Overview of GOES-R Analysis Facility for Instrument Impacts on Requirements (GRAFIIR)
Planned Activities and Recent Progress

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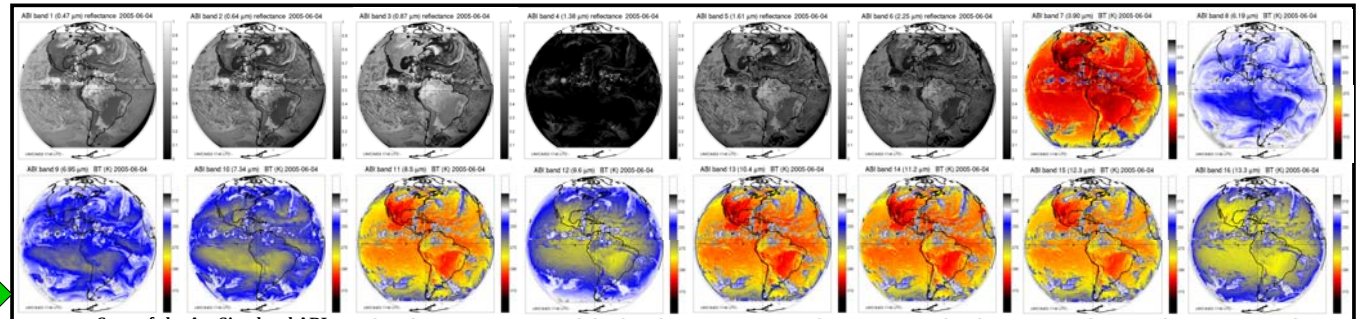
CIMSS

OBJECTIVE

- **GRAFIIR is a facility established to leverage existing capabilities and those under development for both current GOES and its successor in data processing and product evaluation to support GOES-R analysis of instruments impacts on meeting user and product requirements.**
- **GRAFIIR is for "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, diffraction, etc.) and its impact on products.**
- **GRAFIIR is to assess and evaluate many of the GOES-R 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 could be optimized.**
- **GRAFIIR is a coordinated team effort from GOES-R Risk Reduction and Algorithm Working Group and other related projects. It will not independently develop any new algorithms or processing, but will leverage work already available or under development.**



State-of-the-Art Simulated ABI: a) 24 hour dataset (30 minutes interval), b) 6 hour dataset (5 minutes interval), & c) 6 Km spatial resolution, & 4. 3100 by 2600 grid points (16 MB/Band)

ABI Spectral Characteristic, Bit Depth & Utility

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/flora 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	3.80–4.08	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	Mid-level atmospheric water vapor, winds, rainfall
10	7.24–7.64	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

Bit Depth

10 bits:
0.47, 0.86, 1.38, 1.61, & 2.26 µm

11 bits:
6.18, 6.95, 9.61, & 13.3 µm

12 bits:
0.64, 7.34, 8.5, 10.35, 11.20, & 12.30 µm

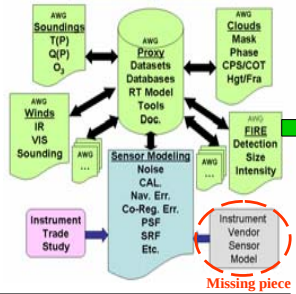
14 bits:
3.90

Modeling of High Spatial Resolution Atmospheric Field for ABI Simulation

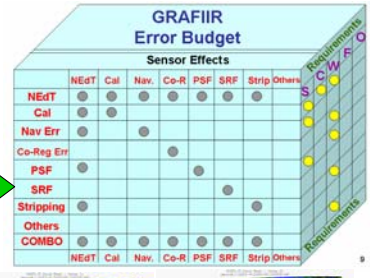
This simulation was performed at the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign. Simulated atmospheric fields were generated using version 2.2 of the WRF model (ARW core). The simulation was initialized at 00 UTC on 04 June 2005 with 1° GFS data and then run for 30 hours using a triple-nested domain configuration. The outermost domain covers the entire GOES-R viewing area (every 15 minutes) with 6-km horizontal resolution while the inner domains cover the CONUS (every 5 minutes) and mesoscale regions (every 1 minute) with 2-km and 0.667-km horizontal resolution, respectively.

The simulation employed the following parameterization schemes:
- **Thompson microphysics**
- **Eta planetary boundary layer**
- **RRTM/Dudhia radiation**
- **NOAH land-surface model**
- **Explicit convection (i.e. no cumulus parameterization)**

GRAFIIR Connecting the Dots



GRAFIIR Error Budget

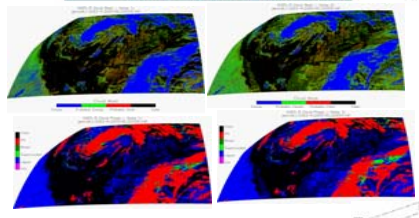


GRAFIIR Cloud Study Examples

	Liquid Phase	Ice Phase
Noise Free Count	N=652573	N=636807
Noise 1x Spec Count	+1.3% N=661252	-2.9% N=618476
Noise 3x Spec Count	+29.4% N=844719	-14.3% N=545560

	Noise 1x Spec	Noise 3x Spec
Ice to Liquid	N=29697	N=74108
Liquid to Ice	N=5186	N=2790

Cloud Phase Pixel Changes



2200 UTC June 04 2005	Cloudy	Prob. Cloudy	Prob. Clear	Clear
Noise Free Simulation Count	26.6% N=672511	16.3% N=412690	10.6% N=277478	46.6% N=1179243
Noise 1x Spec Count % Change	-3.6% N=648537	+3.5% N=426958	-10.0% N=249873	+21.7% N=1204865
Noise 3x Spec Count % Change	-18.5% N=548030	+43.2% N=591114	+9.4% N=303543	-7.8% N=1087030

Noise Impacts on Cloud Mask

Modeling of ABI Instrument Effects
(Using Specifications from the ABI PORD, April 2003)
From M. Gunshor – CIMSS ABI Simulation Lead

Four instrument effects have been applied to simulated (from WRF) ABI data which have been remapped to an ABI-like grid and quantized for ABI bit depth:

- **Noise (NEdT or NEdR)**
  - Vis/NIR (bands 1-6): SNR is 300:1 at 100% albedo
  - IR (bands 7-15): NEdT at 300K is 0.1K, (band 16): 0.3K

  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 IR bands or 300:1 in reflectance units).
- **Calibration Offset**
  - IR Bands: ABI Spec is for absolute accuracy of 1K
  - Vis/NIR Bands: ABI Spec is for absolute accuracy of 3%
- **Navigation Error**

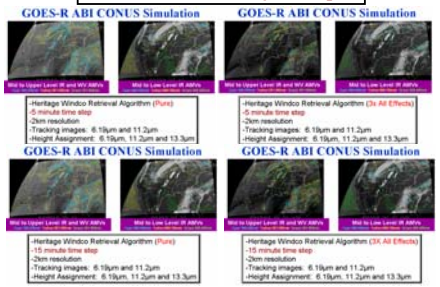
  Spec Navigation Error is 21 microradians. This spec is the largest of any of the navigation/co-registration type errors. To simulate this error a random compass direction (0-359.99 degrees) is selected for each pixel and a normalized random distribution for distance based on 21 micro radians (0.75km) 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**

  The striping specification is "not to exceed the noise". Assuming the ABI will have a detector array that will result in 100 lines of remapped data, striping is added to one of the first 100 lines and every 100th line after that.
- **Combination of the above ABI instrument effect: (1X & 3X)**

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

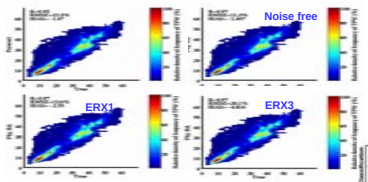
Other effects under consideration are:
- **Co-registration Error**
- **Swath to Swath Offset**

GRAFIIR Wind Study Examples

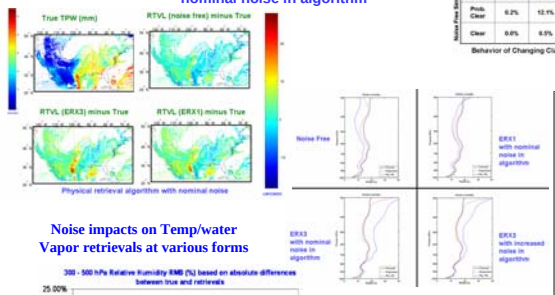


Water Vapor (WV) Atmospheric Motion Vectors						
Image Interval (Minutes)	# Matches		Speed Bias (AMV-WRF)		V_{rms} (AMV Vs WRF)	
	Pure	3X AIE	Pure	3X AIE	Pure	3X AIE
5	3041	534	-0.064	1.6648	5.1523	6.1122
15	2693	1189	0.0554	1.6774	4.7039	5.2942
30	2124	1217	0.0698	1.4038	5.0002	4.8443
Infrared (IR) Atmospheric Motion Vectors						
Image Interval (Minutes)	# Matches		Speed Bias (AMV-WRF)		V_{rms} (AMV Vs WRF)	
	Pure	3X AIE	Pure	3X AIE	Pure	3X AIE
5	4157	1615	-0.355	0.1657	4.449	4.7329
15	3754	2825	-0.564	0.7658	4.0065	3.8399
30	2484	1890	0.5022	0.7612	4.0185	3.4238
All (IR & WV) Atmospheric Motion Vectors						
Image Interval (Minutes)	# Matches		Speed Bias (AMV-WRF)		V_{rms} (AMV Vs WRF)	
	Pure	3X AIE	Pure	3X AIE	Pure	3X AIE
5	7198	2149	-0.232	0.5382	4.7588	5.1105
15	6447	4014	0.0971	1.0358	4.3116	4.322
30	4608	3128	0.3029	1.0129	4.4977	4.0402

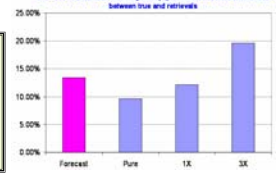
GRAFIIR Sounding Study Examples

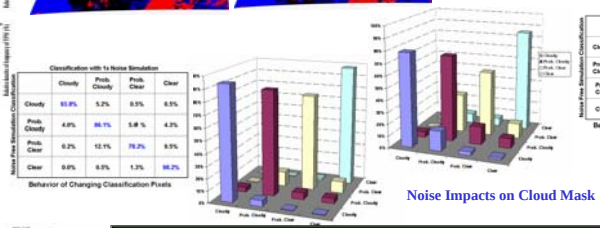


Noise impact on TPW retrievals (mm) – with nominal noise in algorithm



Noise impacts on Temp/water Vapor retrievals at various forms





Noise Impacts on Cloud Mask

GRAFIIR related oral presentations and Posters:

1. 2.2 The ABI (Advanced Baseline Imager) on the GOES-R Series
2. P1.3 Candidate approaches for the real-time generation of cloud properties from GOES-R ABI
3. P1.11 GOES-R wind retrieval algorithm development
   P1.20 Large-scale WRF model simulations used for GOES-R research activities
4. P1.40 Trade-off studies on future GOES hyperspectral infrared sounding instrument
5. P1.68 Verifying large-scale, high-resolution simulations of clouds for GOES-R activities
6. P1.86 Current GOES Sounder applications and future needs
7. P1.87 GOES-R ABI proxy data set generation at CIMSS
8. P1.89 GOES-R/ABI legacy profile algorithm evaluation with MSG/SEVIRI
9. 5.4 NOAA/NESDIS GOES-R Algorithm Working Group (AWG) and its Role in the Development and Readiness of GOES-R Product Algorithms

GRAFIIR Scientists who made significant contributions:

ABI Proxy Data: Jason Otkin & Tom Greenwald
ABI instrument effect simulation: Mat Gunshor
Cloud Mask & Phase: Mike Pavolonis &Justin Sieglaff
Sounding: Jun Li, Xin Jin, & Jinlong Li
Wind: Steve Wanzong, Iliana Genkova, & Chris Velden

SUMMARY

GRAFIIR is to

1. **Implement a facility environment (including leveraging GEOCAT) 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 demonstrate multiple datasets simulated for the ABI with different specifications of sensor components such as noise, navigation, band to band co-registration, optical diffraction, stripping and other effects identified to be significant.**
3. **Conduct processes to produce ABI products such as cloud mask, fire, sounding, winds and others to demonstrate the effects of different sensor components on the products produced.**
4. **Document and analyze the results to identify sensor components that might significantly impact the product performance and specification requirement.**
5. **Recommend alternative algorithm or processing approach to mitigate sensor impacts on product requirements including processing system, time latency, accuracy, precision, and other measures.**

GRAFIIR is now ready to conduct systematic and detail analysis of ABI instrument impacts on key products.