~~$T_{8.5}$~~ – ~~$T_{11.2}$~~
~~$T_{7.34}$~~ – ~~$T_{6.19}$~~	~~$T_{11.2}$~~ – ~~$T_{12.3}$~~

- Only 2 cloud types—no water/ice discrimination → 8 rain classes

Improvement: RH Correction

- **Problem:** *Significant false alarm rainfall in dry regions*
- **Cause:** the evaporation of hydrometeors below cloud base
- **Solution:** Developed a relative humidity (RH) correction based on Global Forecast System (GFS) model
- **Impact**: False alarms greatly reduced, but some additional missed rainfall

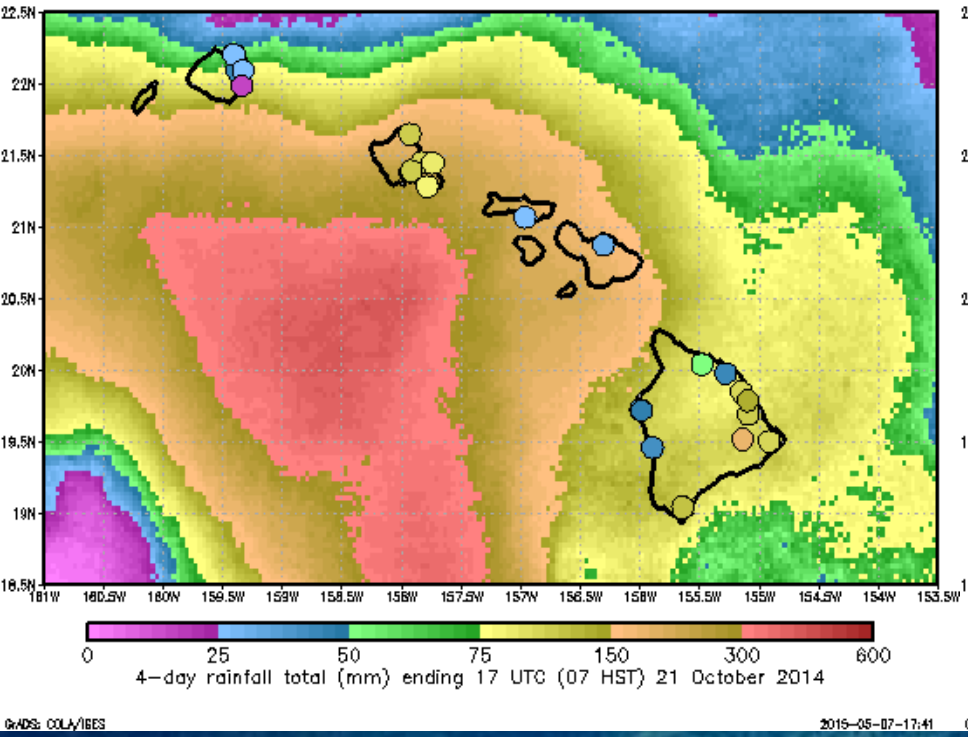
	Bias	RMSE	CC	Thit	Tmiss	Tfalse	Terr
Control	2.385	1.224	0.354	-0.342	0.327	1.386	1.371
w/RH	1.233	0.893	0.374	-0.083	0.399	0.566	0.882

Performance statistics for algorithm with and without the RH correction for 2008-2013

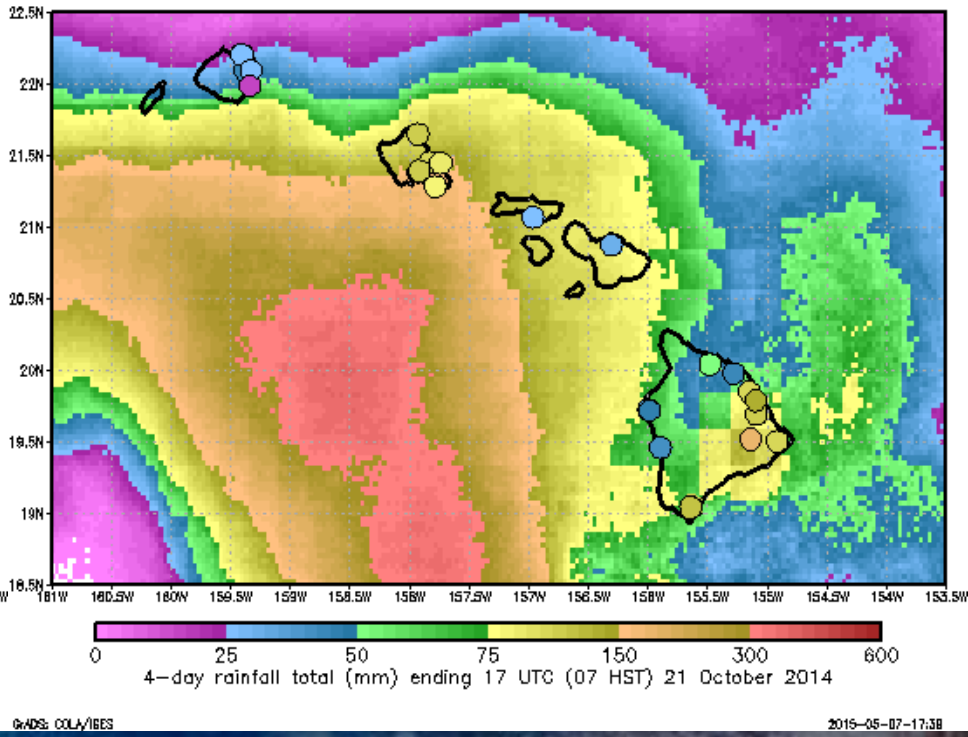
RH Correction for Tropical Storm Ana, 15-19 Oct 2014

Total Rainfall vs. Gauges

No RH Correction



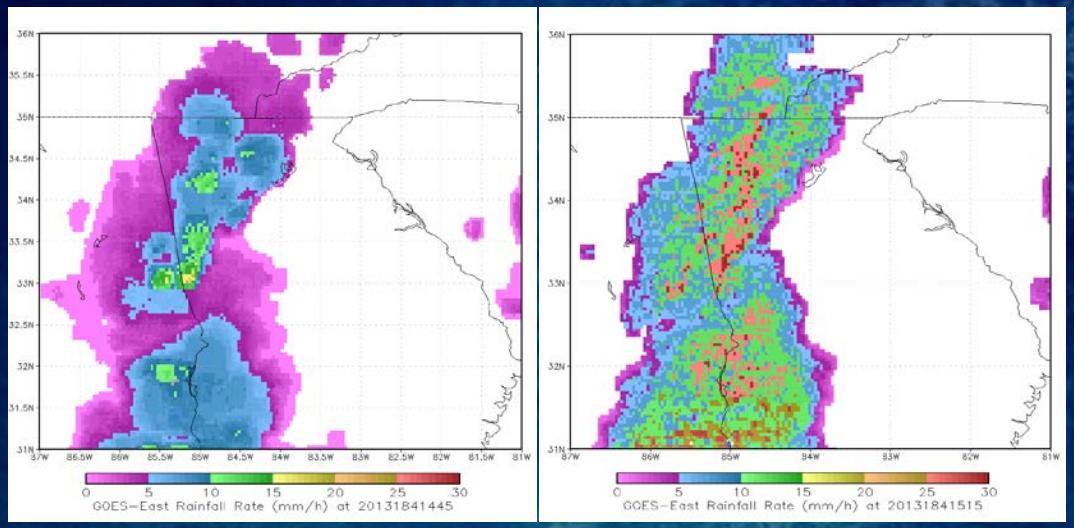
With RH Correction



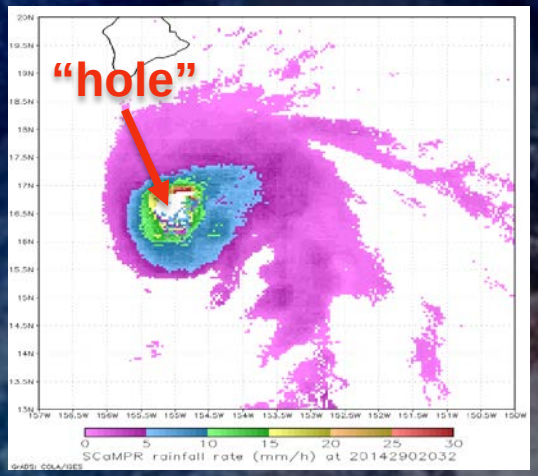
Improvement: Smaller Calibration Regions

- **Problem:** *Occasional inconsistency in retrieved rain rates from one period to the next; Occasional "holes" where the convective and non-convective rain rates were inconsistent with each other*

inconsistency

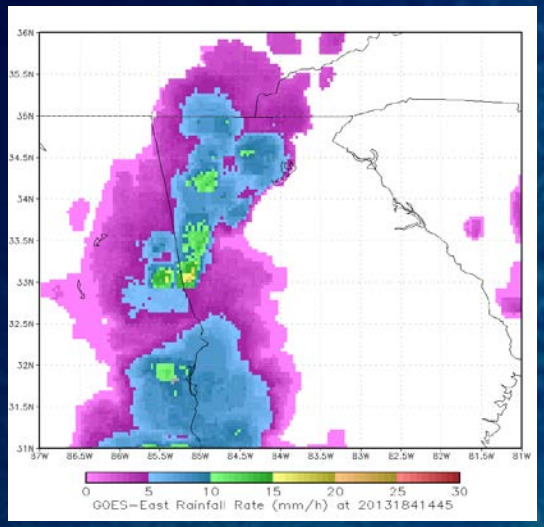


1445 UTC **1545 UTC**



Improvement: Smaller Calibration Regions

- **Cause:** Calibration regions are too large
- **Solution:** Shrank the calibration regions from 30ºx120º latitude / longitude bands to 15ºx15º
- **Impact**: Reduced the overall error by an additional 5%; much more stable calibration (though not perfect); holes dealt with



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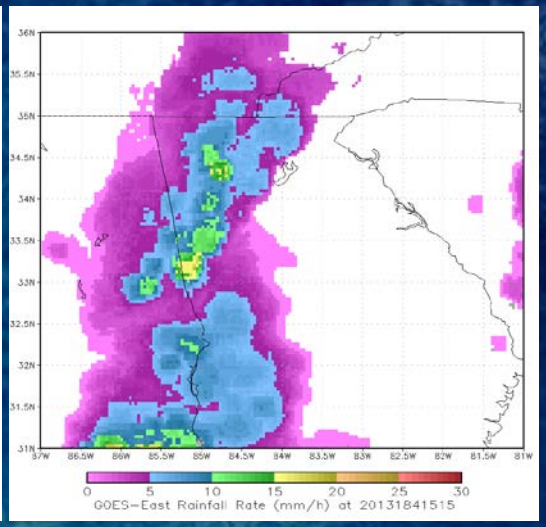
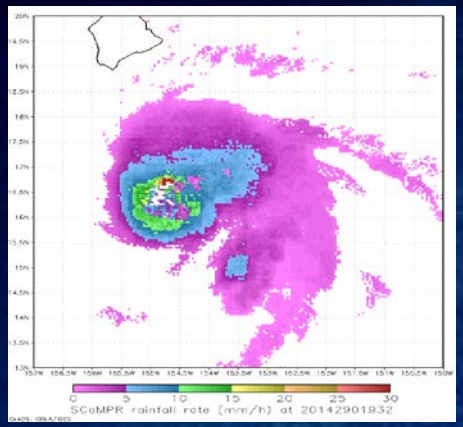
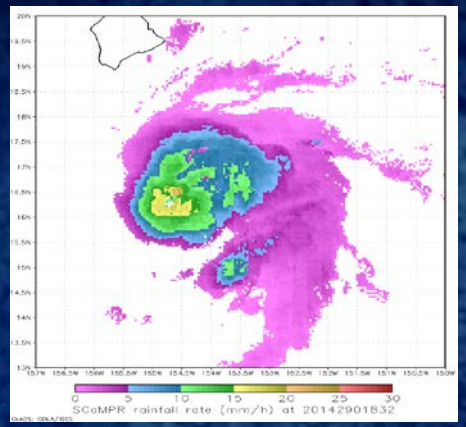


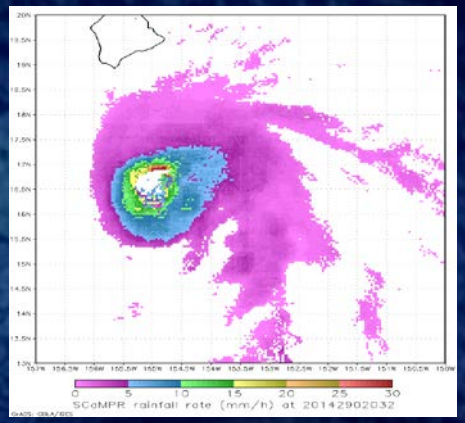
1545 UTC

Tropical Storm Ana, 15-19 Oct 2014

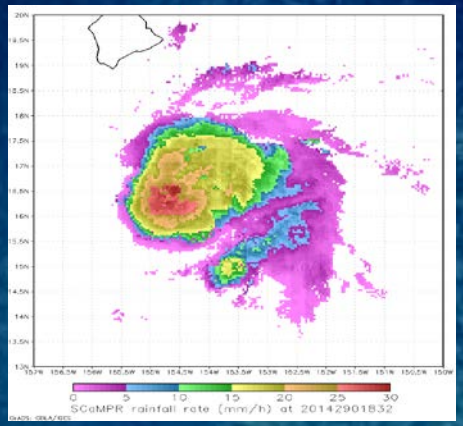
Original

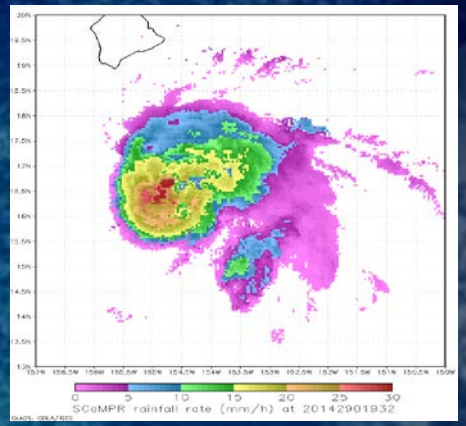


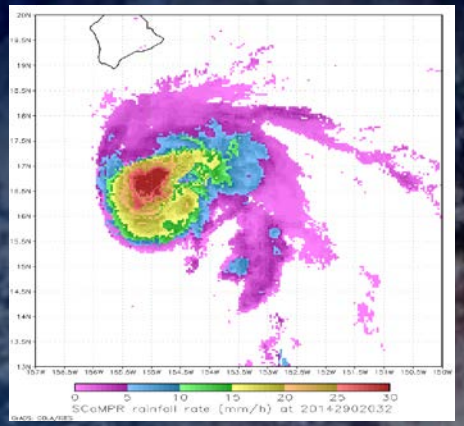




Smaller Calibration Regions







- Introduction of the GOES-R Rainfall Rate Algorithm
- The Modified Current-GOES Version and Recent Improvements to the Algorithm
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Application of Himawari AHI

- Himawari-8 launched 7 October 2014, started operations on July 7, 2015
- Advanced Himawari Imager (AHI) on Himawari-8 is the ***best proxy data*** available for the ABI on GOES-R
- Provides a great opportunity for algorithm evaluation of the GOES-R ABI products in real time prior to GOES-R launch

Application of Himawari AHI

- ***Challenge*** in running GOES-R Rainfall Rate Algorithm on the AHI data ***computing time***

Calibration is for each single rain class, the number of rain classes significantly increases for the AHI data with 15ºx15º calibration regions

12 classes (**original** 4 lat/lon bands x 3 cloud types)
30ºx120º

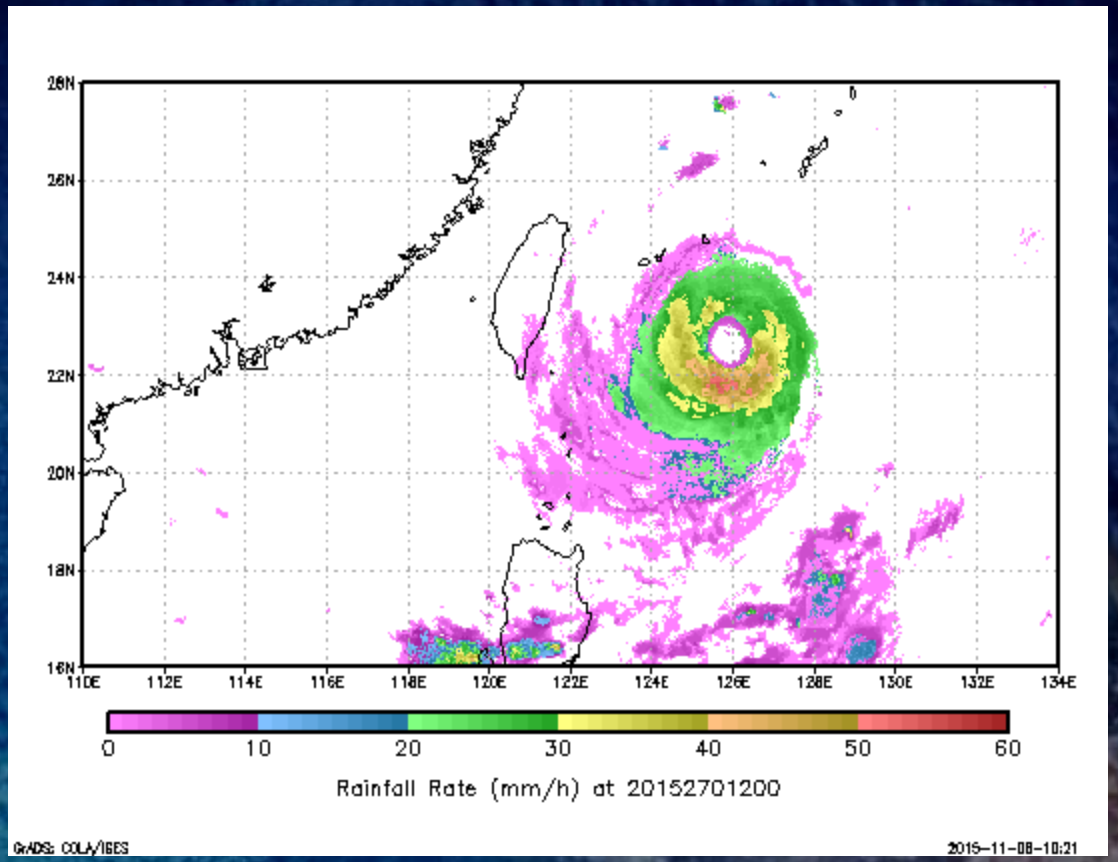
128 classes (**current GOES**
15ºx15º
64 lat/lon bands x 2 cloud types)

264 classes (**AHI** 88 lat/lon ands x 3 cloud types)
15ºx15º + much larger data size of AHI

Require ...
Speed up the algorithm code

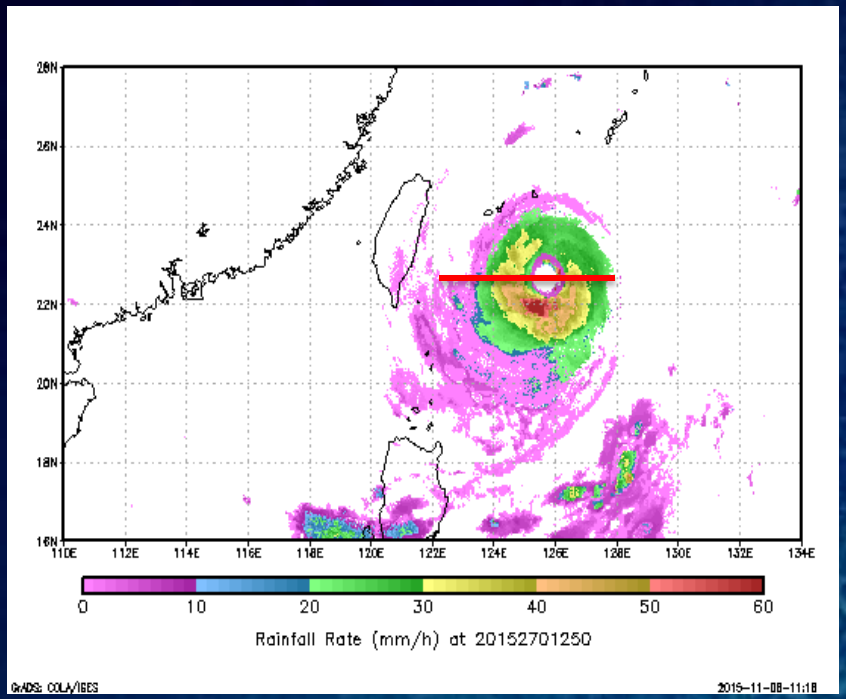
Preliminary Results

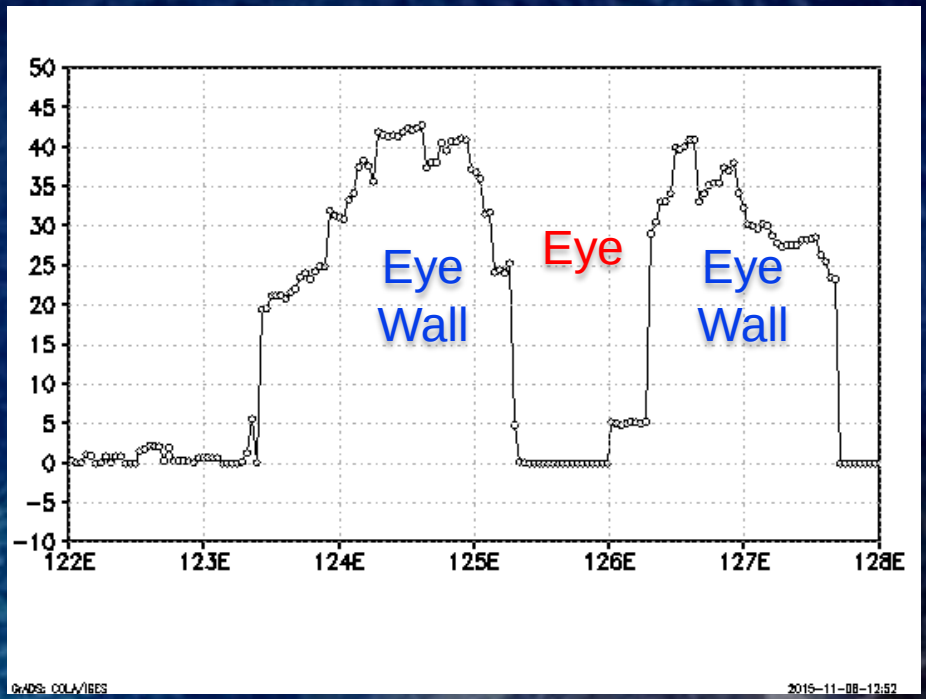
- Typhoon Dujuan was the second most intense tropical cyclone of the Northwest Pacific Ocean in 2015.
- Brought extremely powerful winds, caused 3 deaths in Taiwan.
- The typhoon Dujuan also caused over 4.15 billion RMB (652 million USD) damage in East China.



Retrieved Rain Rates for Typhoon Dujuan 2015

Application of Himawari AHI





Cross section along the red line, the retrieved rain rates clearly show the eye and eye wall

Next Steps

- Run the GOES-R Rainfall Rate Algorithm on the AHI data in real time to evaluate the algorithm prior to GOES-R launch; the findings will motivate improvements to the algorithm
- Utilize cloud property information to help screen out cirrus anvils and improve the detection of warm cloud rainfall
- Refine the RH correction further to improve the performance of the algorithm for heavier rain rates
- Orographic correction: evaluating currently existing orographic adjustments for suitability.

Conclusions

- GOES-R Rainfall Rate algorithm is an effort to combine the rapid refresh and high resolution of IR data and accuracy of MW estimates of precipitation
- Recent improvements to the algorithm include a correction for subcloud evaporation and smaller calibration regions, reduced false alarm and overall error, improved the consistency of the retrieved rain rates in time and space
- The AHI data provides a great opportunity for algorithm evaluation in real time prior to GOES-R launch
- Ran the Rainfall Rate algorithm with AHI data, captured the main structure of the Typhoon Dujuan rain bands

Thank you for your attention!

Questions?