# GRAFIIR and JAFIIR (GOES-R/JPSS Analysis Facility for Instrument Impacts on Requirements)

## Efficient End-to-End Semi-Automated GEO and LEO Sensor Performance Analysis and Verification Systems

95th AMS Annual Meeting; 11th Annual Symposium on New Generation Operational Environmental Satellite Systems; Phoenix, AZ; 4-8 January 2015

*Mat Gunshor, Hong Zhang, Allen Huang, & Eva Schiffer -- CIMSS/SSEC UW-Madison*

*Special thanks to Jaime Daniels, Mitch Goldberg, and Ajay Mehta – NOAA/NESDIS*

STAR Center for Satellite Applications and Research
formerly ORA — Office of Research and Applications

## GOES-R ABI and JPSS VIIRS

### GRAFIIR and JAFIIR OBJECTIVEs

- **Leverage existing capabilities and those under development for current GOES, its successor ABI, MODIS, and VIIRS in data processing and product evaluation to support analysis of instruments impacts on meeting user and product requirements.**
- **"Connecting the dots", the components that have been built and/or are under development, to provide a flexible frame work to effectively adopt component algorithms toward analyzing the sensor measurements with different elements of sensor characteristic (i.e. noise, navigation, band to band co-registration, etc.) and its impact on products.**
- **Assess and evaluate data and products (i.e. imagery, clouds, derived products, soundings, winds, etc.) in a consistent way to ensure the instrument effects on the products can be fully accounted for, characterized and product performance can be analyzed.**
- **This is a coordinated team effort from GOES-R and JPSS Risk Reductions, Algorithm Working Groups, Calibration Working Groups, and other related projects. It will not independently develop any new algorithms or processing, but will leverage work already available or under development.**
- **GRAFIIR is a key component of the government's waiver analysis plan concerning the ABI and JAFIIR is developing this capability for JPSS.**

ABI Spectral Characteristics

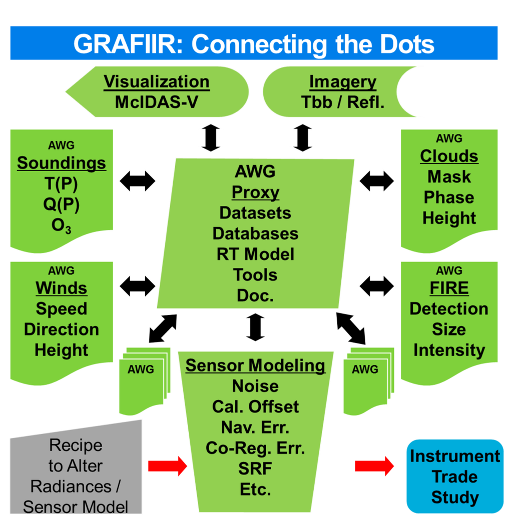
| Future GOES imager (ABI) band | Wavelength range (µm) | Central wavelength (µm) | Nominal subsatellite IGFOV (km) | Sample use |
|---|---|---|---|---|
| 1 | 0.45–0.49 | 0.47 | 1 | Daytime aerosol over land, coastal water mapping |
| 2 | 0.59–0.69 | 0.64 | 0.5 | Daytime clouds fog, insolation, winds |
| 3 | 0.846–0.885 | 0.865 | 1 | Daytime vegetation/burn scar and aerosol over water, winds |
| 4 | 1.371–1.386 | 1.378 | 2 | Daytime cirrus cloud |
| 5 | 1.58–1.64 | 1.61 | 1 | Daytime cloud-top phase and particle size, snow |
| 6 | 2.225–2.275 | 2.25 | 2 | Daytime land/cloud properties, particle size, vegetation, snow |
| 7 | 3.80–4.00 | 3.90 | 2 | Surface and cloud, fog at night, fire, winds |
| 8 | 5.77–6.6 | 6.19 | 2 | High-level atmospheric water vapor, winds, rainfall |
| 9 | 6.75–7.15 | 6.95 | 2 | Midlevel atmospheric water vapor, winds, rainfall |
| 10 | 7.24–7.44 | 7.34 | 2 | Lower-level water vapor, winds, and $SO_2$ |
| 11 | 8.3–8.7 | 8.5 | 2 | Total water for stability, cloud phase, dust, $SO_2$ rainfall |
| 12 | 9.42–9.8 | 9.61 | 2 | Total ozone, turbulence, and winds |
| 13 | 10.1–10.6 | 10.35 | 2 | Surface and cloud |
| 14 | 10.8–11.6 | 11.2 | 2 | Imagery, SST, clouds, rainfall |
| 15 | 11.8–12.8 | 12.3 | 2 | Total water, ash, and SST |
| 16 | 13.0–13.6 | 13.3 | 2 | Air temperature, cloud heights and amounts |

VIIRS Spectral Characteristics

| | Band No. | Wavelength (um) | Nadir Horiz Sample Interval (km Downtrack x Crosstrack) | Driving EDR |
|---|---|---|---|---|
| VIS/NIR Bands | M1 | 0.412 | 0.742 x 0.259 | Ocean Color Aerosols |
| | M2 | 0.445 | 0.742 x 0.259 | Ocean Color Aerosols |
| | M3 | 0.488 | 0.742 x 0.259 | Ocean Color Aerosols |
| | M4 | 0.555 | 0.742 x 0.259 | Ocean Color Aerosols |
| | I1 | 0.640 | 0.371 x 0.387 | Imagery |
| | M5 | 0.672 | 0.742 x 0.259 | Ocean Color Aerosols |
| | M6 | 0.746 | 0.742 x 0.776 | Atmospheric Correction |
| | I2 | 0.865 | 0.371 x 0.387 | NDVI |
| | M7 | 0.865 | 0.742 x 0.259 | Ocean Color Aerosols |
| CCD | DNB | 0.7 | 0.742 x 0.742 | Imagery |
| S/MWIR Bands | M8 | 1.24 | 0.742 x 0.776 | Cloud Particle Size |
| | M9 | 1.379 | 0.742 x 0.776 | Cirrus/Cloud Cover |
| | I3 | 1.61 | 0.371 x 0.387 | Binary Snow Map |
| | M10 | 1.61 | 0.742 x 0.776 | Snow Fraction |
| | M11 | 2.25 | 0.742 x 0.776 | Clouds |
| | I4 | 3.74 | 0.371 x 0.387 | Imagery Clouds |
| | M12 | 3.70 | 0.742 x 0.776 | SST |
| | M13 | 4.05 | 0.742 x 0.259 | SST Fires |
| LWIR Bands | M14 | 8.55 | 0.742 x 0.776 | Cloud Top Properties |
| | M15 | 10.763 | 0.742 x 0.776 | SST |
| | I5 | 11.450 | 0.371 x 0.387 | Cloud Imagery |
| | M16 | 12.013 | 0.742 x 0.776 | SST |

GRAFIIR primarily uses AWG Proxy Team simulated ABI data:

- ABI data generated from WRF model analysis performed on a super computer.
- Full disk (15-min, 6-km)
- CONUS (5-min, 2-km)
- Mesoscale (1-min, 667-m)
- All 16 bands




JAFIIR is able to use Suomi-NPP VIIRS data.

Realtime RDRs collected at SSEC, direct broadcast

- RDR to SDR to EDR processing done in real-time.
- All data archived locally.

### Modeling of Instrument Effects (Using Instrument Specifications)

**Four basic instrument effects have been applied to simulated (from WRF) ABI data which have been remapped to the ABI Fixed Grid Format and to Suomi NPP VIIRS:**

- **Noise (NEdT or NEdR)**

**Random noise is generated such that for m lines by n elements in an image a random number generator is used on all mXn points where the standard deviation of what will be added to those mXn points is the noise (such as the NEdR equivalent of 0.1K at 300K for ABI IR bands).**

- **Calibration Offset**

**• IR Bands: Example, add radiance equivalent to 1K to every pixel.**
**• Vis/NIR Bands: Example, add reflectance factor to every pixel.**

- **Navigation Error**

**To simulate this error a random compass direction (0-359.99 degrees) is selected for each pixel and a normalized random distribution for distance based on 21 micro radians (0.75km, ABI spec) is added. Then the radiance for that pixel is "smudged" in that direction using linear interpolation. The result is a new image with the original Lat/Lon grid but slightly altered radiances. A few pixels may have large differences from the original because they were on the edge of a feature such as a cloud.**

- **Striping**

**A calibration offset on the order of the noise for any given band is added to every nth line, to simulate a certain number of bad detectors.**

- **Combination of the above instrument effects: (1x & 3x)**

**Datasets were created for ABI that applied all four instrument effects at 1x spec and 3x spec to determine their effects on certain algorithms.**

## Glance: An Efficient Evaluation and Validation Tool

### baseline_cld_hght_seviri_cloud_top_temperature Variable Comparison

report produced with glance, version 0.2.6.10
comparison generated Mon Oct 19 17:54:38 2009 by user wstraka on craackly.ssec.wisc.edu

file A:

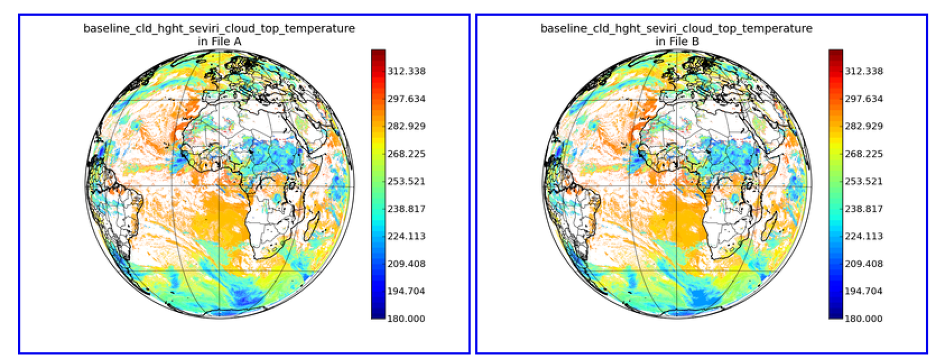
path: /home/wstraka/geocat/data_in_out/geocatL2.Meteosat-8.2006237.120000.ALLATONCE.ALLALG.hdf
md5sum for file A: 56cb4b93e00b7894d38788ca9439737f
last modified: Thu Oct 15 00:47:36 2009

file B:

path: /home/wstraka/geocat/data_in_out/geocatL2.Meteosat-8.2006237.120000.hdf
md5sum for file B: 36d63d0044e721c4608d8263739c0494
last modified: Mon Oct 19 17:45:05 2009

latitude: pixel_latitude
longitude: pixel_longitude

**Original Data**




**Comparison Information**

variable name: baseline_cld_hght_seviri_cloud_top_temperature
epsilon value: 0.1
"missing" data value in A: -32768
"missing" data value in B: -32768

**Statistical Summary**

Finite Data Statistics
a_finite_count*: 5839352
a_finite_fraction*: 0.4238
b_finite_count*: 5830257
b_finite_fraction*: 0.4231
common_finite_count*: 5829663
common_finite_fraction*: 0.4231
finite_in_only_one_count*: 10283
finite_in_only_one_fraction*: 0.0007463

General Statistics
a_missing_value*: -32768
b_missing_value*: -32768
epsilon*: 0.1
max_a*: 324.1
max_b*: 324.1
min_a*: 180
min_b*: 180
num_data_points*: 13778944
shape*: (3712, 3712)
spatially_invalid_pts_ignored_in_a*: 3498035
spatially_invalid_pts_ignored_in_b*: 3498035
trouble_points_count*: 87676
trouble_points_fraction*: 0.006363

Numerical Comparison Statistics
correlation*: 0.9979
diff_outside_epsilon_count*: 77393
diff_outside_epsilon_fraction*: 0.01328
max_diff*: 106.1
mean_diff*: 0.08044
median_diff*: 0
perfect_match_count*: 5666354
perfect_match_fraction*: 0.972
rms_diff*: 1.748
std_diff*: 1.745

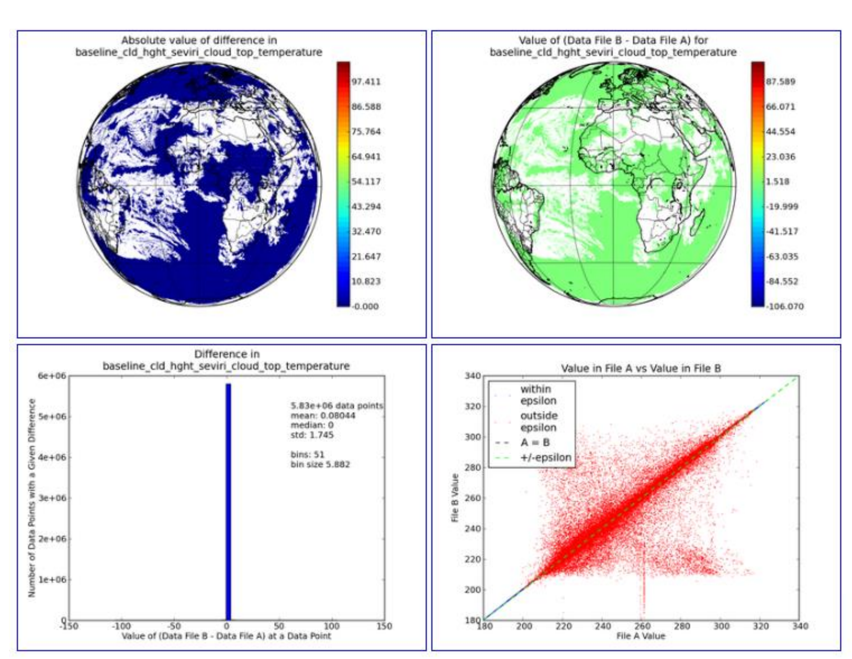
- GLANCE is a Python software tool in development by the UW-CIMSS GRAFIIR team to efficiently & consistently compare two datasets in a semi-automated way. "Glance at the differences."
- The code is user input driven, so statistics, such as epsilon (threshold) are dynamically changed by user input for each variable.
- Glance can generate a report in html format which includes product images, difference images, scatter plots, and histograms; also included are various statistics.
- Compare algorithm output to ensure processing system, algorithm and ancillary datasets are installed correctly.
- Compare algorithm outputs and obtain useful statistics for varying instrument effect(s)/added noise
- Automating time consuming manual GRAFIIR analyses
- Glance will be used as a validation tool for Imagery and other AWG teams

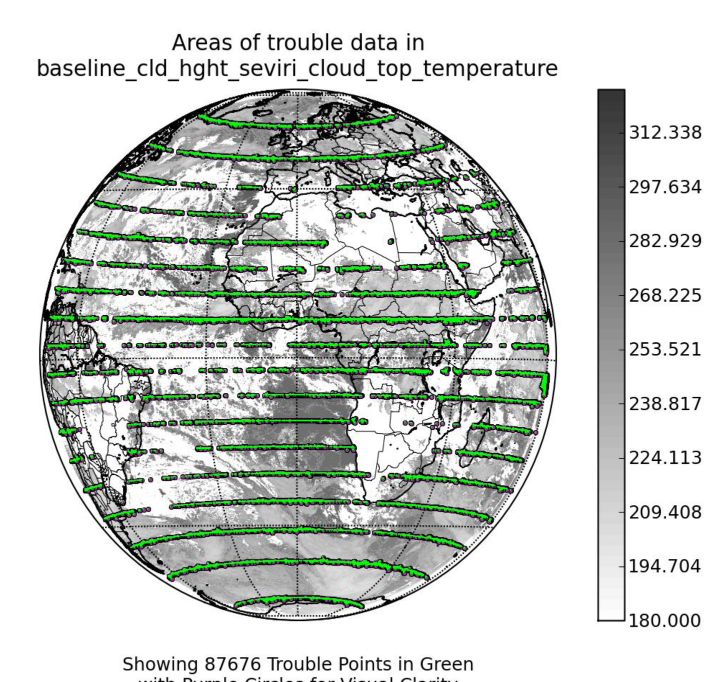
This Glance report demonstrates Cloud Top Height run on SEVIRI data (12:00 UTC 25 Aug 2006).

- File A is the entire full disk processed at one time.
- File B is the full disk divided into "chunks" and processed one chunk at a time.

**W**hat happens when certain algorithms, such as cloud top temperature which rely on n by n uniformity values, are processed in multiple chunks and then processed later as a single chunk (full disk at a time) for comparison?

**T**rouble spots manifest themselves in "stripes" along the beginning and ending lines of each chunk as well as a spread in the data greater than machine precision, as exhibited by the scatter plot.

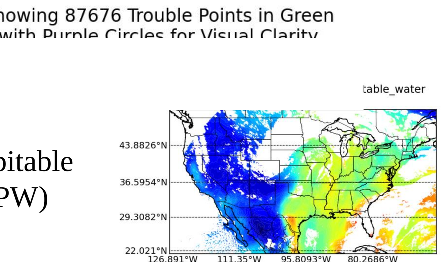


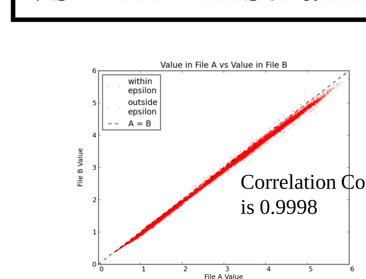




### Soundings Example

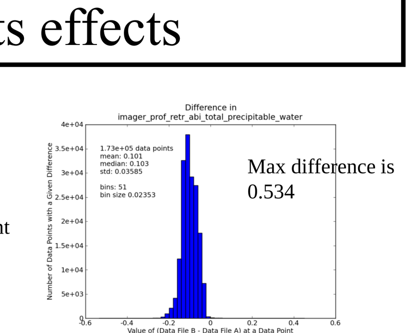
"Pure" Proxy Team CONUS image vs "1x" instruments effects

Total Precipitable Water (TPW)





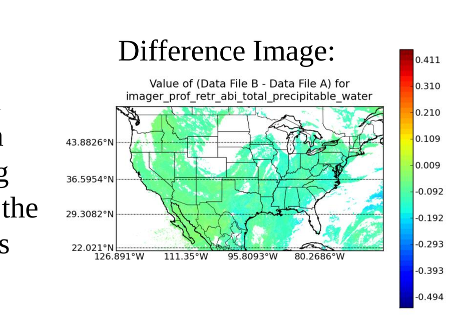

Correlation Coefficient is 0.9998




Max difference is 0.534

Spec-level (1x) noise, calibration offset, navigation error, and striping affects TPW, but the algorithm appears robust.

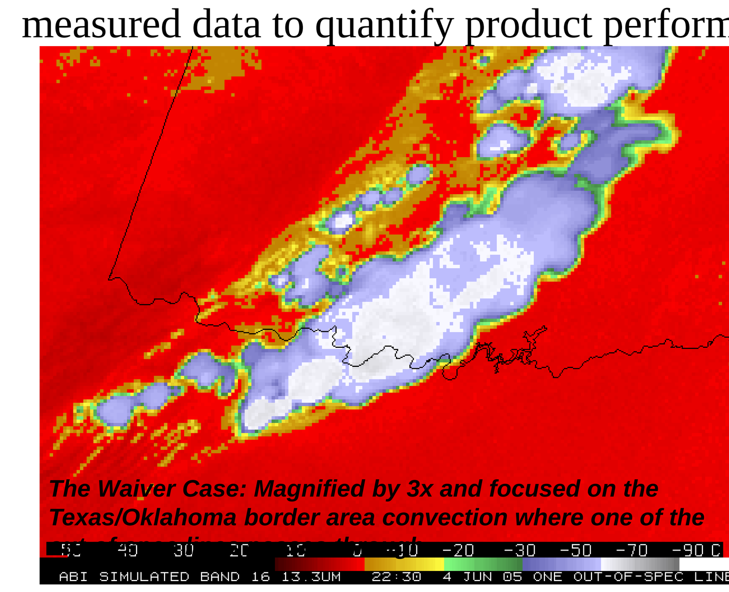
Difference Image:

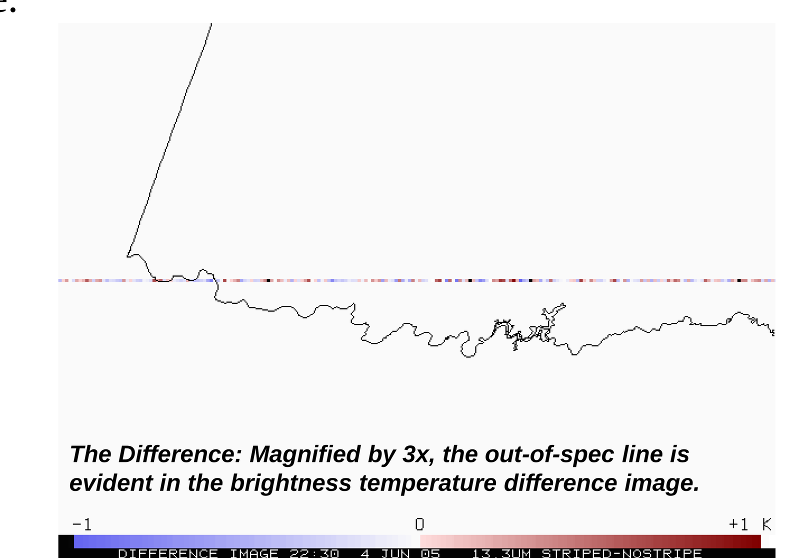



Epsilon used here is 0.0

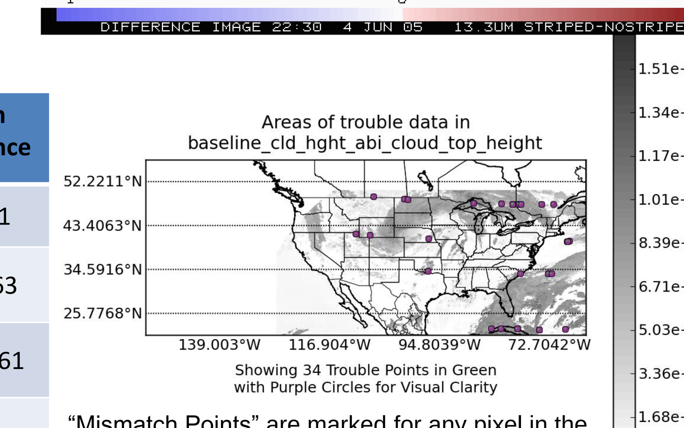
## GRAFIIR Response to ABI Waivers

- Most of GRAFIIR's waiver tasks are to measure the effects of a change on product output
- Many algorithm teams have a need to validate their product against another type of measured data to quantify product performance.




| Product | Mismatch Points | Mismatch Point Fraction | Max Difference | Mean Difference |
|---|---|---|---|---|
| Height (500m) | 34 | 1.048e-05 | 6,456 | 0.2491 |
| Pressure (50hPa) | 14 | 4.317e-06 | 280.3 | 0.01163 |
| Temperature (3K) | 50 | 1.542e-05 | 47.47 | 0.002161 |
| Cloud Mask | 0 | 0 | 0 | 0 |
| Cloud Phase | 0 | 0 | 0 | 0 |
| Cloud Type | 0 | 0 | 0 | 0 |

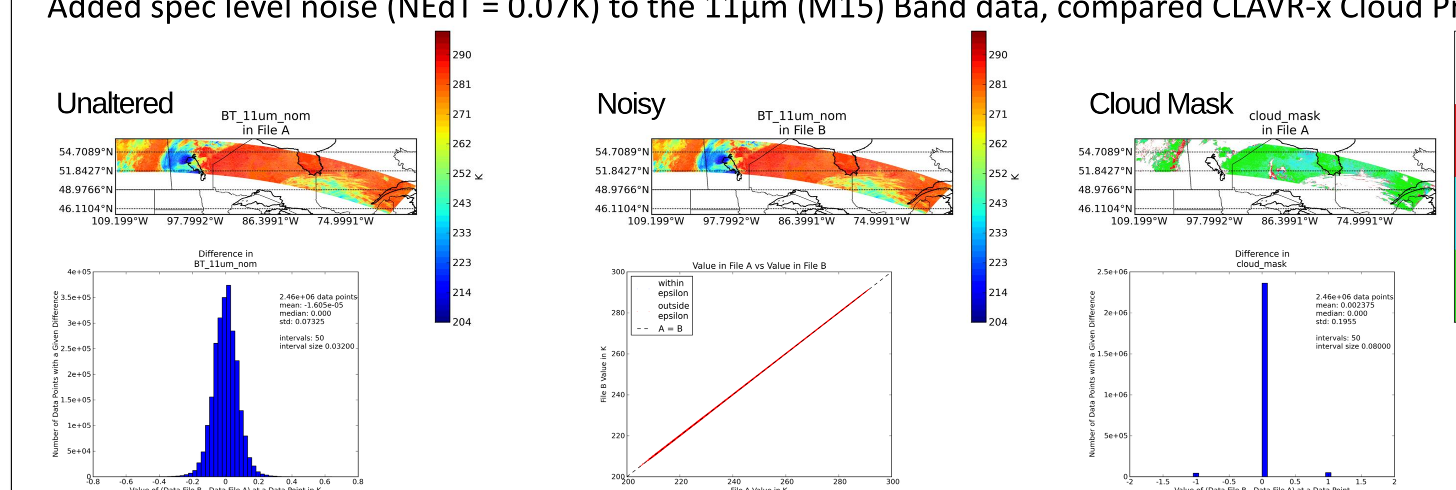



"Mismatch Points" are marked for any pixel in the two output files whose difference exceeds epsilon (which is 500m in this case).

## JAFIIR Makes Use of Glance and CSPP

Suomi-NPP VIIRS, 21 Aug 2014 at 08:04UTC.

Added spec level noise (NEdT = 0.07K) to the 11µm (M15) Band data, compared CLAVR-x Cloud Products




Numerical Comparison Statistics -- 11µm Band (M15) Difference
correlation*: 1.000
diff_outside_epsilon_count*: 2417231
diff_outside_epsilon_fraction*: 0.9836
max_delta*: 0.6421
mean_delta*: -1.605e-05
median_delta*: 0.000
min_delta*: -0.6323
std_val*: 0.07325

Numerical Comparison Statistics -- Cloud Mask Difference
correlation*: 0.9895
diff_outside_epsilon_count*: 93902
diff_outside_epsilon_fraction*: 0.03821 ← *4% changed due to added noise.*
max_diff*: 2
mean_diff*: 0.03822
median_diff*: 0.000
perfect_match_count*: 2363650
perfect_match_fraction*: 0.9618

### GRAFIIR SUMMARY

**GRAFIIR is to**

1. **Implement a facility environment (including leveraging GEOCAT and the AIT "Framework") to allow easy and consistent use of AWG application team proxy data and product algorithms.**
2. **Design an efficient approach in coordination with ABI sensor and algorithm scientists to analyze the effects of sensor components such as noise, navigation, band to band co-registration, optical diffraction, striping and other effects identified to be significant on product algorithms and imagery.**
3. **Assist the government's response to ABI instrument waivers requested by industry by providing statistical analysis, reports, and imagery.**
4. **The CIMSS GOES-R AWG GRAFIIR Team has responded to 12 ABI waiver/deviation requests to date.**

### JAFIIR Summary

**JAFIIR is to**

1. **Implement a facility environment (including leveraging CSPP direct broadcast realtime RDR to SDR to EDR functionality) to allow easy and consistent use of Suomi-NPP VIIRS data and product algorithms.**
2. **Design an efficient approach in coordination with VIIRS sensor and algorithm scientists to analyze the effects of sensor components such as noise, navigation, band to band co-registration, optical diffraction, striping and other effects identified to be significant on product algorithms and imagery.**
3. **Assist the government's response to VIIRS instrument waivers requested by industry by providing statistical analysis, reports, and imagery.**
4. **The CIMSS JPSS JAFIIR Team has demonstrated the key components of responding to waiver/deviation requests and provided input on 1 issue so far for J1.**