



# GOES-R AWG Team: Cloud and Moisture Imagery

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Thanks to the whole imagery team!



# CMIP (Cloud and Moisture Imagery Product) Team

- **Co-Chairs:** Tim Schmit and Walter Wolf
- **Cloud and Moisture Imagery Team**
  - » K. Bah, T. Rink, M. Gunshor
  - » Gang Fu, Yi Song and Hua Xie
- **Others**
  - » C. Cao (calibration working group chair)
  - » X. Wu and R. Iacovazzi
  - » J. Sieglaff, C. Schmidt, S. Lindstrom, R. Kohrs , W. Straka, T. Olander
  - » Shuang Qui



# Executive Summary

- The purpose of the imagery team is two-fold:
  - » Demonstrate how to convert from GRB scaled integers to other physical units, such as radiance, brightness temperatures and brightness values.
  - » Build files that can be used for processing most all of the ABI products, such as clouds, soundings, etc.
- Imagery is the key product for GOES-R.
- The team has met the schedules (draft ATBD, CDR, TRR), mostly using simulated ABI data.
- The products appear to be within spec.
- Visualization examples progressing, including the Fixed Grid Format (FGF).



# Requirements

- Develop algorithms and deliver Algorithm Theoretical Basis Documents (ATBDs) to the GOES-R Ground Segment Project (GSP)
  - » Cloud and Moisture Imagery for ABI
    - 54 F&PS Requirements
      - | 16 ABI channels multiplied by 3 coverage areas
      - | Multi-band spectral products (16 channels at 2 km resolution) by 3 coverage areas in NetCDF4 format
      - | Multi-band spectral products (16 channels at 2 km resolution) by 3 coverage areas in McIDAS format



# Requirements - Cloud and Moisture Imagery

Product	Measurement Precision	Cloud and Moisture Imagery Requirements								
		Refresh Rate/Coverage Time Option (Mode 3)	Refresh Rate Option (Mode 4)	Data Latency	User & Priority	Geographic Coverage (G, H, C, M)	Vertical Resolution	Horizontal Resolution	Mapping Accuracy	Measurement Accuracy
Cloud and Moisture Imagery	GOES-R	C	N/A	2 km, with finer daytime observations	1 km	N/A	N/A	5 min	5 min	50 sec
Cloud and Moisture Imagery	GOES-R	FD	N/A	2 km, with finer daytime observations	1 km	N/A	N/A	15 min	5 min	50 sec
Cloud and Moisture Imagery	GOES-R	M	N/A	2 km, with finer daytime observations	1 km	N/A	N/A	30 sec	23 sec	N/A

**C** – CONUS

**FD** – Full Disk

**M** - Mesoscale



# Cloud and Moisture Imagery Product Qualifiers

Name	User & Priority	Geographic Coverage (G, H, C, M)	Temporal Coverage Qualifiers	Product Extent Qualifier	Cloud Cover Conditions Qualifier	Product Statistics Qualifier
Cloud and Moisture Imagery	GOES-R	C, FD, M	Day and night	N/A	In presence of clear air and clouds	Over specified geographic area

**C** – CONUS

**FD** – Full Disk

**M** - Mesoscale



# Algorithm Description

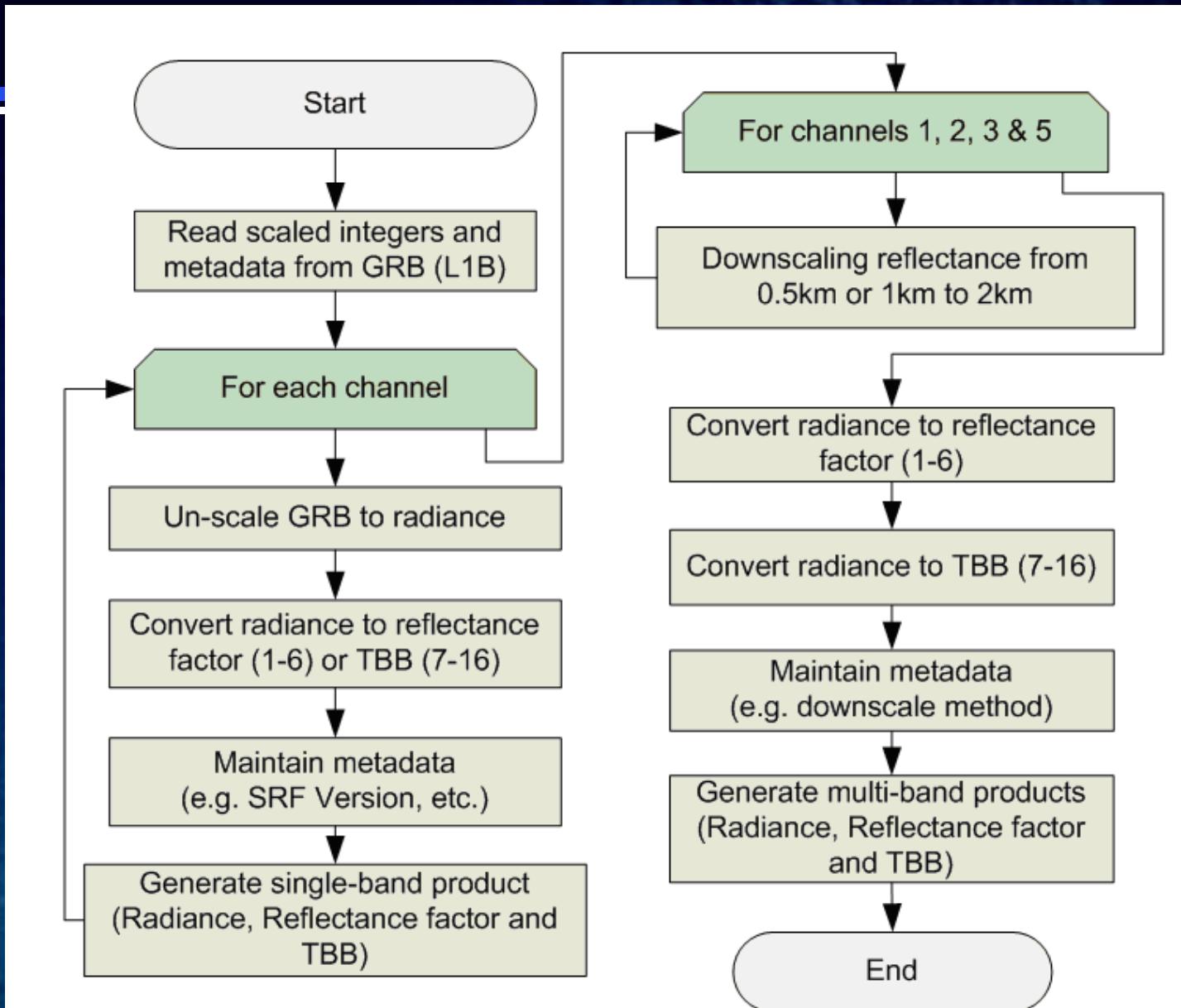


# Algorithm Summary

- » Convert scaled integers (SI) from the input data stream to an unscaled [spectral] radiances (bands 1-16).
- » Convert unscaled radiance to reflectance factor to Brightness Value (BV) (bands 1-6).
  - reflectance factor is similar to the albedo on current GOES
  - includes normal incidence and average sun-Earth distance
  - Supply coefficients (from Calibration WG) for conversion
- » Resample bands 1, 2, 3, and 5 for 2 km multi-band product
- » Convert scaled radiance from the input data stream to an unscaled spectral radiance (bands 7-16).
- » Convert unscaled spectral radiance to equivalent Brightness Temperature (BT) (bands 7-16).
- » Convert BT to BV (bands 7-16).

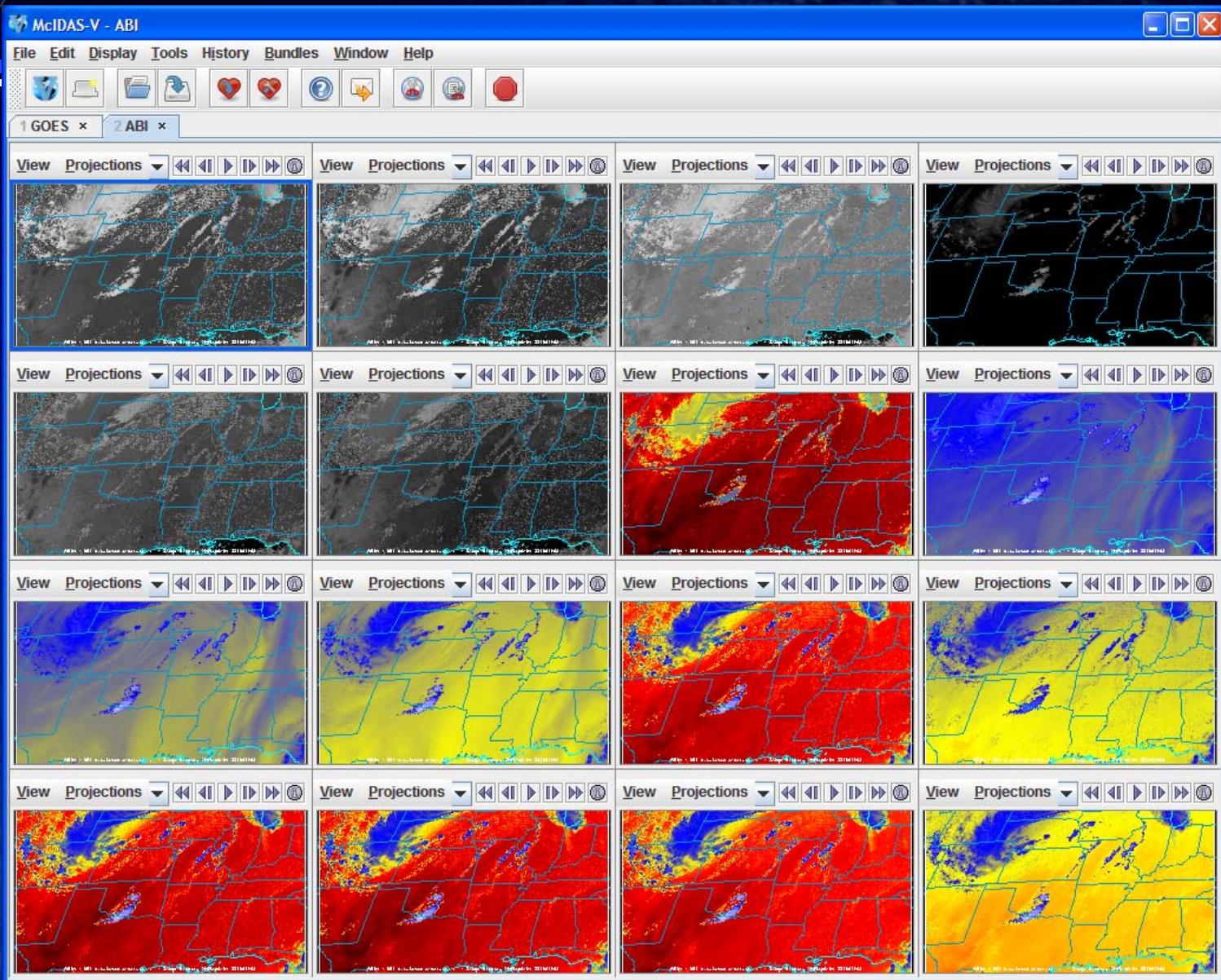


# Processing Outline CMIP Flowchart



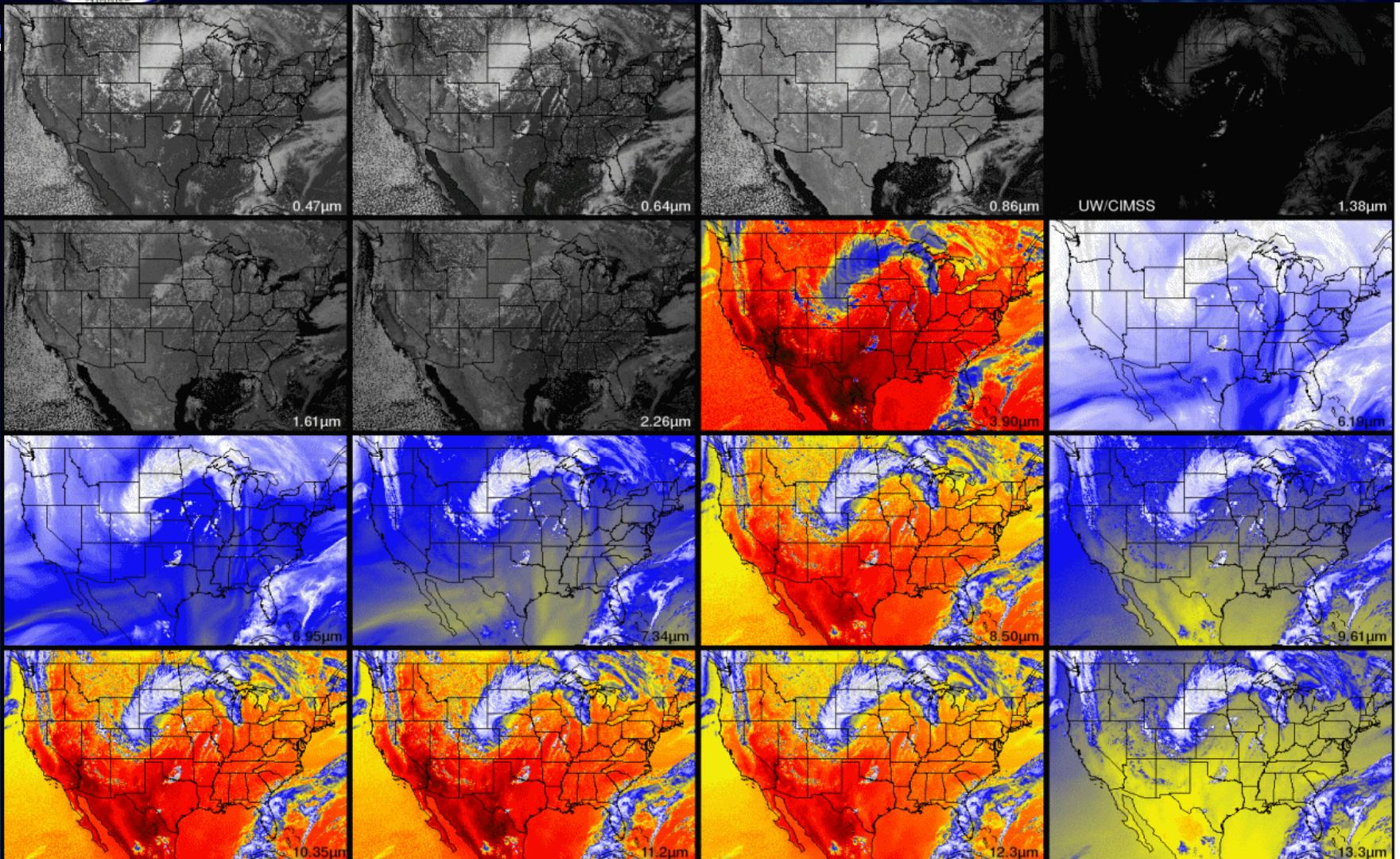


# Example CMIP Output ABI bands in McIDAS-V





# Example CMIP Output ABI bands in McIDAS-V (animation)



ABI band data for 2005 June 04 22:00 UTC

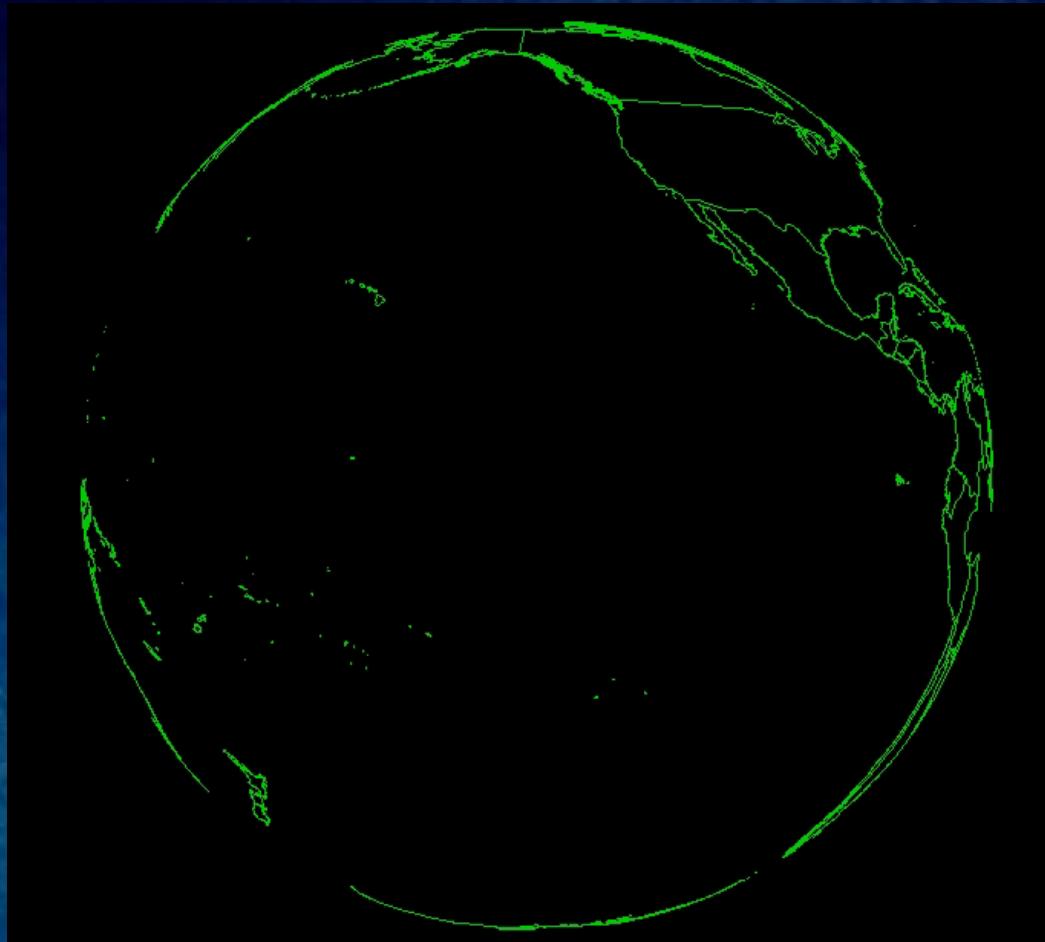


# Algorithm Changes from 80% to 100%

- Processing flow better defined
- ABI Fixed Grid Format (FGF) better understood and defined (e.g., full disk at 2km is 5534 x 5534).
- With CWG, better understand how much earth-edge atmosphere that will be part of a FD (~70 km at equator)
- Scaling bands 1-6 to radiance (direction from ‘white paper’); awaiting min/max for scale factors
- ABI bit depth definition (on-going)

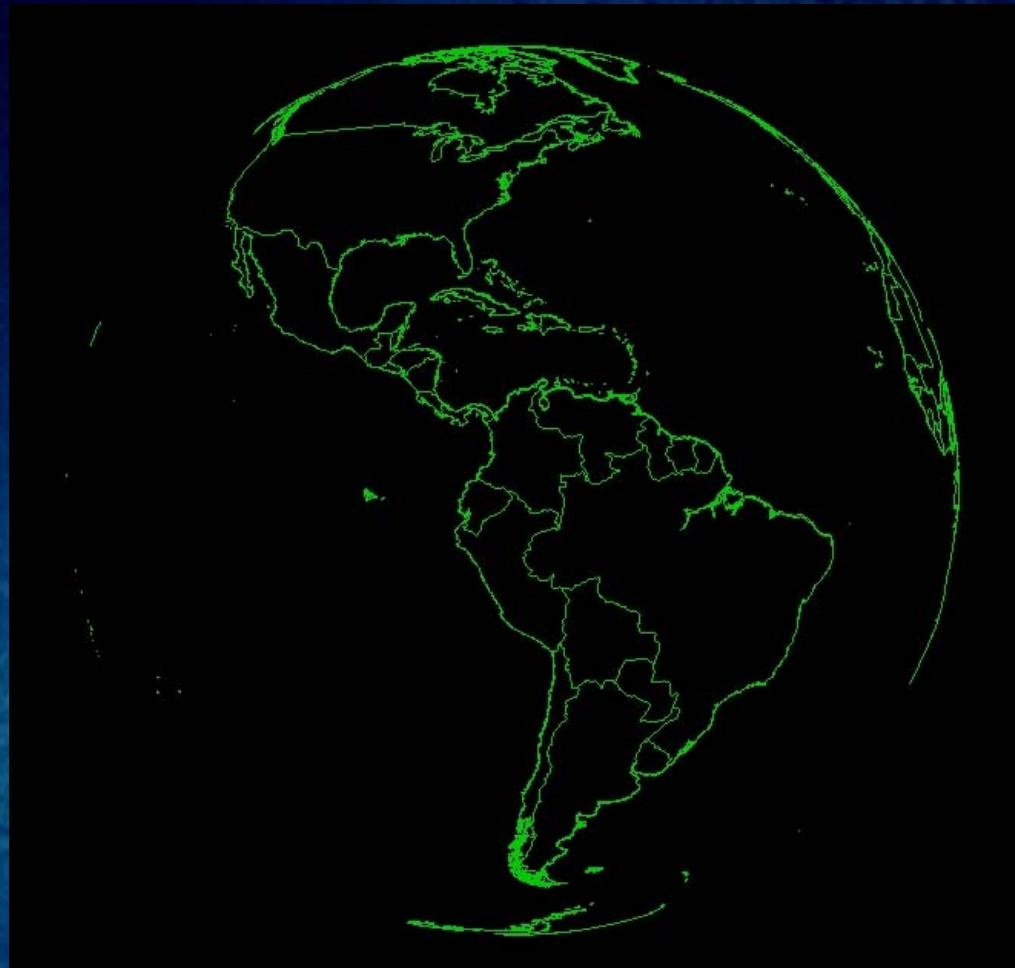


# FGF Example (137W)





# FGF Example (75W)





# ABI Band Characteristics

(consist with heritage – MODIS, VIIRS, etc.)

Band #	Central Wavelength (um)	Spatial Resolution (km)	Bit-Depth (Recommended)	Used in Cloudy and Moisture Imagery
1 Reflective bands	0.47	1	12	Yes
2	0.64	0.5	12	Yes
3	0.86	1	12	Yes
4	1.38	2	12	Yes
5	1.61	1	12	Yes
6	2.26	2	12	Yes
7 Emissive (IR) bands	3.9	2	14	Yes
8	6.15	2	12	Yes
9	7.0	2	12	Yes
10	7.4	2	12	Yes
11	8.5	2	12	Yes
12	9.7	2	12	Yes
13	10.35	2	12	Yes
14	11.2	2	12	Yes
15	12.3	2	12	Yes
16	13.3	2	12	Yes



# ADEB and IV&V Response Summary

- Major ATBD errors and clarification requests have been addressed. Provided responses.
- Some issues require more ‘upstream’ (e.g., GRB) detail/information
- No feedback required substantive modifications to the approach.



# Validation Approach



# ABI Visible/Near-IR Bands

Future GOES imager (ABI) band	Wavelength range ( $\mu\text{m}$ )	Central wavelength ( $\mu\text{m}$ )	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, insulation, 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



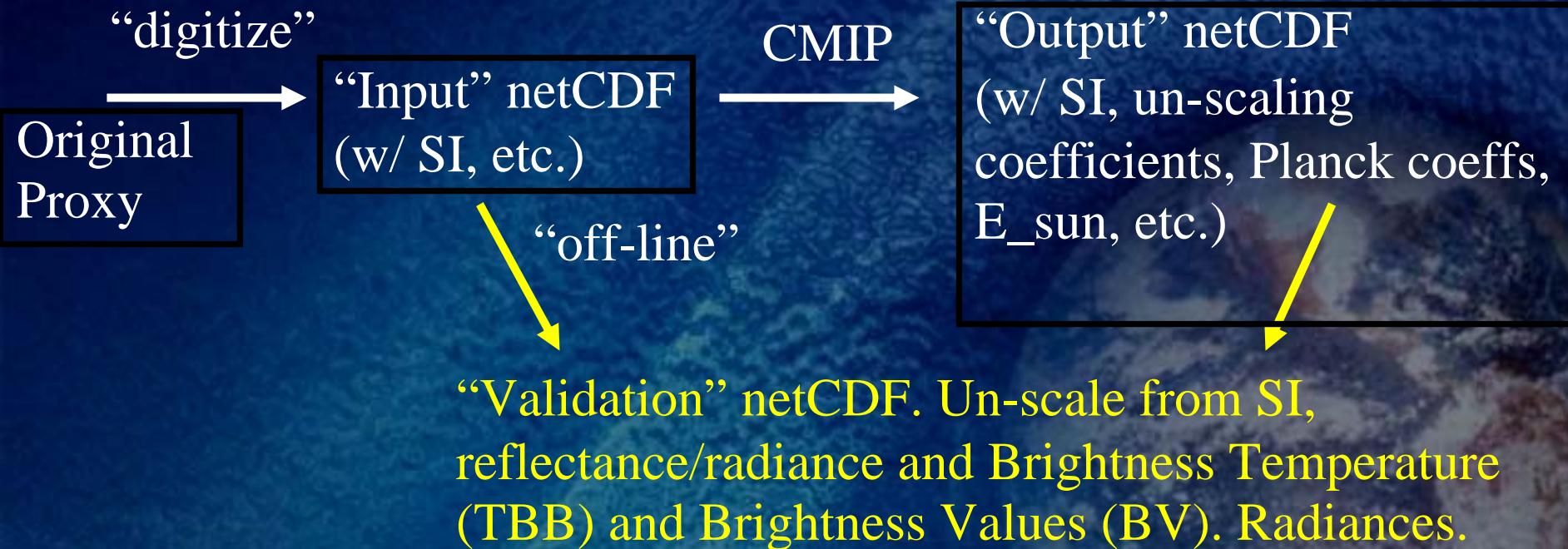
# ABI IR Bands

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 $\text{SO}_2$
11	8.3–8.7	8.5	2	Total water for stability, cloud phase, dust, $\text{SO}_2$ , 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



# Validation

Imagery does not have traditional ‘truth’ datasets for comparison, such as radiosondes or aircraft data. In light of this, we have defined our own ‘truth’ data via high resolution NWP runs, coupled with advanced forward modeling.





# Validation Results



# Test Readiness Review: Imagery - Software Verification (bands 1-6)

## Difference of (AIT-UW)

Band	Reflectance			Radiance			Brightness Value		
	mean(s - t)	stdev(s - t)	max( s - t )	mean(s - t)	stdev(s - t)	max( s - t )	mean(s - t)	stdev(s - t)	max( s - t )
01	-1.80270e-09	8.77219e-09	5.96046e-08	-8.23024e-06	1.14099e-05	9.15527e-05	1.93469e-05	0.00439843	1.00000
02	5.43765e-10	9.10306e-09	5.96046e-08	-4.51243e-06	7.01644e-06	6.10352e-05	0.00000	0.00000	0.00000
03	-3.63924e-09	1.04284e-08	5.96046e-08	-5.55586e-06	6.18800e-06	4.57764e-05	0.00434283	1.88608e-05	1.00000
04	6.02707e-10	1.39890e-09	2.98023e-08	1.53219e-08	2.71043e-07	7.62939e-06	0.00000	0.00000	0.00000
05	6.95558e-09	-8.69477e-10	5.96046e-08	1.03450e-06	-6.73960e-07	1.14441e-05	0.00000	0.00000	0.00000
06	-4.82609e-10	5.72237e-09	2.98023e-08	-1.45095e-07	2.36706e-07	1.90735e-06	0.00000	0.00000	0.00000

These small differences for the various parameters demonstrate that the conversion processes can be reproduced via the cloud and moisture imagery team processing.



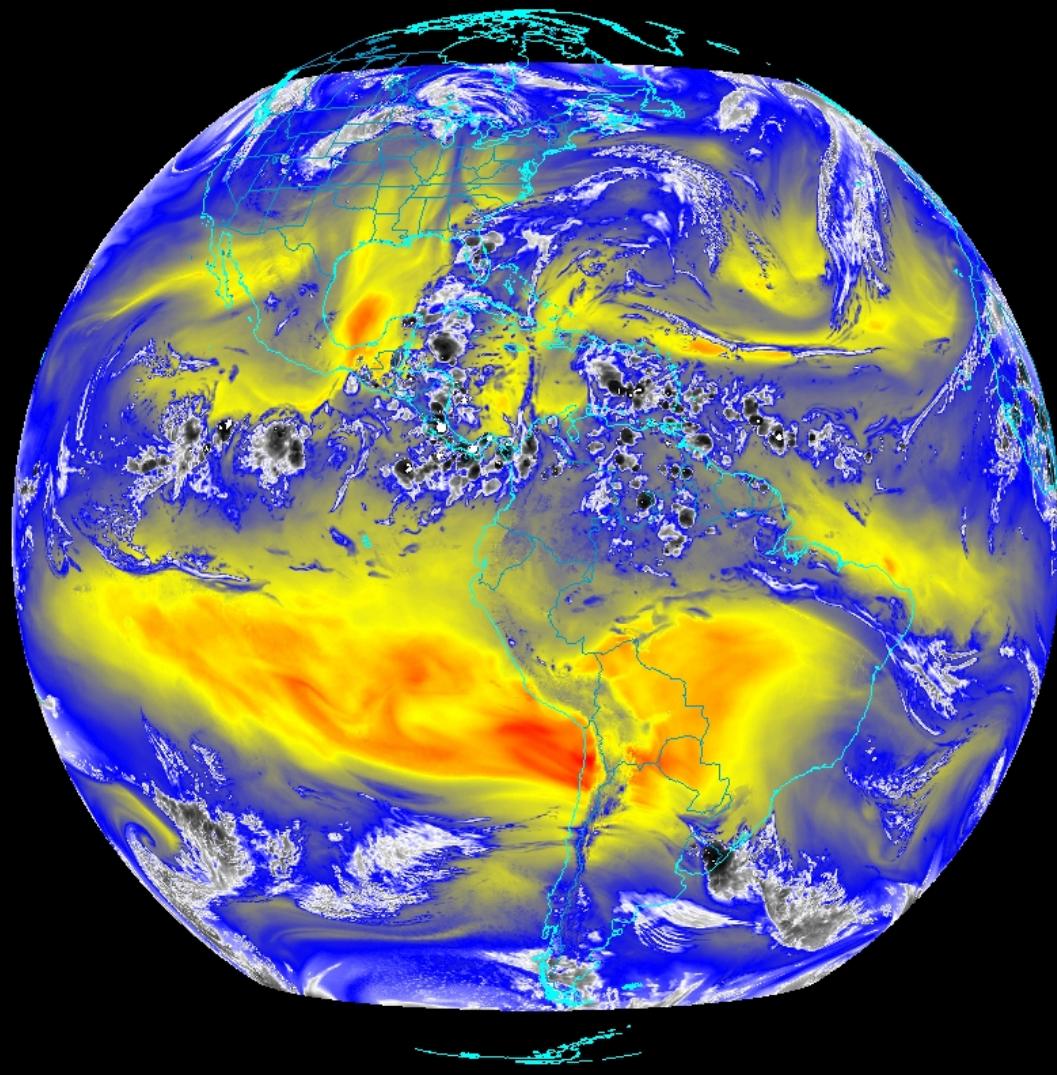
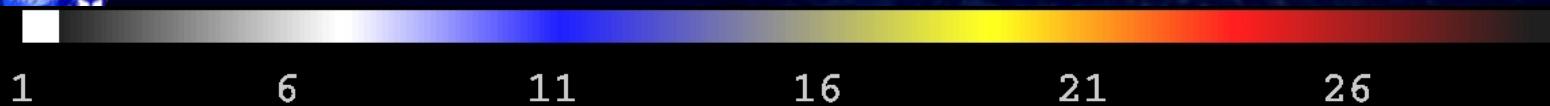
# Test Readiness Review: Imagery - Software Verification (bands 7-16)

## Difference of (AIT-UW)

Band	Radiance			Brightness Temperature			Brightness Value		
	mean(s - t)	stdev(s - t)	max( s - t )	mean(s - t)	stdev(s - t)	max( s - t )	mean(s - t)	stdev(s - t)	max( s - t )
07	8.07578e-09	2.31943e-08	1.19209e-07	7.14495e-06	1.57137e-05	6.10352e-05	0.00000	0.00000	0.00000
08	-3.38373e-07	1.27241e-07	5.96046e-07	-7.39373e-07	1.18933e-05	6.10352e-05	0.0000	0.0000	0.0000
09	-4.15323e-07	3.61135e-07	9.53674e-07	4.15826e-06	1.04421e-05	3.05176e-05	0.00000	0.00000	0.00000
10	-5.85536e-09	7.67321e-07	1.90735e-06	6.83676e-06	1.29271e-05	6.10352e-05	0.00000	0.00000	0.00000
11	-5.51336e-07	2.43044e-06	7.62939e-06	-7.01631e-06	1.64498e-05	6.10352e-05	0.00000	0.00000	0.00000
12	-2.97309e-07	2.42303e-06	3.81470e-06	-5.58301e-06	1.43563e-05	6.10352e-05	0.00000	0.00000	0.00000
13	2.34330e-06	3.65624e-06	1.52588e-05	2.67977e-06	1.58865e-05	6.10352e-05	0.00000	0.00000	0.00000
14	1.27602e-06	2.86722e-06	1.52588e-05	4.47034e-06	1.55042e-05	6.10352e-05	0.00000	0.00000	0.00000
15	-1.57553e-06	3.15149e-06	1.52588e-05	-5.84233e-06	1.57901e-05	6.10352e-05	0.00000	0.00000	0.00000
16	5.44584e-06	3.28566e-06	7.62939e-06	4.06769e-06	1.72088e-05	6.10352e-05	0.000372250	0.0192876	1.00000



# In ABI FGF (75W)

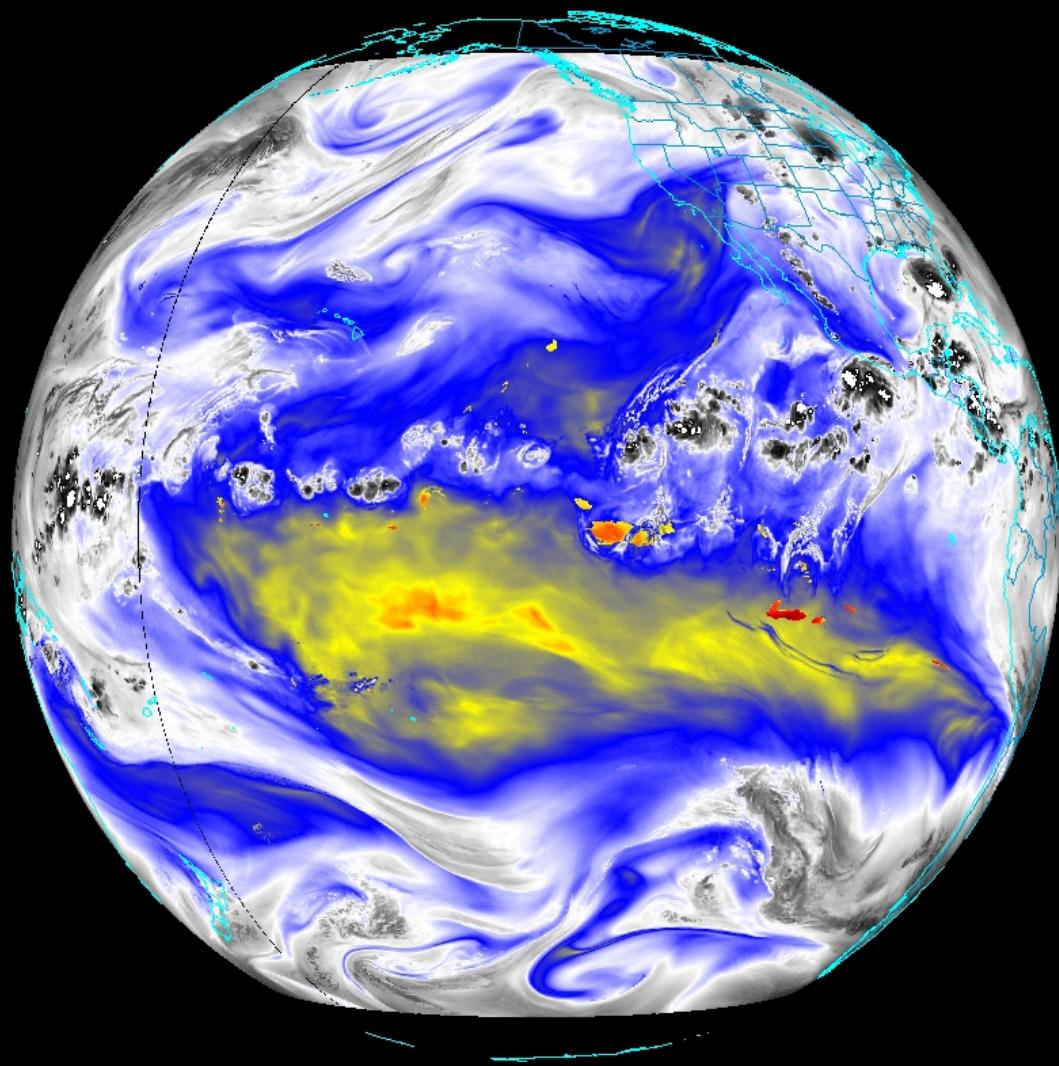


SSEC

WRF Simulation - 7.4  $\mu\text{m}$  Radiance - GOES-R EAST (75W)



# In ABI FGF (137W)

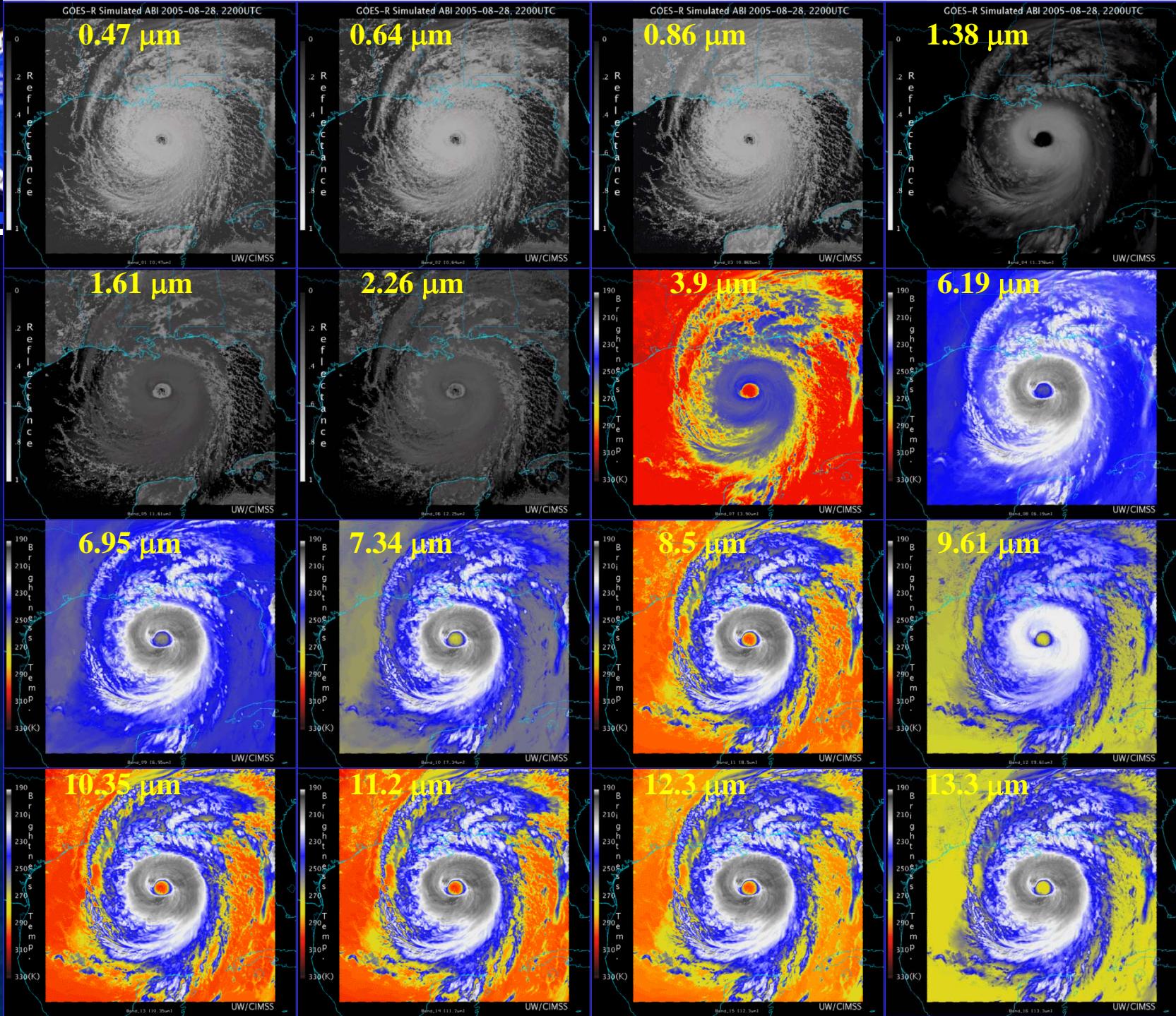


SSEC

WRF Simulation - 6.15 um Radiance - GOES-R WEST (137W)



AWG Proxy ABI Simulations of Hurricane Katrina

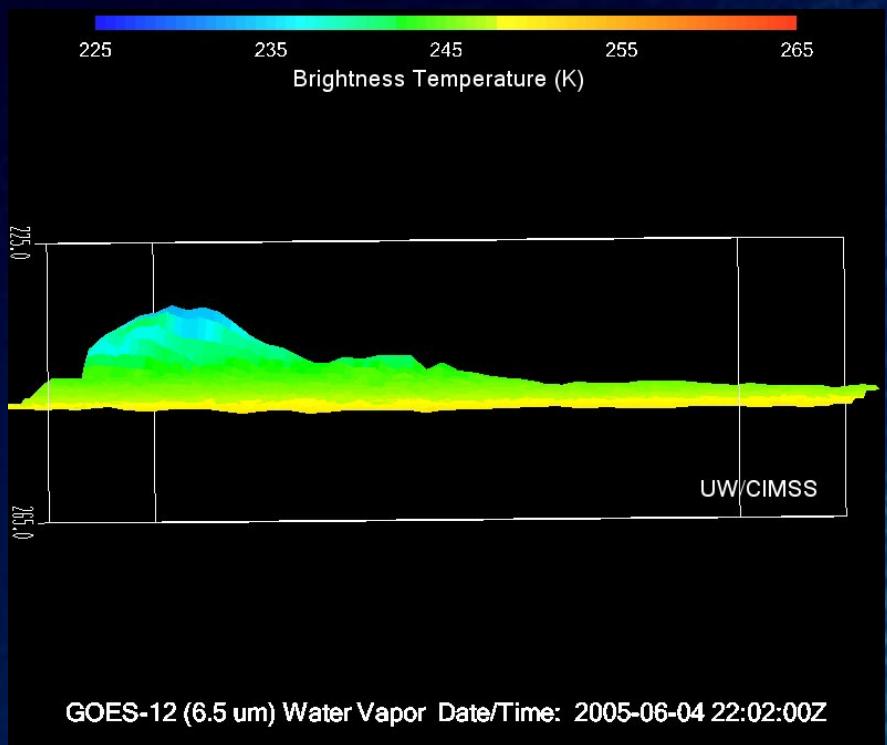


NOAA/NESDIS STAR and GOES-R Imagery Team

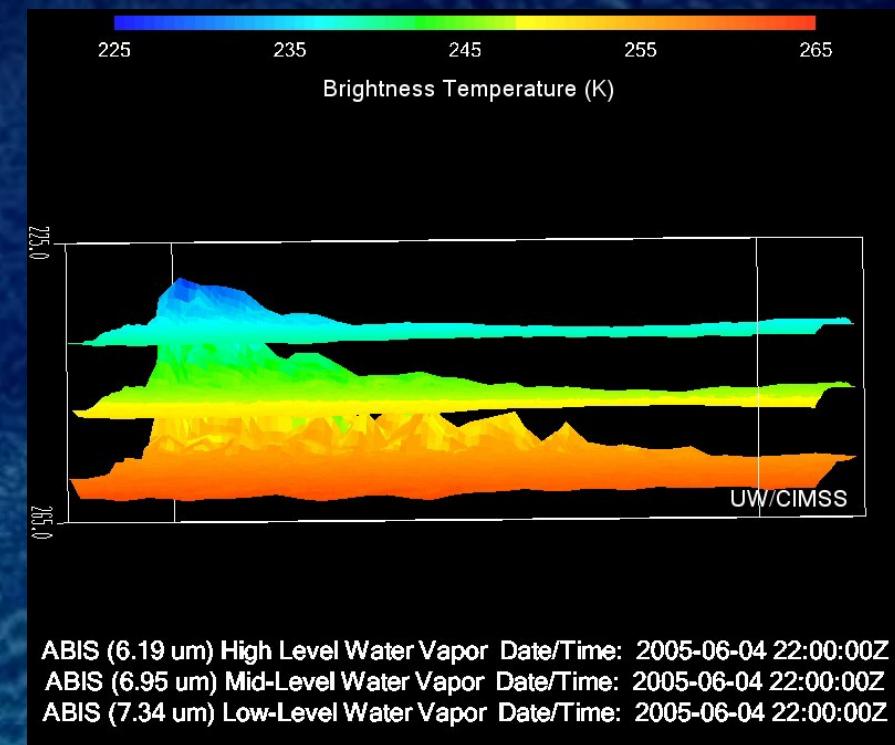


# McIDAS-V

<http://www.ssec.wisc.edu/mcidas/software/v/>



Current GOES



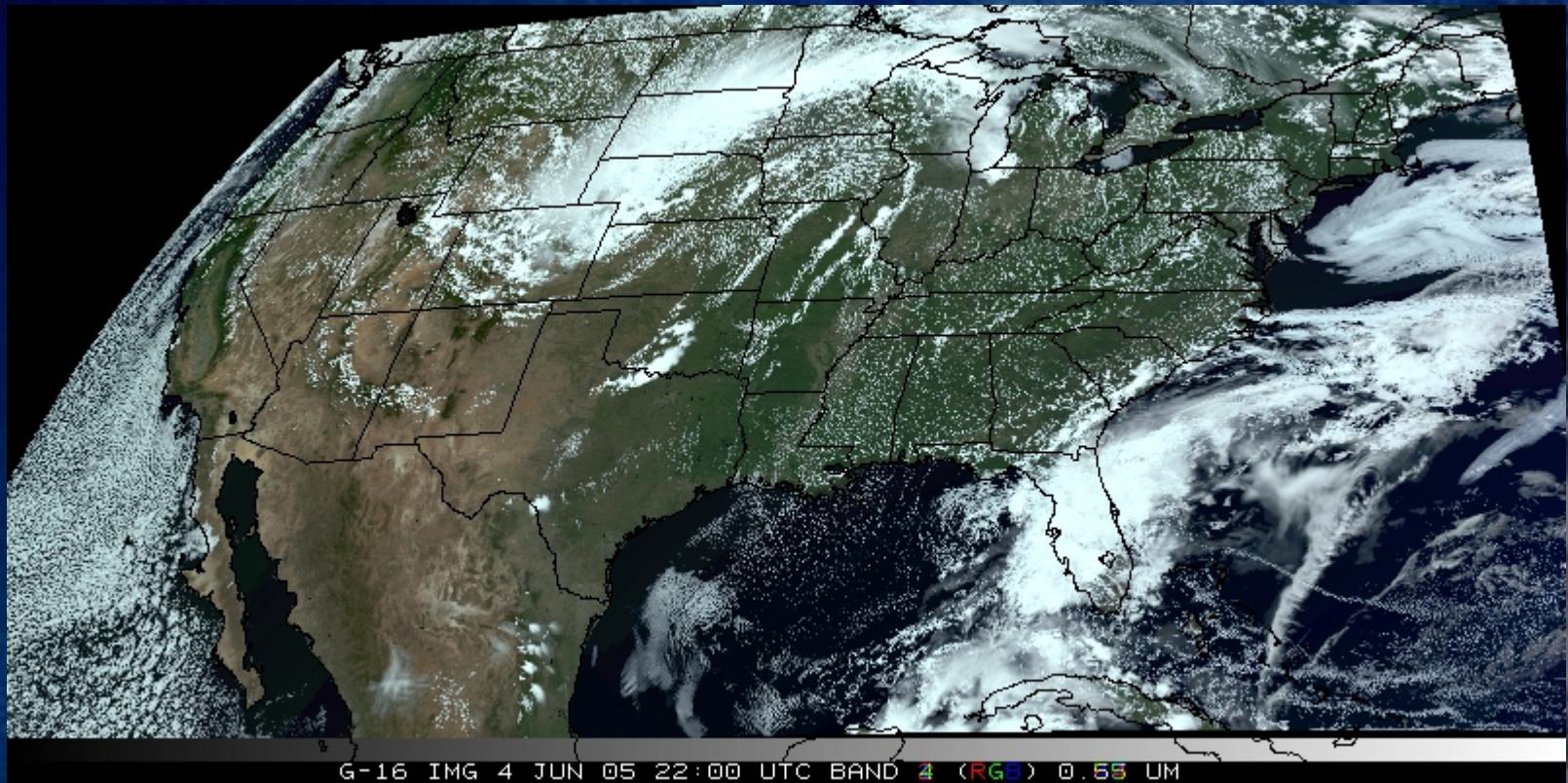
Future GOES

Images from J. Feltz, SSEC



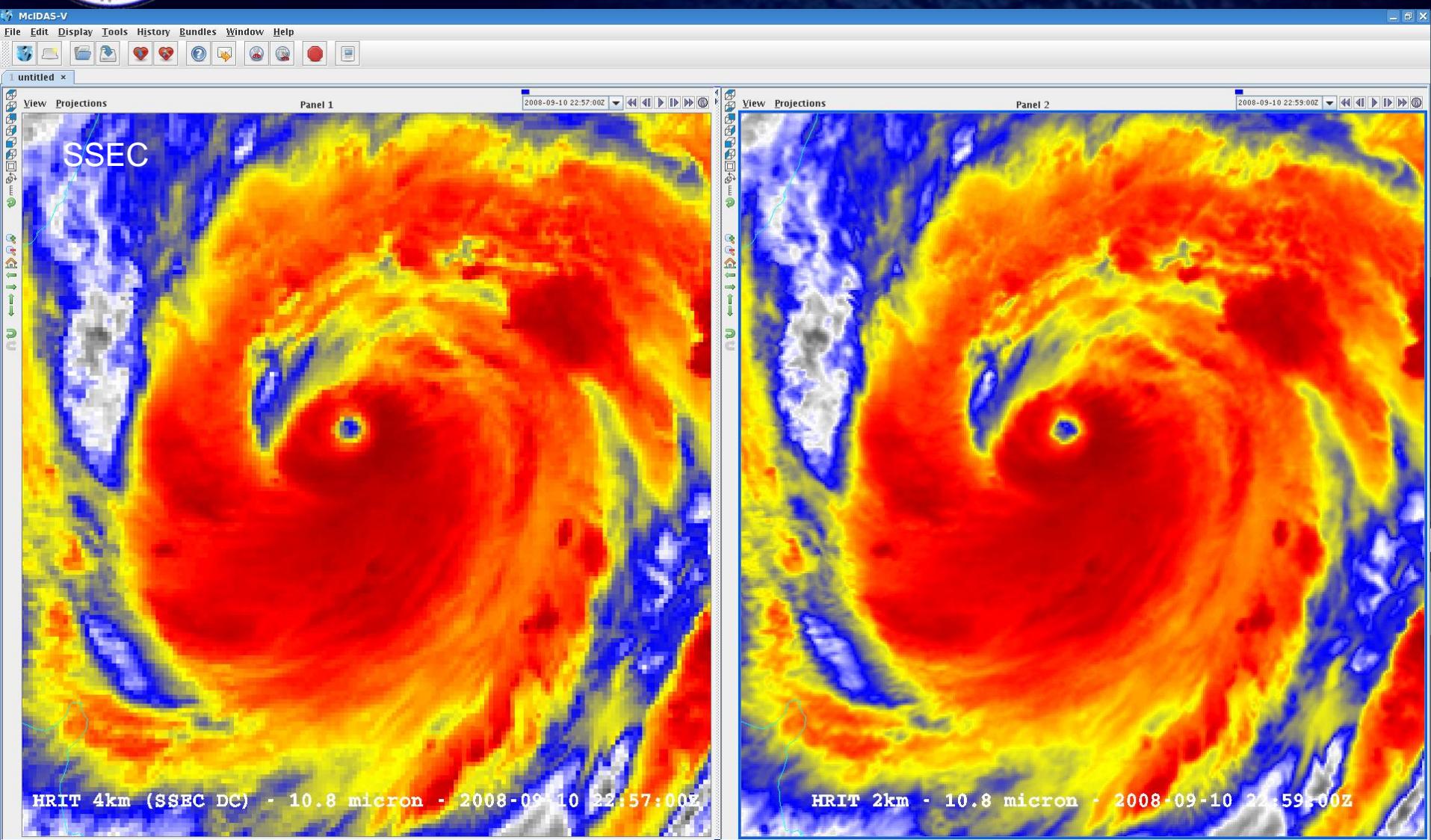
# Visualization ("decision aid")

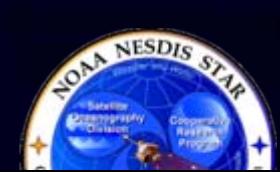
- “True Color” with “synthetic” green from ABI simulated data (from CIMSS); image from Don Hillger, RAMMB.





# Visualization (2 km MTSAT; data from JMA)





# Visualization (animation)

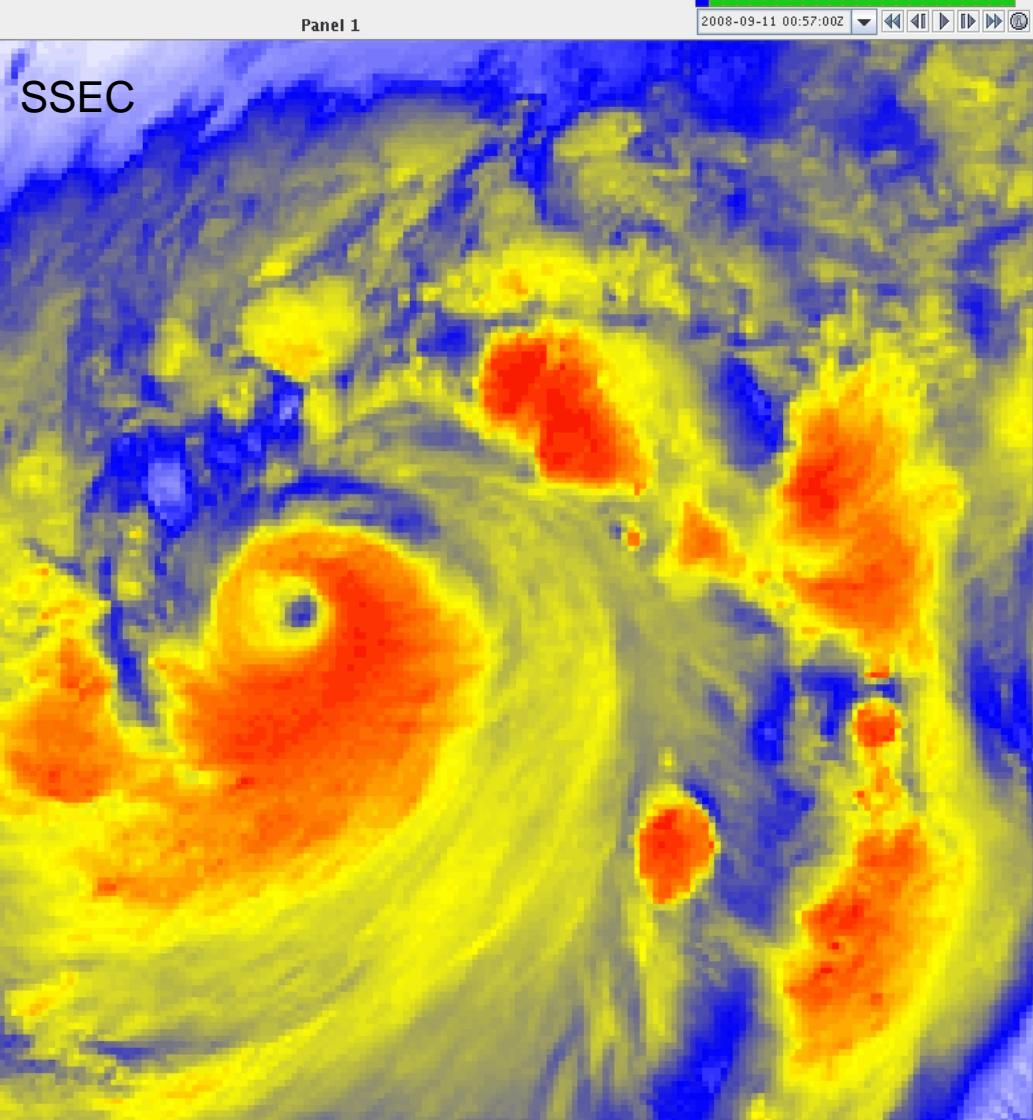
History Bundles Window Help



Panel 1

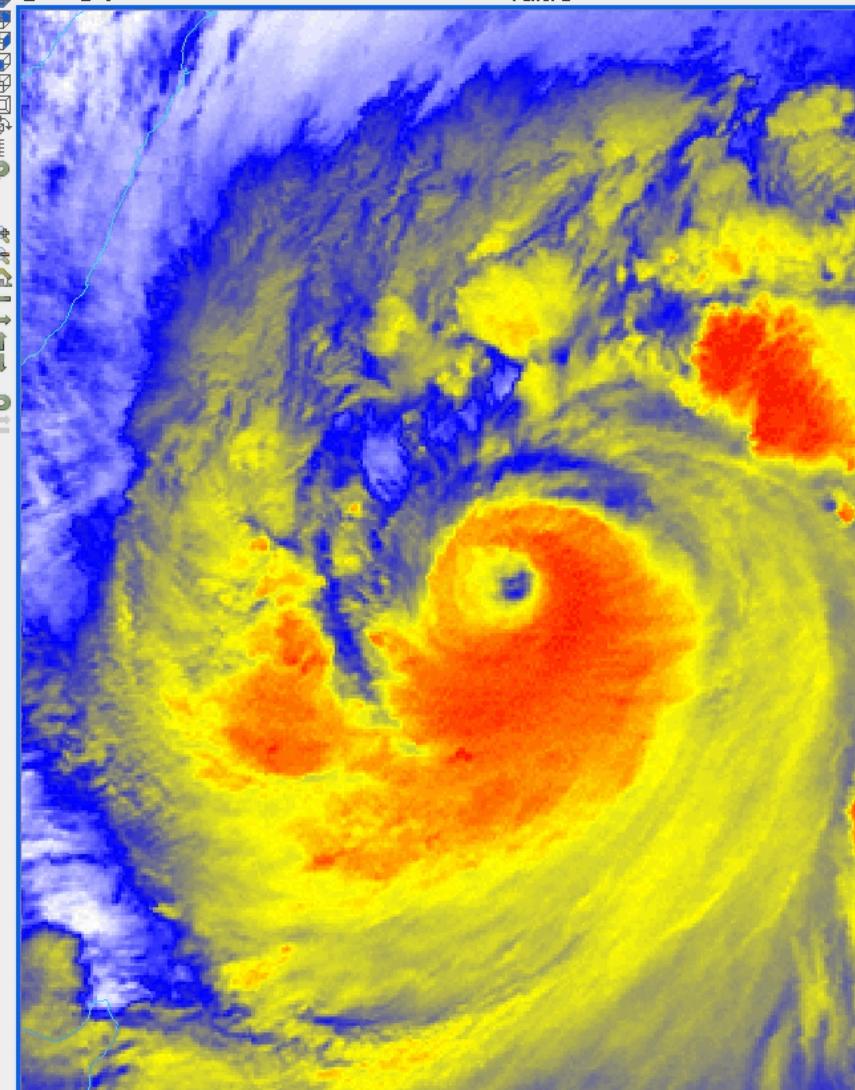
2008-09-11 00:57:00Z

SSEC



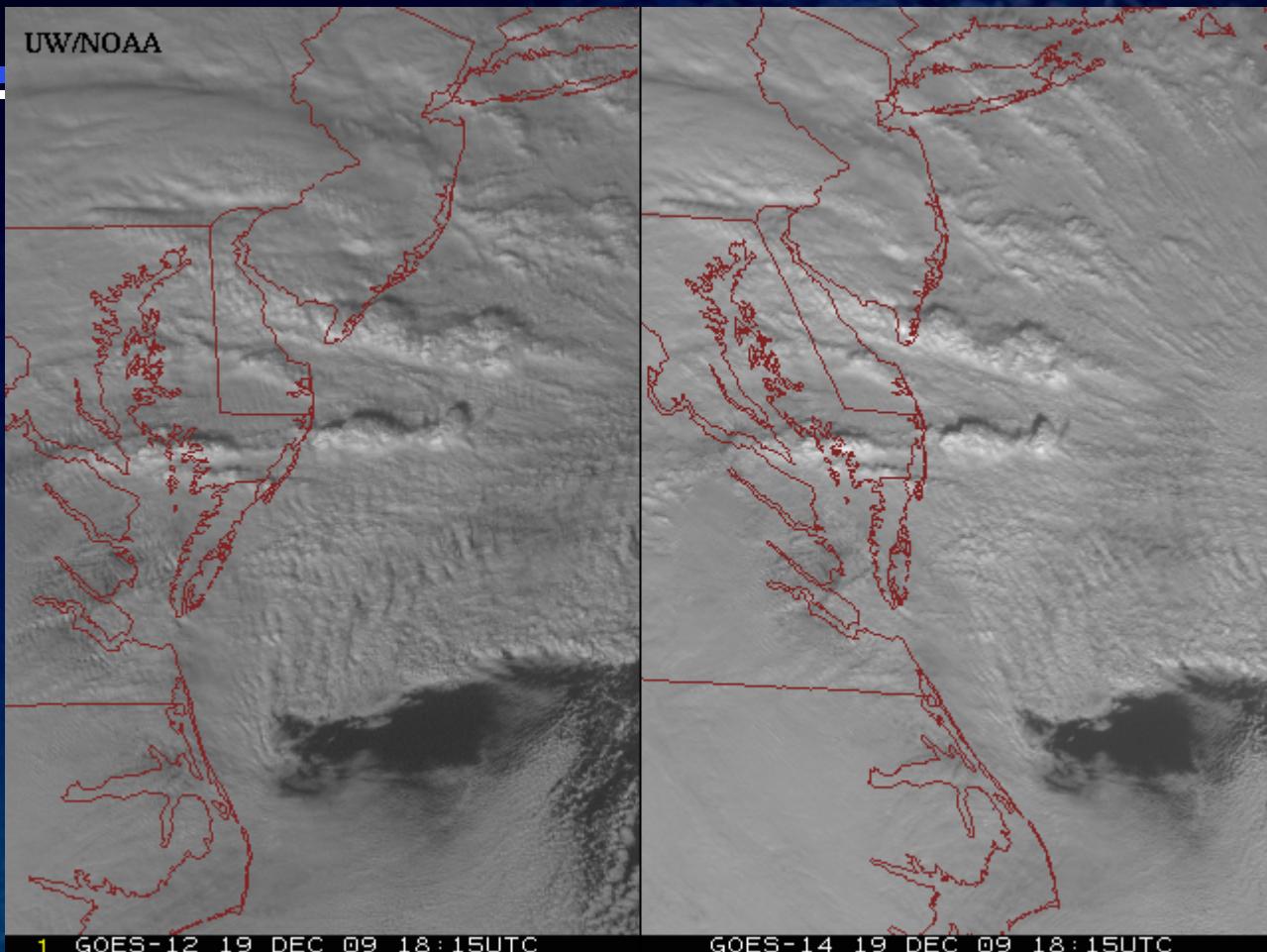
View Projections

Panel 2





# GOES-14: Sample “1-min” imagery



GOES-12

GOES-14

Visible data from the recent NOAA Science Test, lead by Hillger and Schmit



# Summary

- The imagery team was one of the last baseline product teams to form (Imagery Kickoff Meeting – 06/26/08)
- The 80% imagery ATBD was completed in September 2009.
- Imagery is the key product for GOES-R.
- The team has met the schedules (draft ATBD, CDR, TRR), mostly using simulated ABI data.
- Re-working for radiance scaling (bands 1-6), bit depth, FGF, etc.