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

NWP opportunities with the Advanced Baseline Imager (ABI) on the GOES-R series

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Science Center
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JCSDA Seminar
14 December 2011

UW-Madison

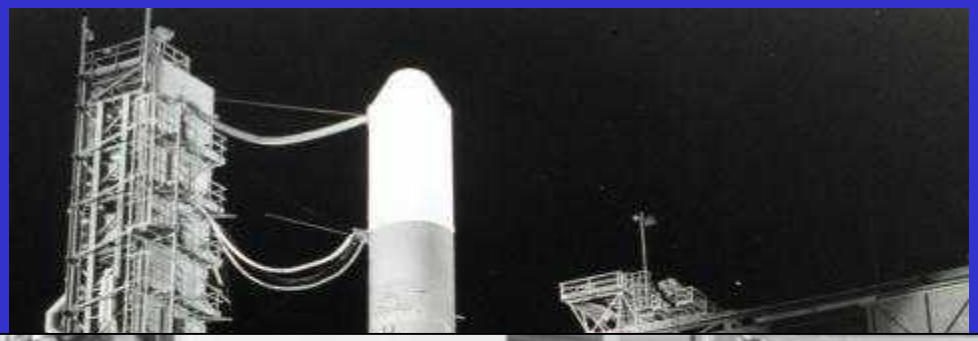
Thanks to…

- The JCSDA for the invitation.
- Shobha Kondragunta, Brad Pierce, Kaba Bah, Mathew M. Gunshor, Jun Li, Scott Bachmeier, Steve Ackerman, Bob Aune, Don Hillger, Paul Menzel, Steve Ackerman, Tony Schreiner, Jason Otkin, Justin Sieglaff, Jim Jung, Elaine Prins, Joleen Feltz, Wayne Feltz, Jean Phillips, Gary Wade, Don Hillger, Jinlong Li, Jing Zheng, William Straka, Allen Huang, Bob Rabin, the SSEC data center, Mike Pavolonis, Jaime Daniels, ASPB, STAR, NESDIS, NSSL, Steve Weygandt, Haidao Lee, Mark DeMaria, and many others!
- GOES-R Program Office (Steve Goodman, Jim Gurka, etc.), NASA, ITT Industries, other industry partners, etc.
- You.

Outline

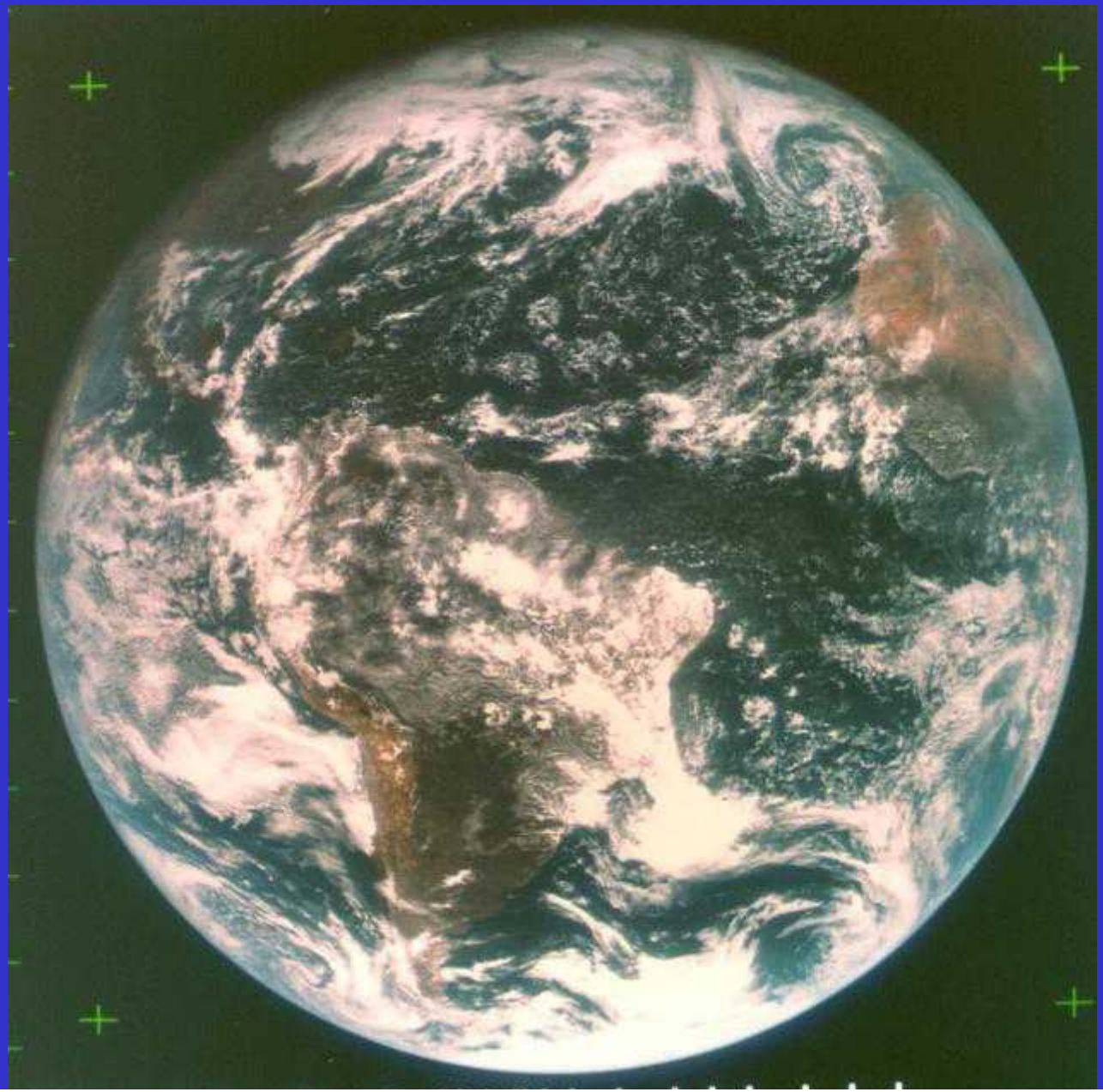
- History
- Current GOES Imager and Sounder
  - GOES-14/15
- ABI (Advanced Baseline Imager)
  - Temporal
  - Spatial
  - Spectral
- Select Products
- High Spectral resolution
- Summary
  - More information
  - Questions

On 6 December 1966 the Applications Technology Satellite (ATS-1) was launched. We have had the benefit of the geostationary perspective for 45 years!



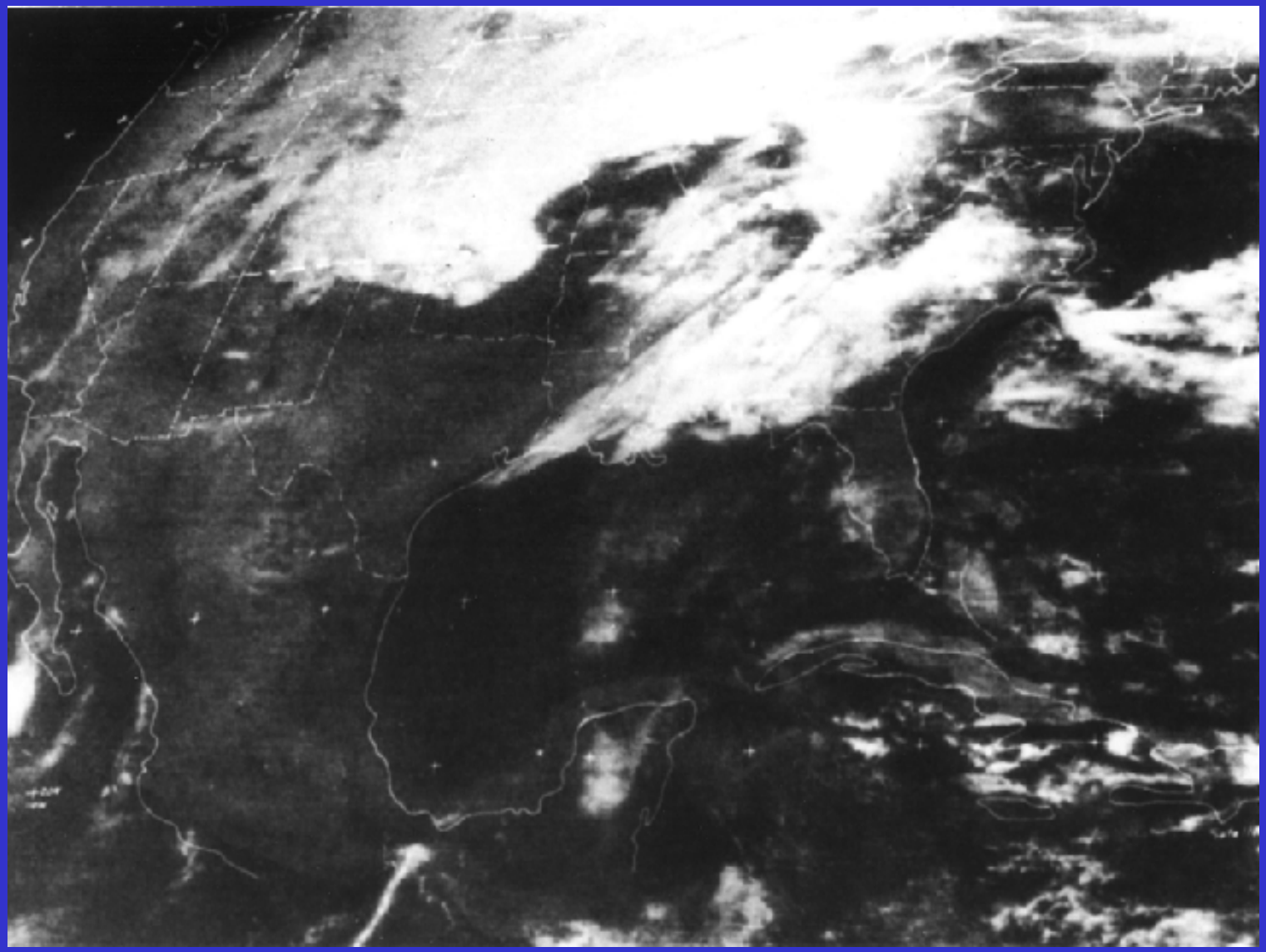
ATS-1's spin scan cloud camera (UW's Suomi and Parent 1968) provided full disk visible images of the earth and its cloud cover every 20 minutes. The spin scan camera on ATS-1 occurred because of an extraordinary effort by Verner Suomi and Homer Newell, when the satellite was already well into its fabrication.

ATS-III 18Nov1967 15UTC



Verner E. Suomi and Robert J. Parent

ATS-3: Visible (3 April 1974)



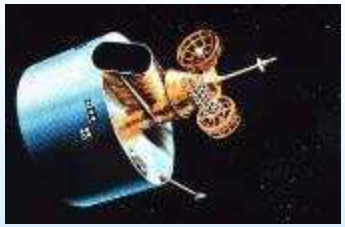
ATS -3

GOES History

GOES-1/3

Launched
1975
1977
1978

One visible and one infrared . Operational.



GOES-4/7

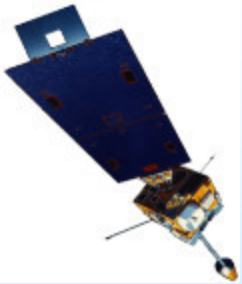
Launched
1980
1981
1983
1987

VISSR–VAS visible, 12 IR. MSI (visible, IRW, and 2 additional IR channels)

GOES-8/12

Launched
1994
1995
1997
2000
2001

3-axis stabilized. Imager Bands: 4 IR; 1 visible. Operational Sounder (18 IR bands)



GOES-13/14/15

Launched
2005
2009
2010

Better navigation and calibration.
No eclipse outages.
Better spatial resolutions for the 6.5 um on GOES-12+ and the 13.3 um band on GOES-14/15.
Operational Sounder

GOES-R/S+

Planned Launch
2015
2017
2020
2025

Faster coverage.
16 Imager Bands.
Improved spatial.
No sounder.
GLM

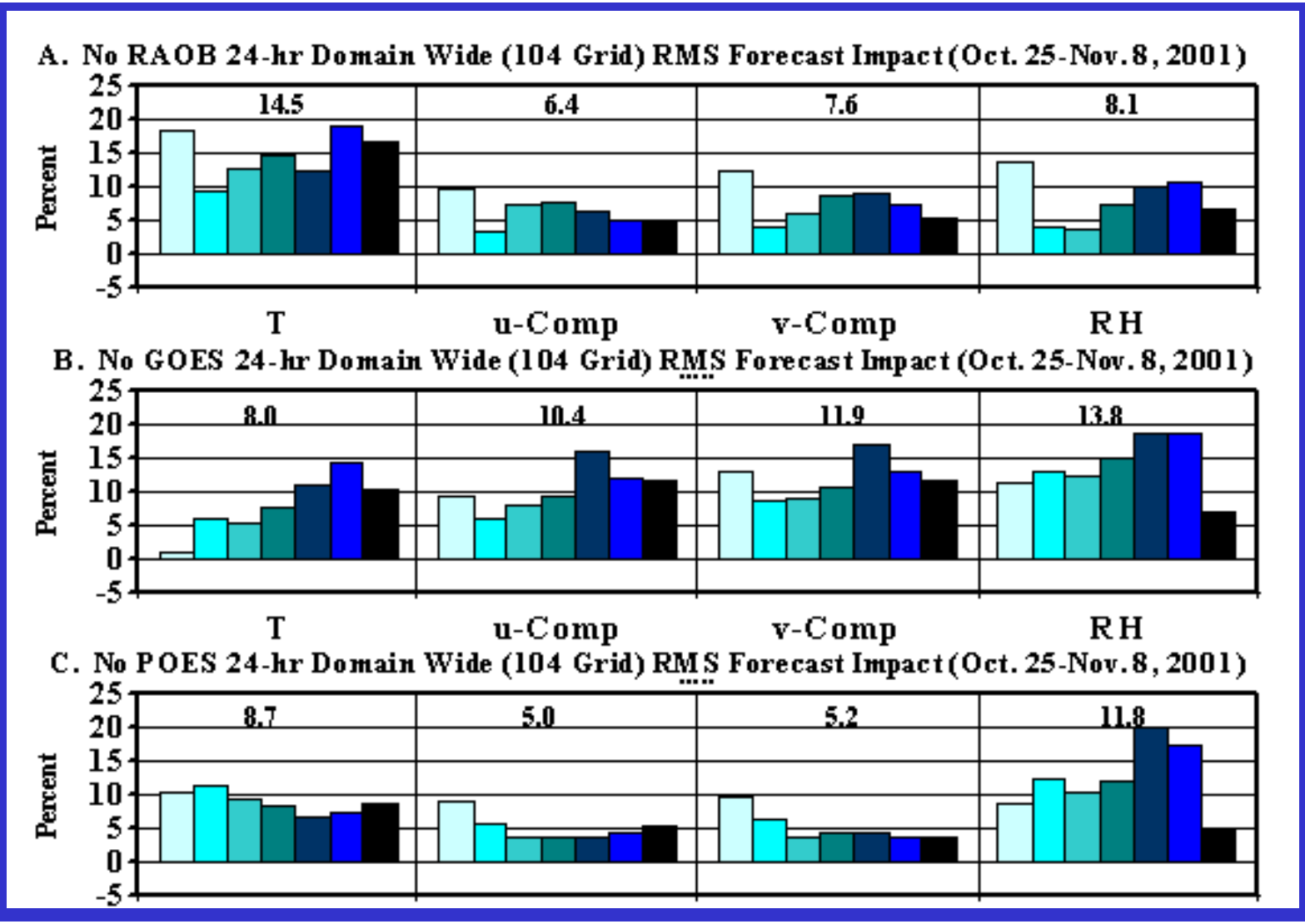
Impact Study of RAOB, GOES, and POES data on Eta Data Assimilation System

RAOBs, GOES and POES all contribute unique information!

Zapotocny, T. H., W. P. Menzel, J. A. Jung, and J. P. Nelson III, 2005: A four season impact study of rawinsonde, GOES and POES data in the Eta Data Assimilation System. Part I: The total contribution. Wea. Forecasting, **20**, 161-177.

Zapotocny, T. H., W. P. Menzel, J. A. Jung, and J. P. Nelson III, 2005: A four season impact study of rawinsonde, GOES and POES data in the Eta Data Assimilation System. Part II: Contribution of the components. Wea. Forecasting, **20**, 178-198.

Zapotocny, T. H., W. P. Menzel, J. P. Nelson III, and J. A. Jung, 2002: Impact Study of Five Satellite Data Types in the Eta Data Assimilation System in Three Seasons. Weather and Forecasting, **17**, 263-285.

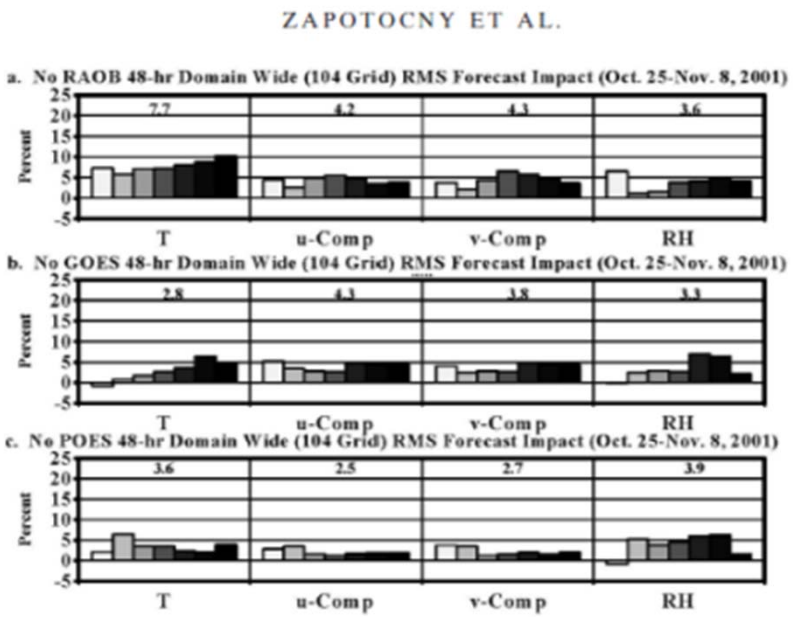


Oct 2001 forecast impact (%) for T, u, v, RH fields after 24-hrs of Eta model integration

Zapotocny, 2005

Positive Impact still at 48-hours

- Regional forecast impact at 48 h
- Overall, the forecast impact from virtually every parameter, data type, and level decreased from 24 to 48 h.
- Some impacts decreased by as much as a factor of 3, while others decreased by substantially less.
- A drop in forecast impact from 24 to 48 h is not surprising, considering the regional nature of the EDAS and the ever-growing importance of the lateral boundary conditions as the integration proceeds.
- Finally, there is limited evidence that global models exhibit the opposite trend, with the importance of some remotely sensed data sources increasing as the length of the integration proceeds (T. J. Schmit, 2003, personal communication).

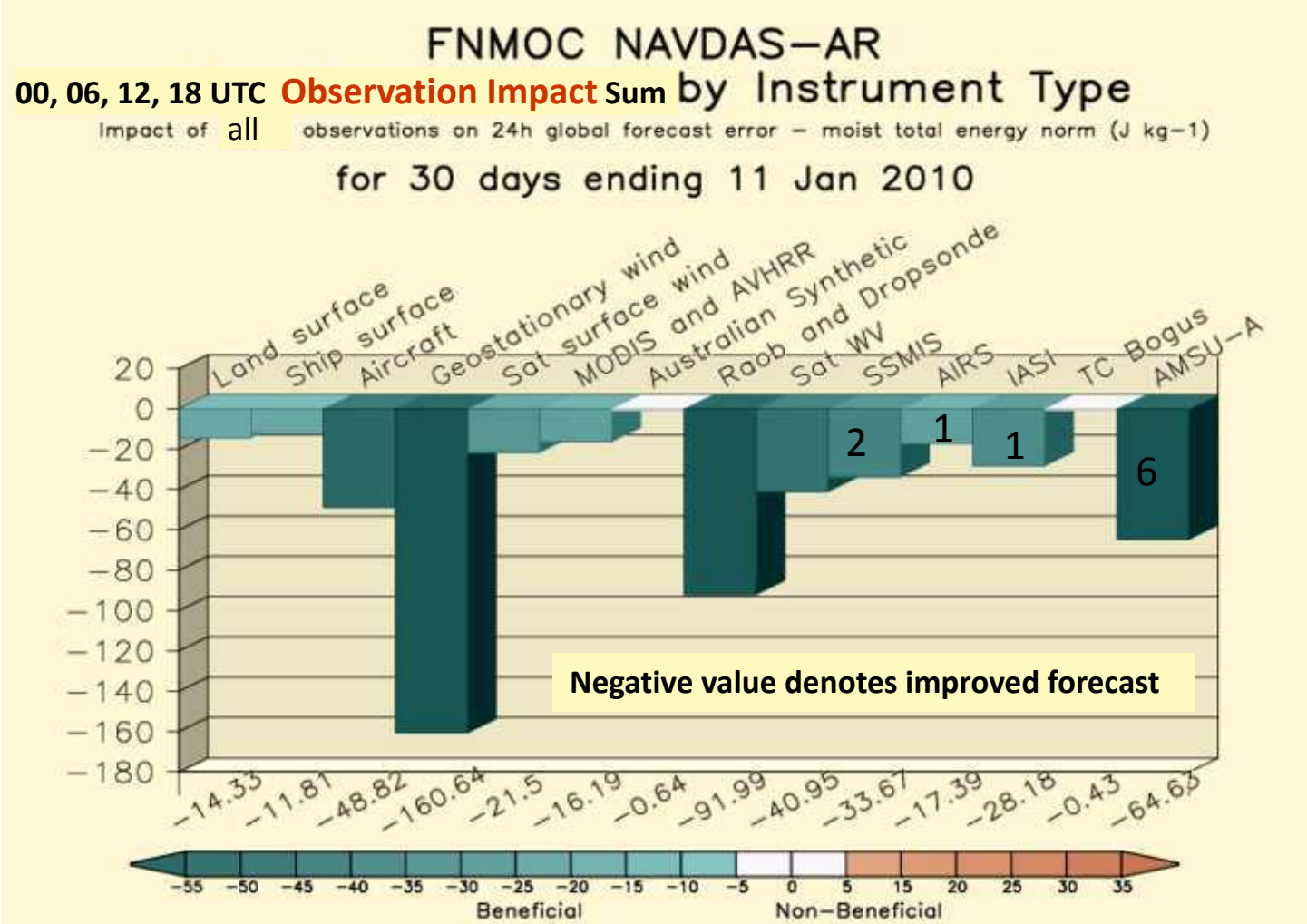


Zapotocny, 2005

Importance of Satellite Data in NWP

http://www.nrlmry.navy.mil/obsens/

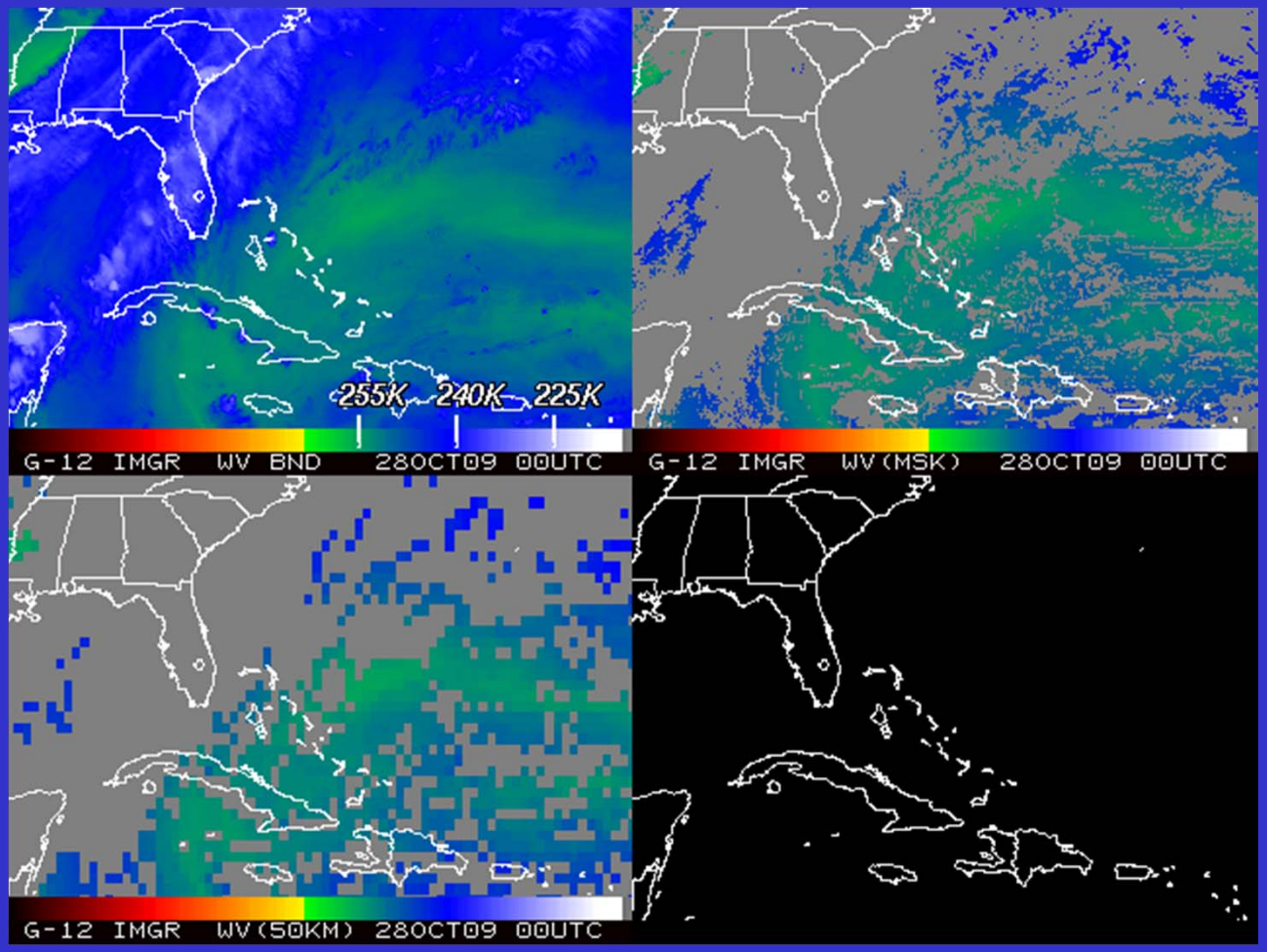
Satellite Data has become the single most important component of the global observing network for NWP



Nancy Baker, NRL

Σ Sat Winds = -198.3 **Σ Conv = -168.0** **Σ Sat Radiances = -143.9**

Satellite Data Assimilation



The challenge (from satellite imagery to NWP)!

Outline

- History
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- Select Products
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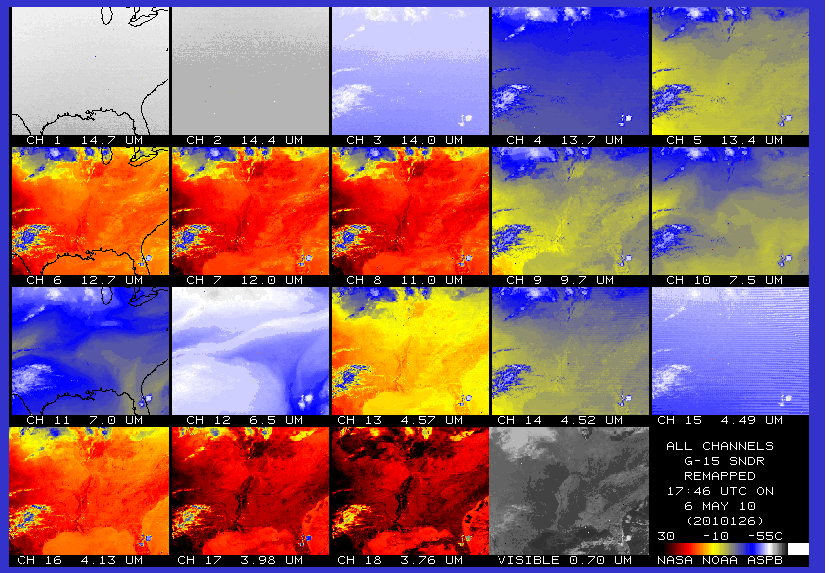


GOES-15

GOES-13/14/15 have similar instruments to GOES-8-12, but on a different spacecraft bus.

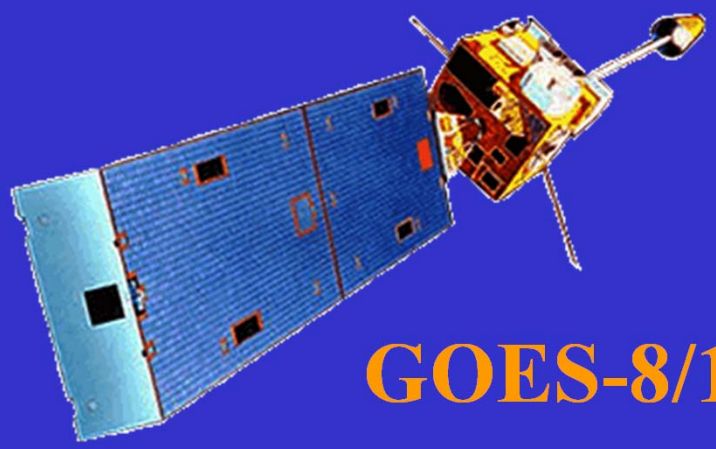
Spring and fall eclipse outages will be avoided by larger onboard batteries.

Improved navigation

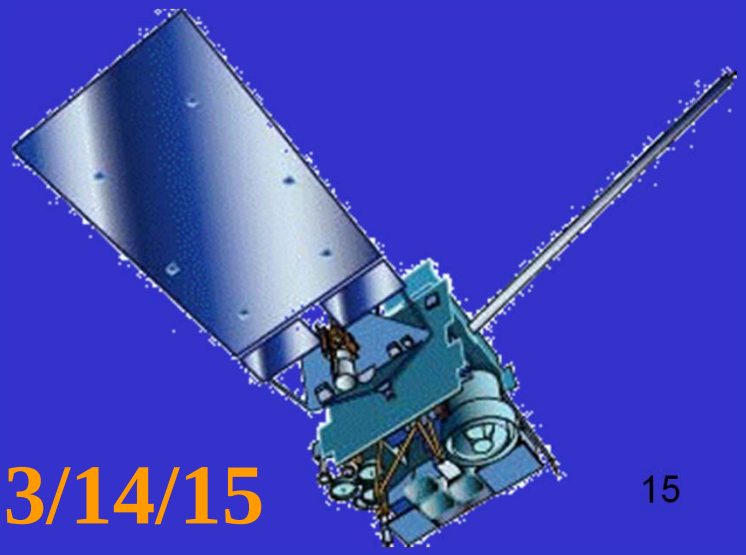
Improved radiometrics

Similar stray light to GOES-13/14

Operational on Dec 6th, 2011

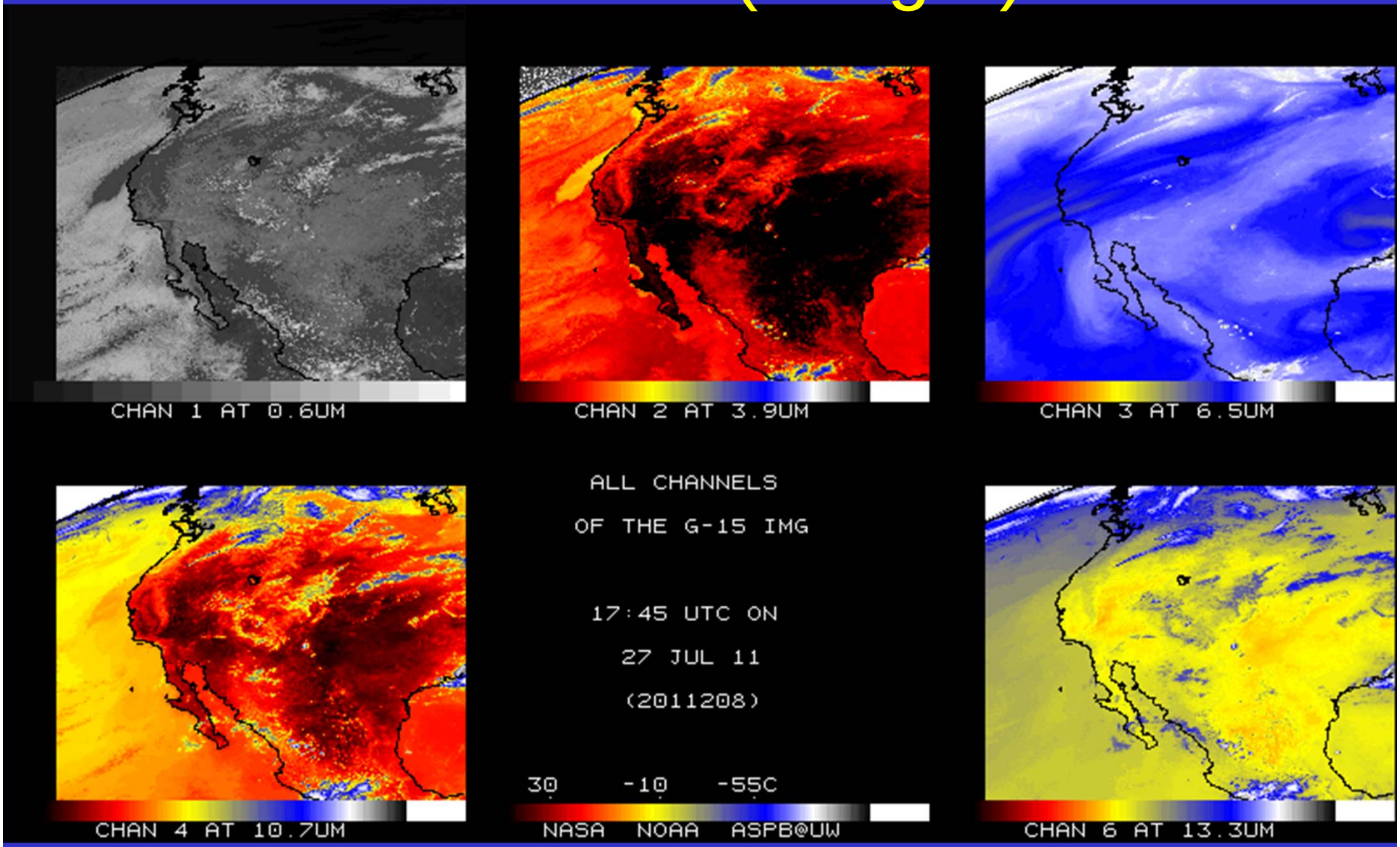


GOES-8/12



GOES-13/14/15

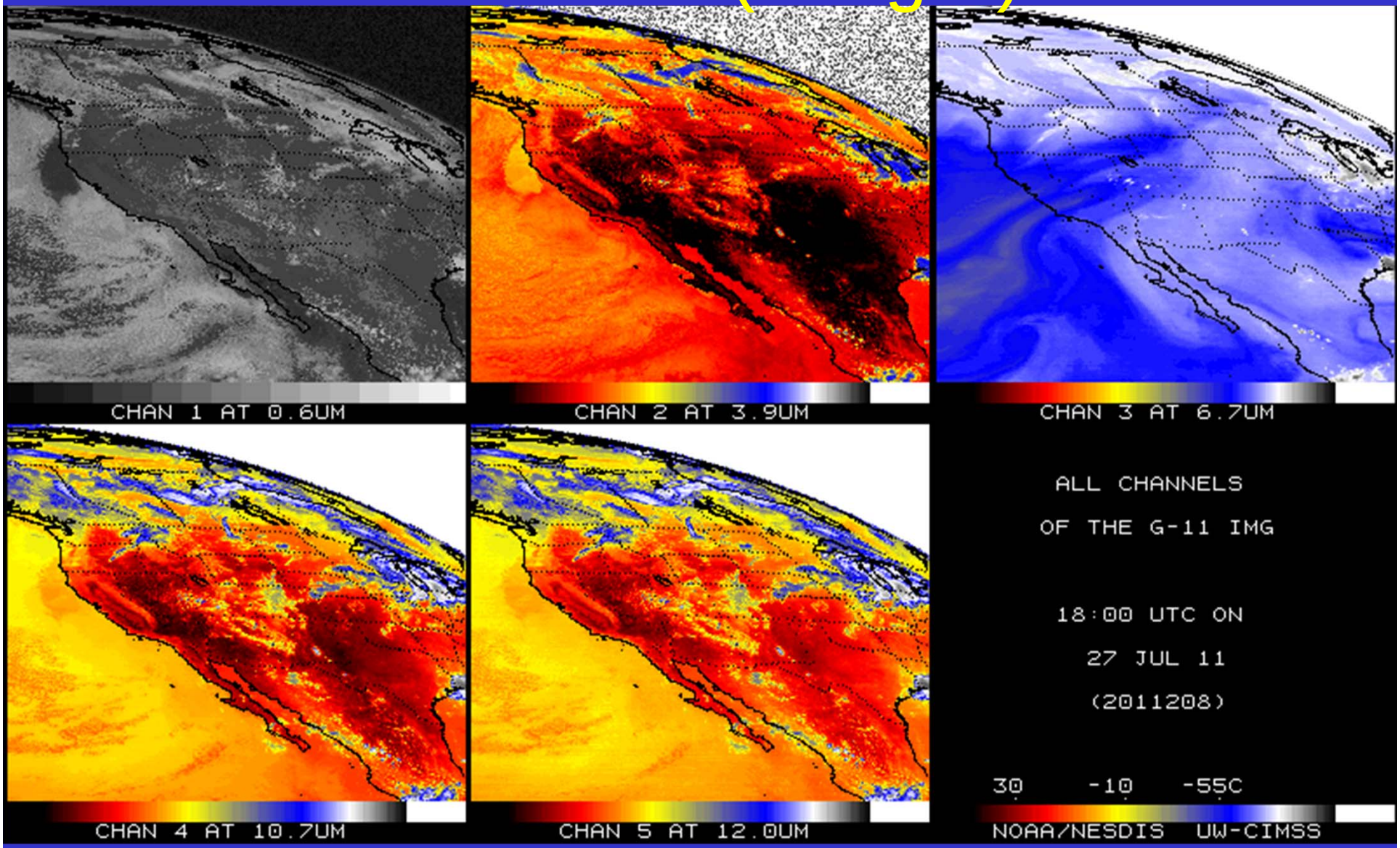
GOES-15 (Imager)



Native projection

From NOAA ASPB

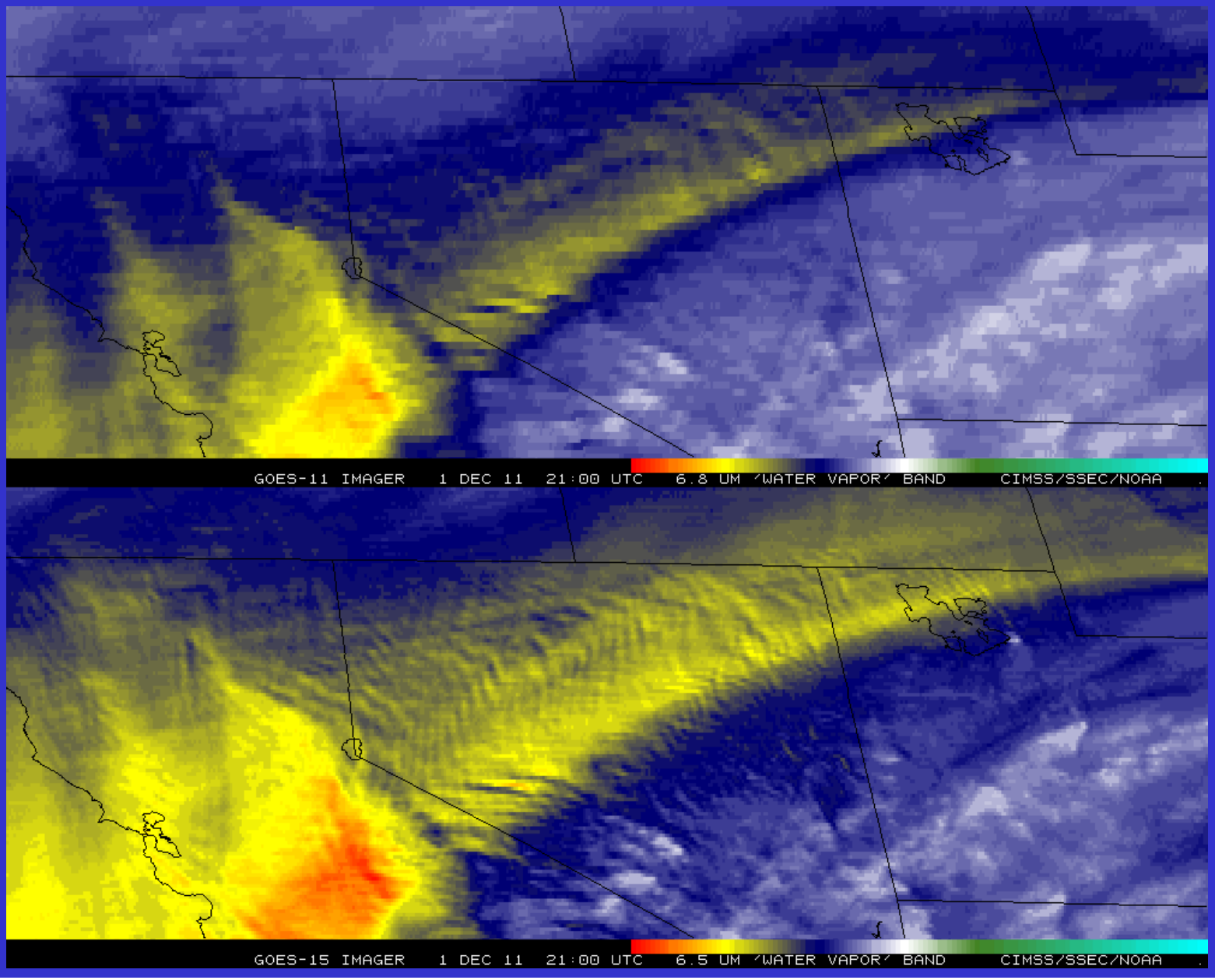
GOES-11 (Imager)



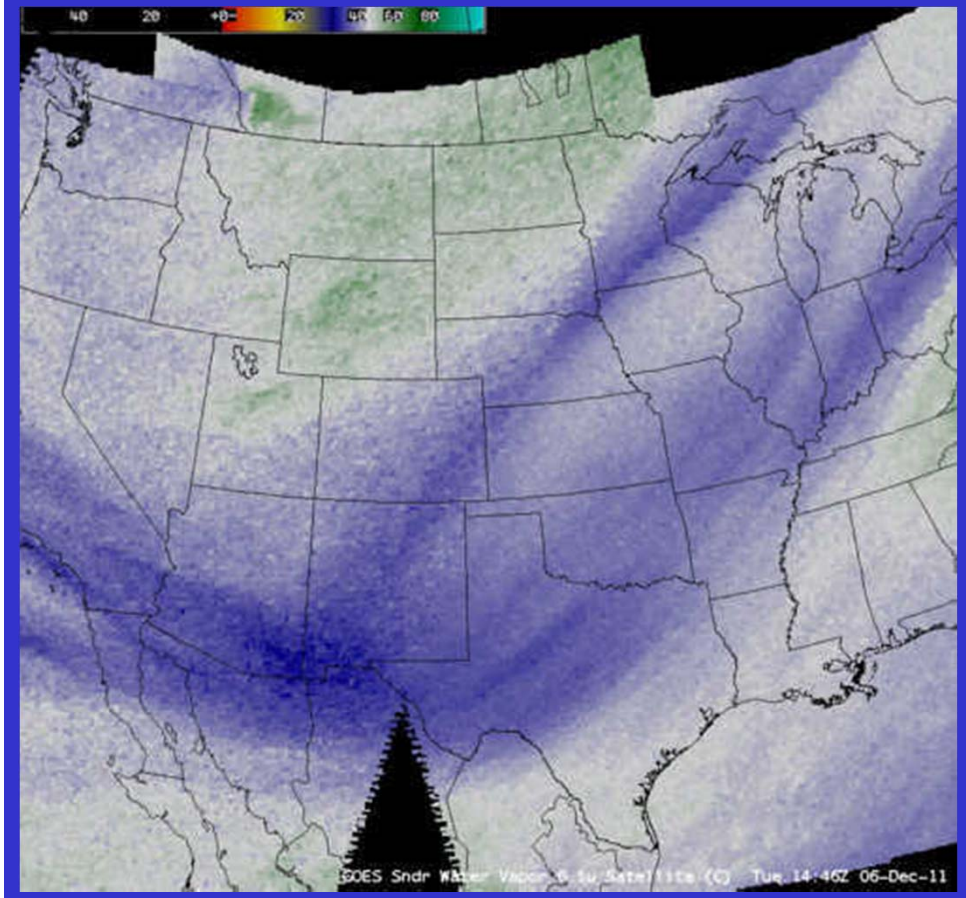
Native projection

From NOAA ASPB

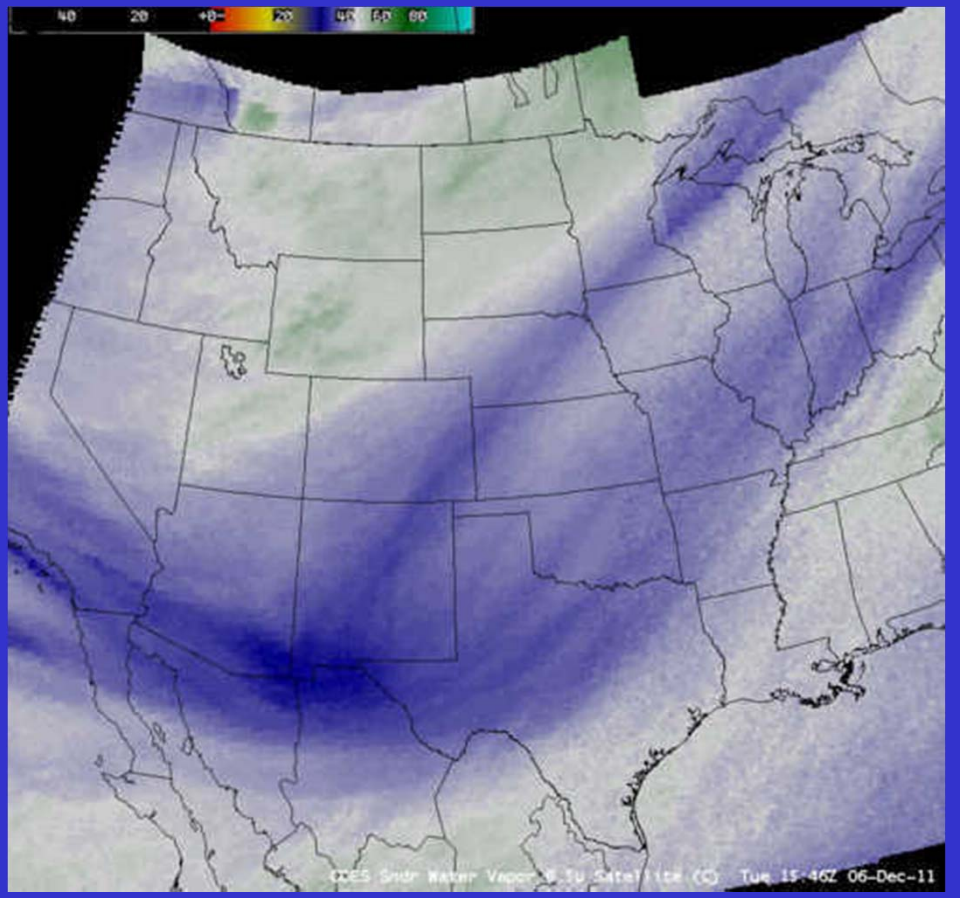
GOES-11 vs GOES-15 (WV)



GOES-11 vs GOES-15 (Sounder)



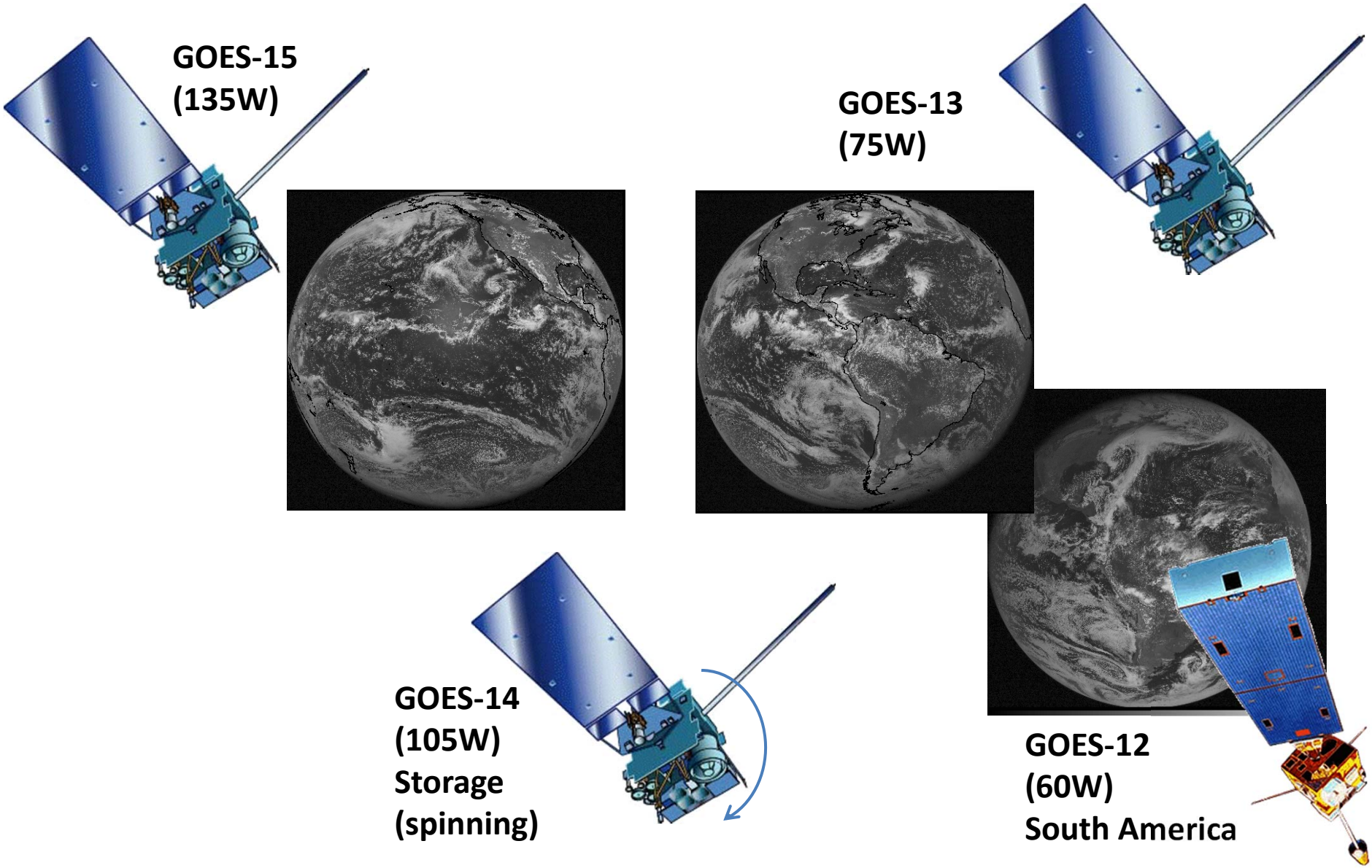
GOES-11



GOES-15

AWIPS – Sounder band 12; 6.5 micrometers

NOAA GOES Constellation



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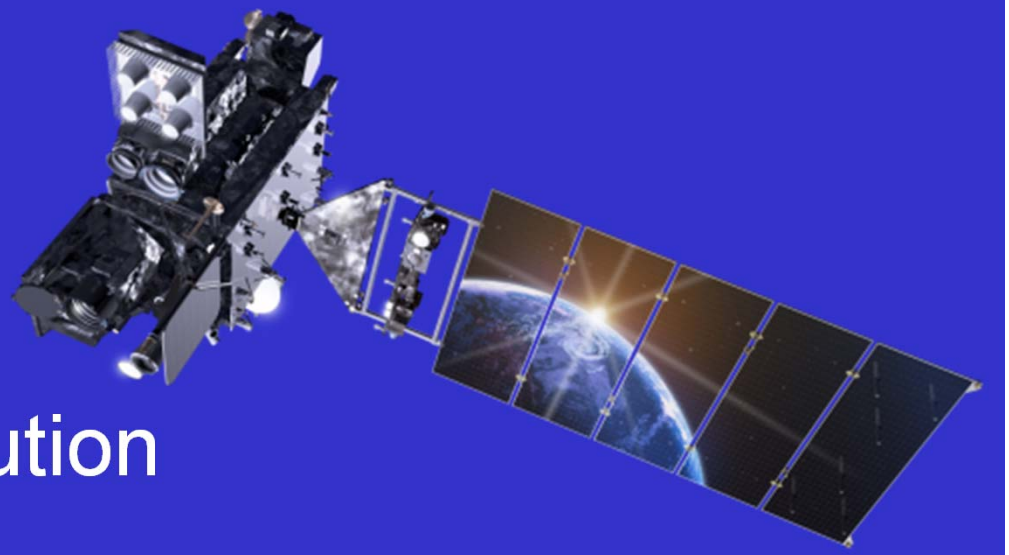
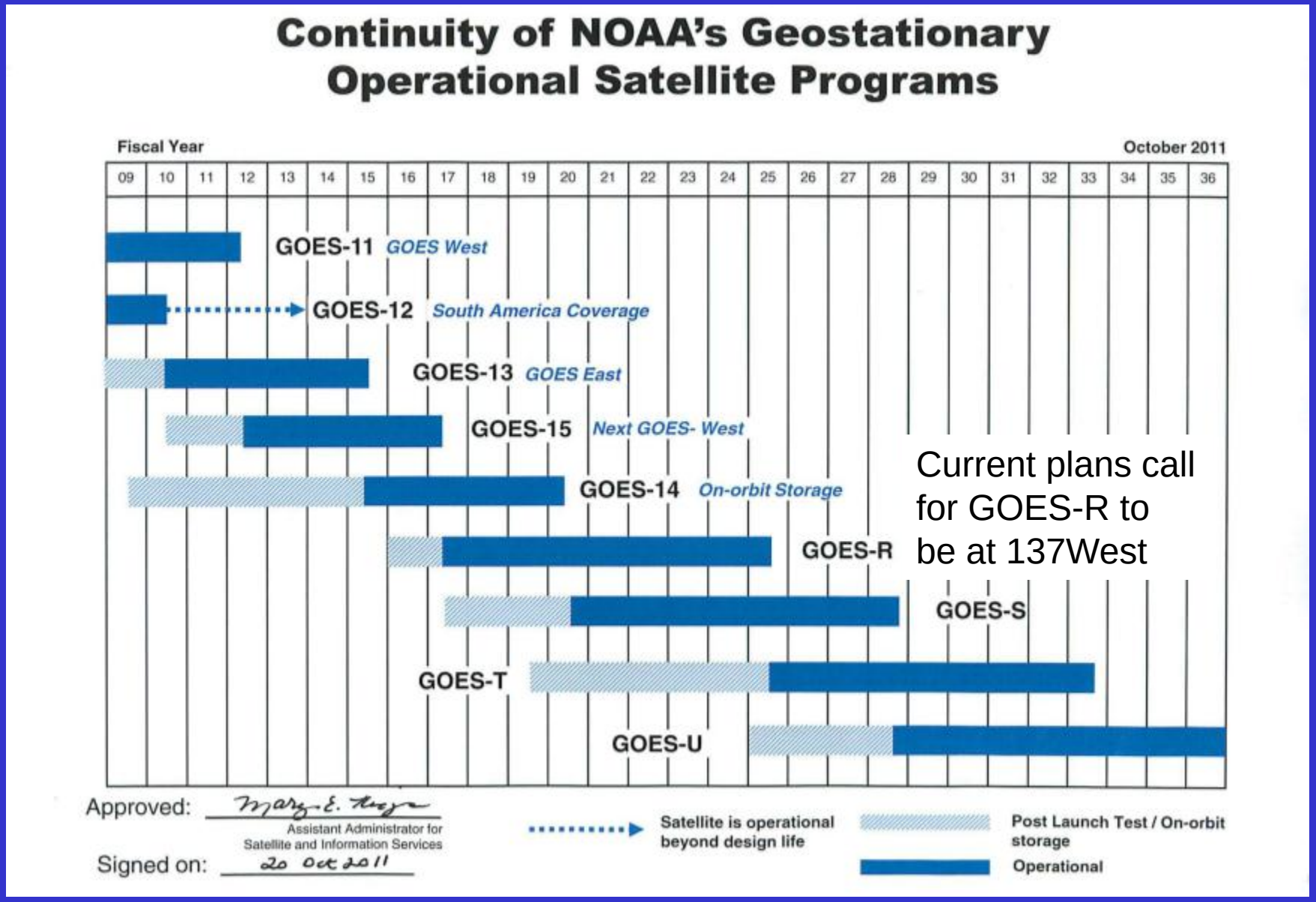


Lockheed Martin

GOES-R Overview

- Advanced Baseline Imager (ABI)
- No dedicated Sounder
- Geostationary Lightning Mapper (GLM)
- Space Weather
  - Space Environmental In-Situ Suite (SEISS)
  - Solar Ultra Violet Imager (SUVI)
  - Extreme Ultra Violet/X-Ray Irradiance Sensor (EXIS)
  - Magnetometer
- Communications
  - GOES Rebroadcast (GRB)
  - Low Rate Information Transmissions (LRIT)
  - Emergency Managers Weather Information Network (EMWIN)
  - Search and Rescue (SAR)
  - Data Collection System (DCS)

GOES Fly-out


Continuity of NOAA's Geostationary Operational Satellite Programs
Fiscal Year
October 2011
09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
GOES-11 GOES West
GOES-12 South America Coverage
GOES-13 GOES East
GOES-15 Next GOES- West
GOES-14 On-orbit Storage
GOES-R
GOES-S
GOES-T
GOES-U
Current plans call for GOES-R to be at 137West
Approved:
Assistant Administrator for Satellite and Information Services
Signed on: 20 Oct 2011
Satellite is operational beyond design life
Post Launch Test / On-orbit storage
Operational

The Advanced Baseline Imager:

	ABI	Current
Spectral Coverage		
	16 bands	5 bands
Spatial resolution		
0.64 μm Visible	0.5 km	Approx. 1 km
Other Visible/near-IR	1.0 km	n/a
Bands (>2 μm)	2 km	Approx. 4 km
Spatial coverage		
Full disk	4 per hour	Scheduled (3 hrly)
CONUS	12 per hour	~4 per hour
Mesoscale	Every 30 sec	n/a
Visible (reflective bands)		
On-orbit calibration	Yes	No

Mission Planning

- STAR very involved during the early GOES-R series development. This includes: formulation studies for both ABI and advanced geostationary sounder, ABI band selection and modification, Technical Requirement Documents, Performance and Operational Requirements Document, etc.

Proposed ABI (8 or 12) channels

Wavelengths Range (μm)	Center	Description	Primary Use
0.59 – 0.69	**0.64**	Visible	Daytime cloud, smoke, fog
0.81 - 0.91	**0.86***	Solar window	Daytime cloud, NDVI, fog, aerosol, ocean studies
1.36 - 1.39	**1.375***	Near IR	Daytime thin cirrus detection
1.58 – 1.64	**1.61**	Near IR	Daytime clouds/snow, water/ice clouds
3.8 – 4.0	**3.9**	Shortwave IR	Nighttime low clouds, fog, fire detection
5.7 – 6.6	**6.15**	Water Vapor 1	Upper tropospheric flow, winds
6.8 – 7.2	**7.0**	Water Vapor 2	Mid tropospheric flow, winds
8.3 – 8.7	**8.5***	IR Window 1	Sulfuric acid aerosols, cloud phase
10.1 – 10.6	**10.35***	IR Window 2	Cloud particle size, sfc properties
10.8 – 11.6	**11.2**	IR Window 3	Clouds, low-level water vapor, fog, winds, SST
11.8 – 12.8	**12.3**	IR Window 4	Low-level water vapor, volcanic ash, SST
13.0 – 13.6	**13.3**	Carbon Dioxide	Cloud-top parameters, heights for winds

* proposed additional channel to baseline of eight channels.

NOAA's Technical Requirements for a Geostationary Advanced Baseline Imager (ABI)

October 19, 1999
Draft Version 0.5

1. Requirements Overview

This technical requirements document (TRD) presents detailed requirements for an operational advanced imaging instrument for the GOES platform. The TRD is NOAA's statement of performance characteristics drawn from the National Weather Service (NWS) Operational Requirements Document (ORD), January 1999, from the results of Phase-A instrument concept studies, and from scientific technical and cost trade analyses. The requirements represent NOAA's advanced baseline for geostationary imaging performance, and thus the notional instrument they define is termed the Advanced Baseline Imager (ABI).

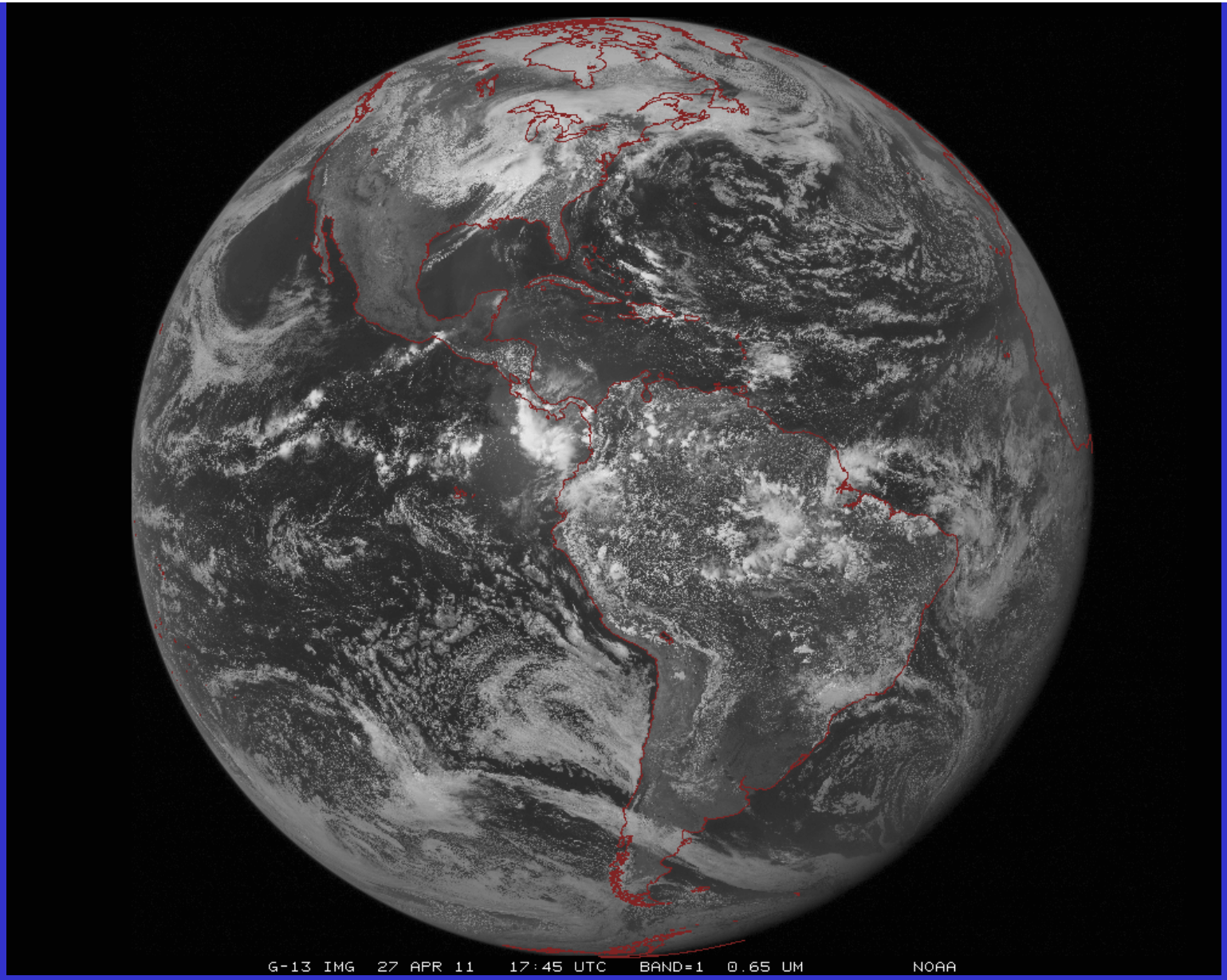
NOAA is submitting this TRD to NASA for use in generating requests for proposals for the ABI. NOAA assumes that the ABI is distinct from an atmospheric sounding instrument, and spacecraft-specific and ground-processing requirements are excluded wherever possible. However, certain design goals for the ABI, described in Section 2, as well as specific performance characteristics described in Section 3, may result in the inclusion of a ground-processing segment as part of the overall "imager system."

NOAA's Technical Requirements for a Geostationary Advanced Baseline Sounder (ABS)

November 16, 2000
Version 1.1

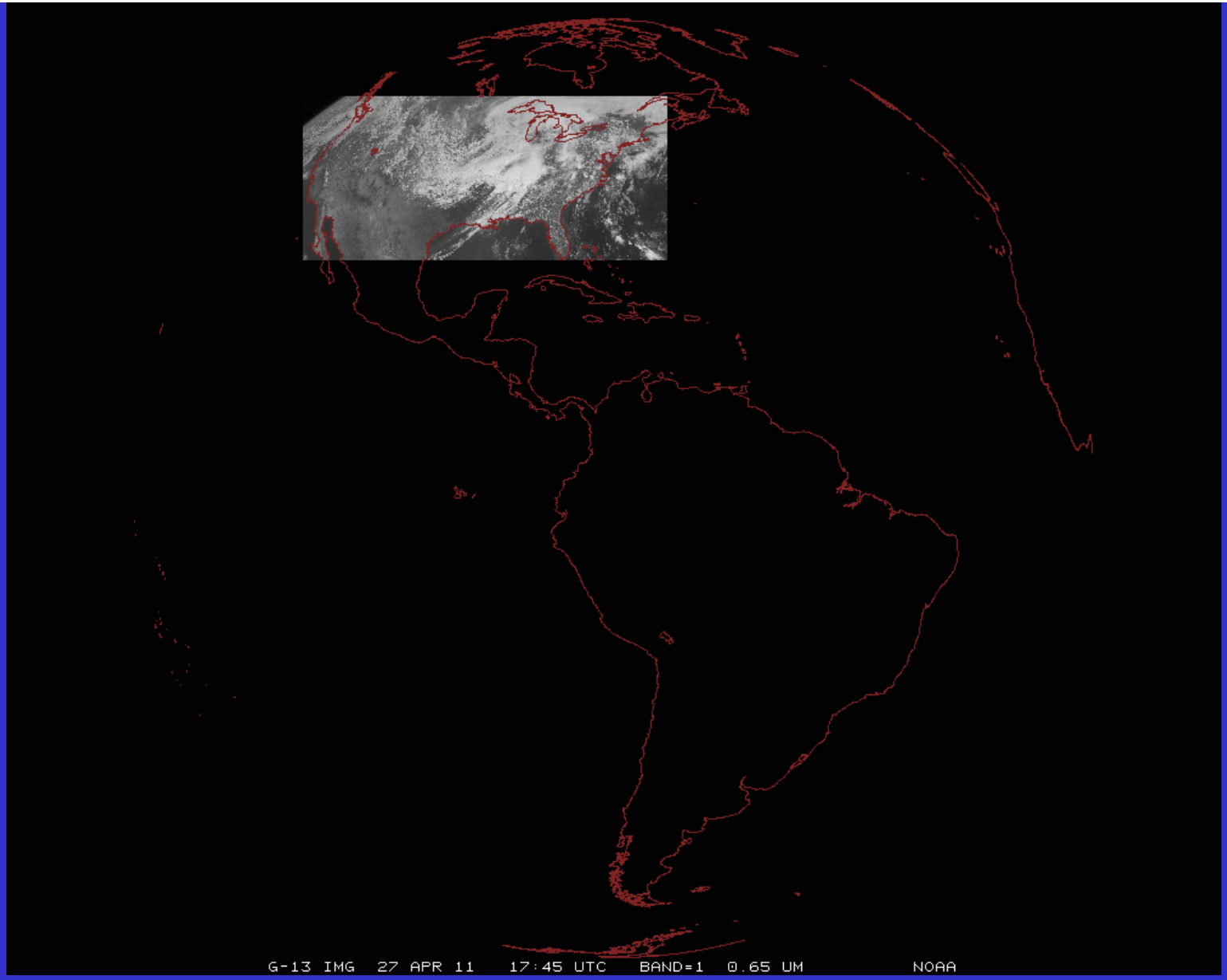
Originally ABI was only 8 spectral bands, now it is 16. All ABI bands were modified with input from STAR and it's Cooperative Institutes.

ABI/ABS Requirements. circa 1999/2000

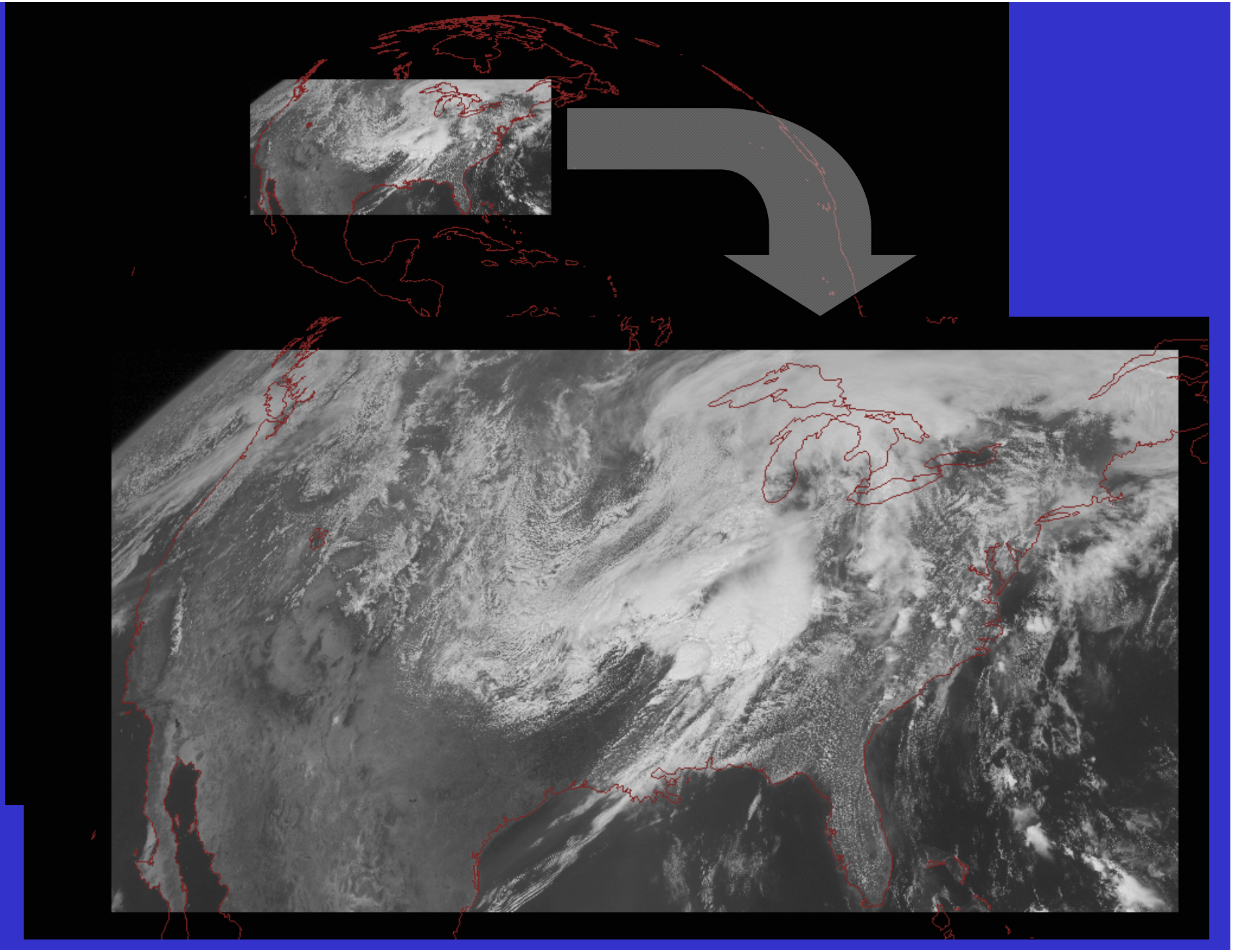


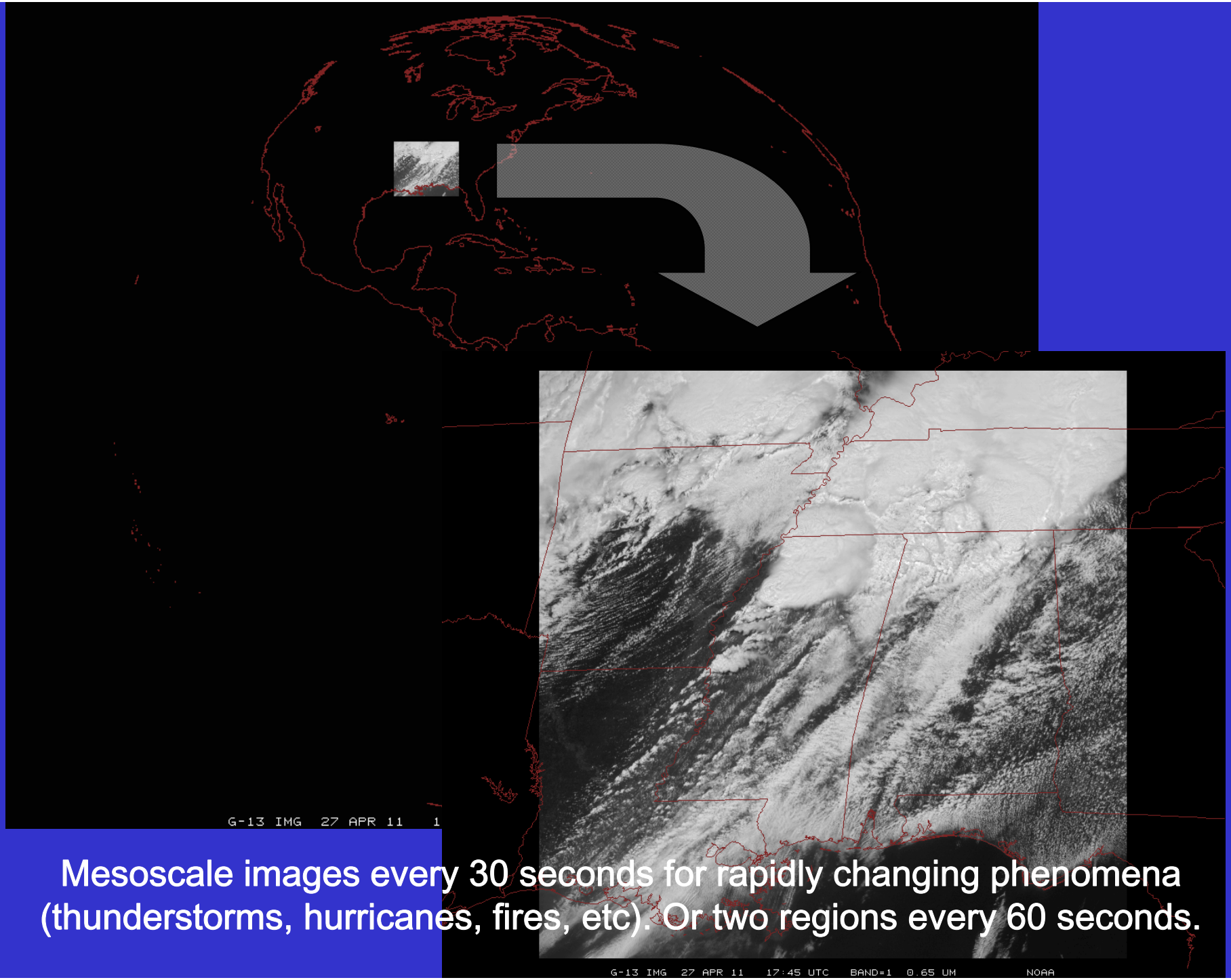
ABI scans about 5 times faster than the current GOES imager

There are two anticipated scan modes for the ABI:
- Full disk images every 15 minutes + 5 min CONUS images + mesoscale,
or - Full disk every 5 minutes.



ABI can offer Continental US images every 5 minutes for routine monitoring of a wide range of events (storms, dust, clouds, fires, winds, etc).
This is every 15 or 30 minutes with the current GOES in routine mode.

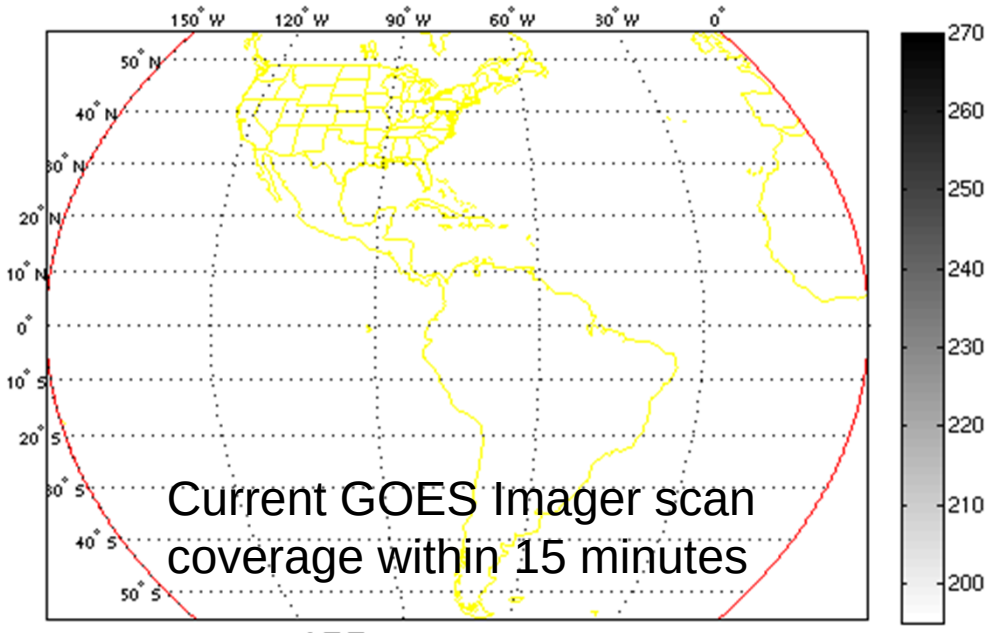




Mesoscale images every 30 seconds for rapidly changing phenomena (thunderstorms, hurricanes, fires, etc). Or two regions every 60 seconds.

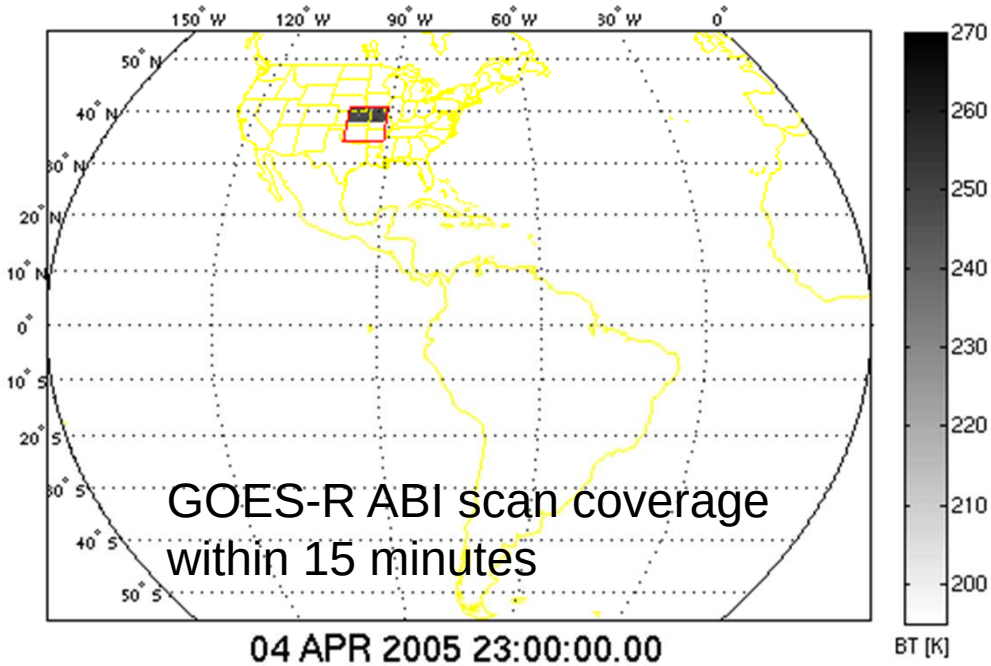
In 15 Minutes
Current GOES Imager can scan:

- Most (3/5) of a Full Disk Image

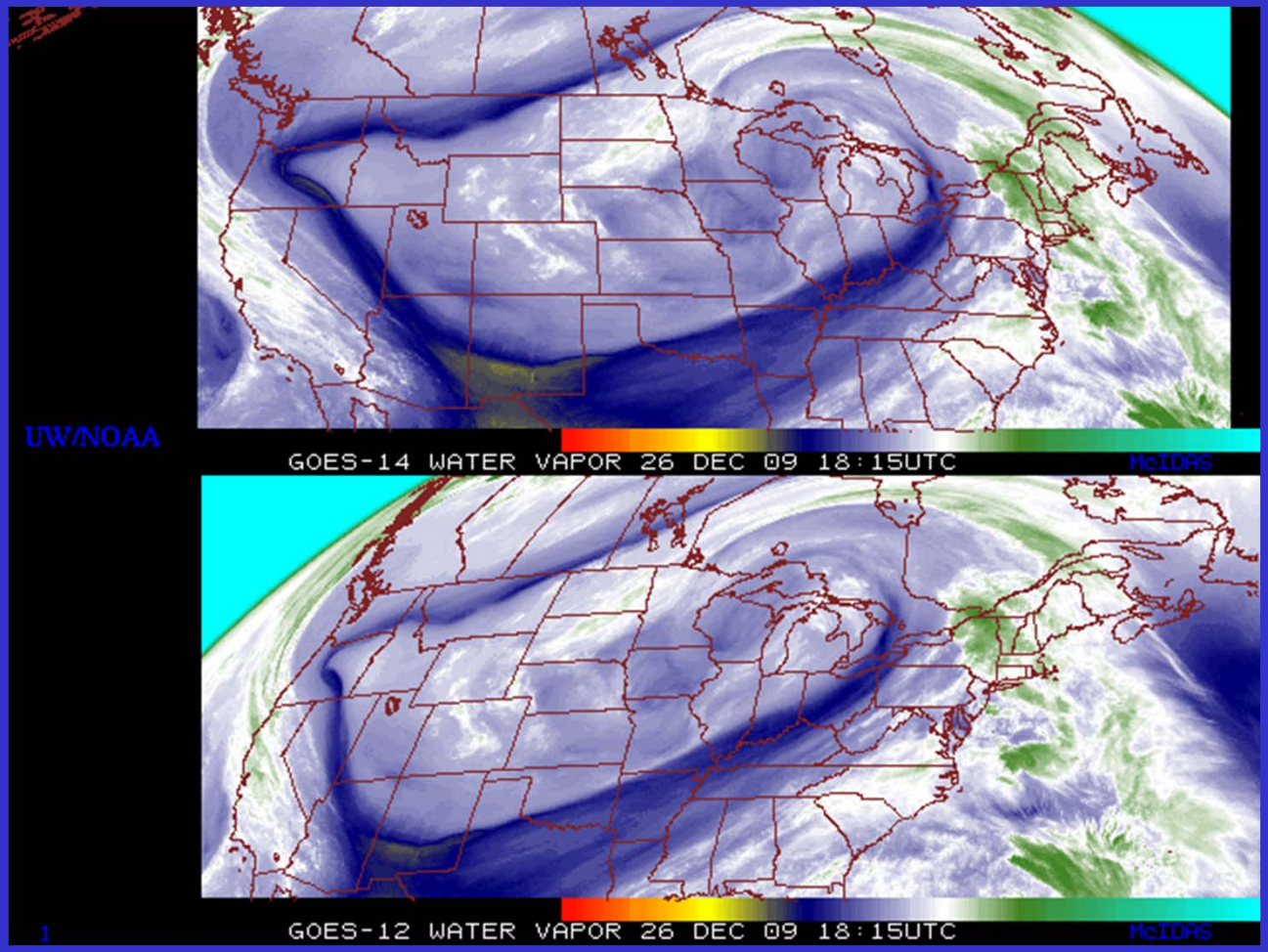


In 15 Minutes
ABI ("Flex Mode") will scan:

- 30 Mesoscale Images
- 3 CONUS Images
- 1 Full Disk Image



GOES-14: Sample “5-min” imagery

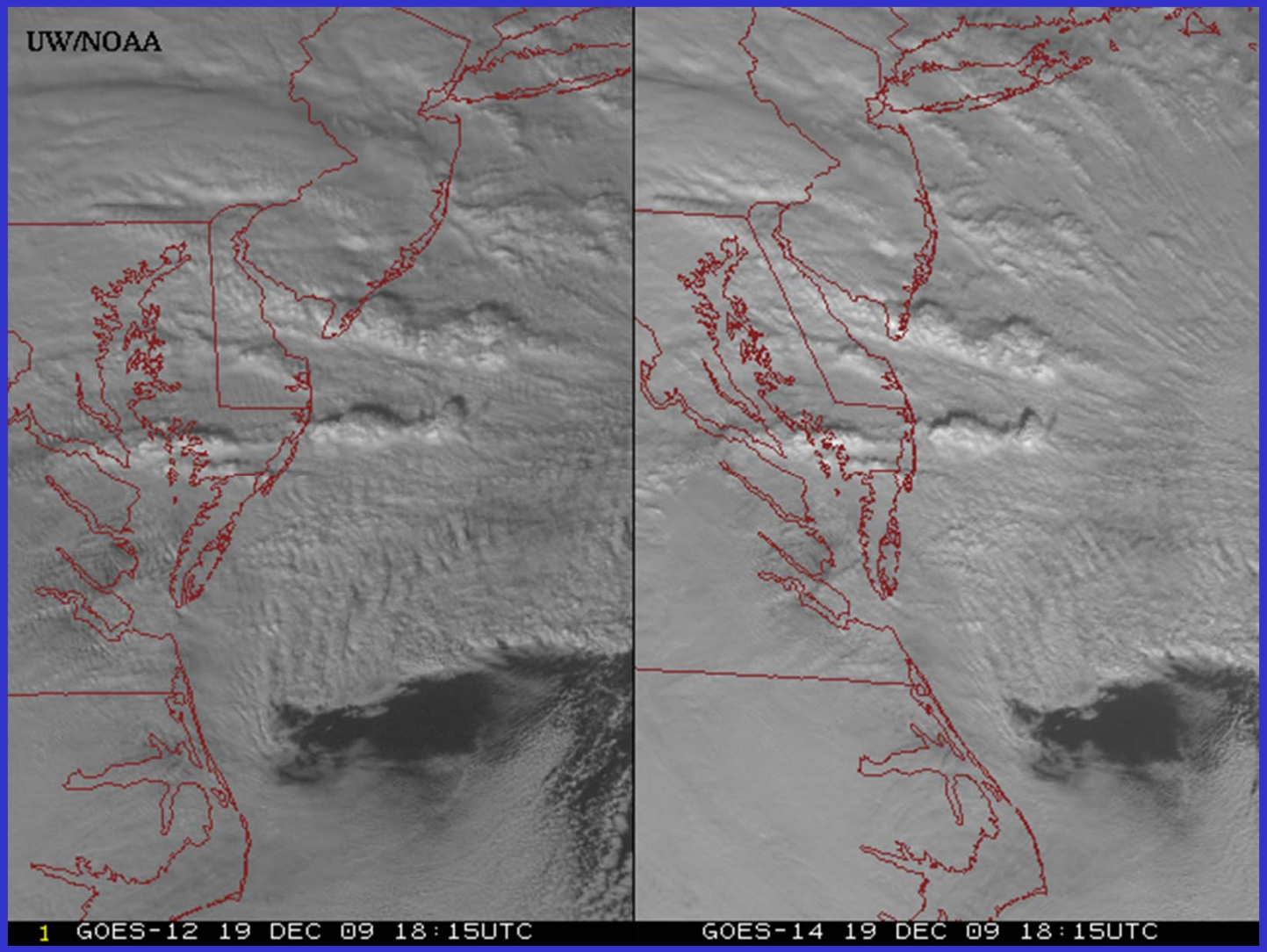


GOES-14

GOES-12

“Water vapor” data from the GOES-14 NOAA Science Test, lead by Hillger and Schmit

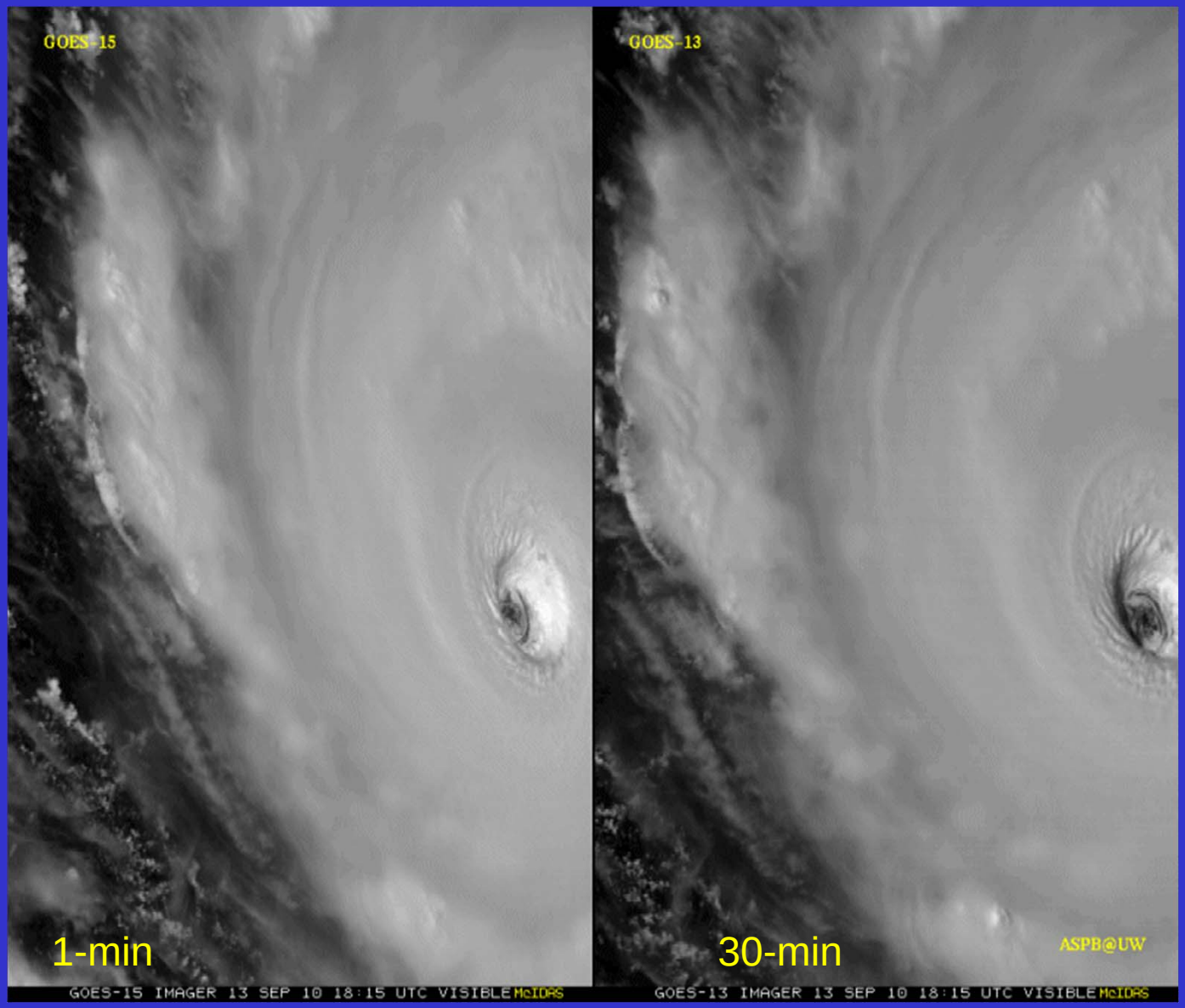
GOES-14: Sample “1-min” imagery



GOES-12 GOES-14

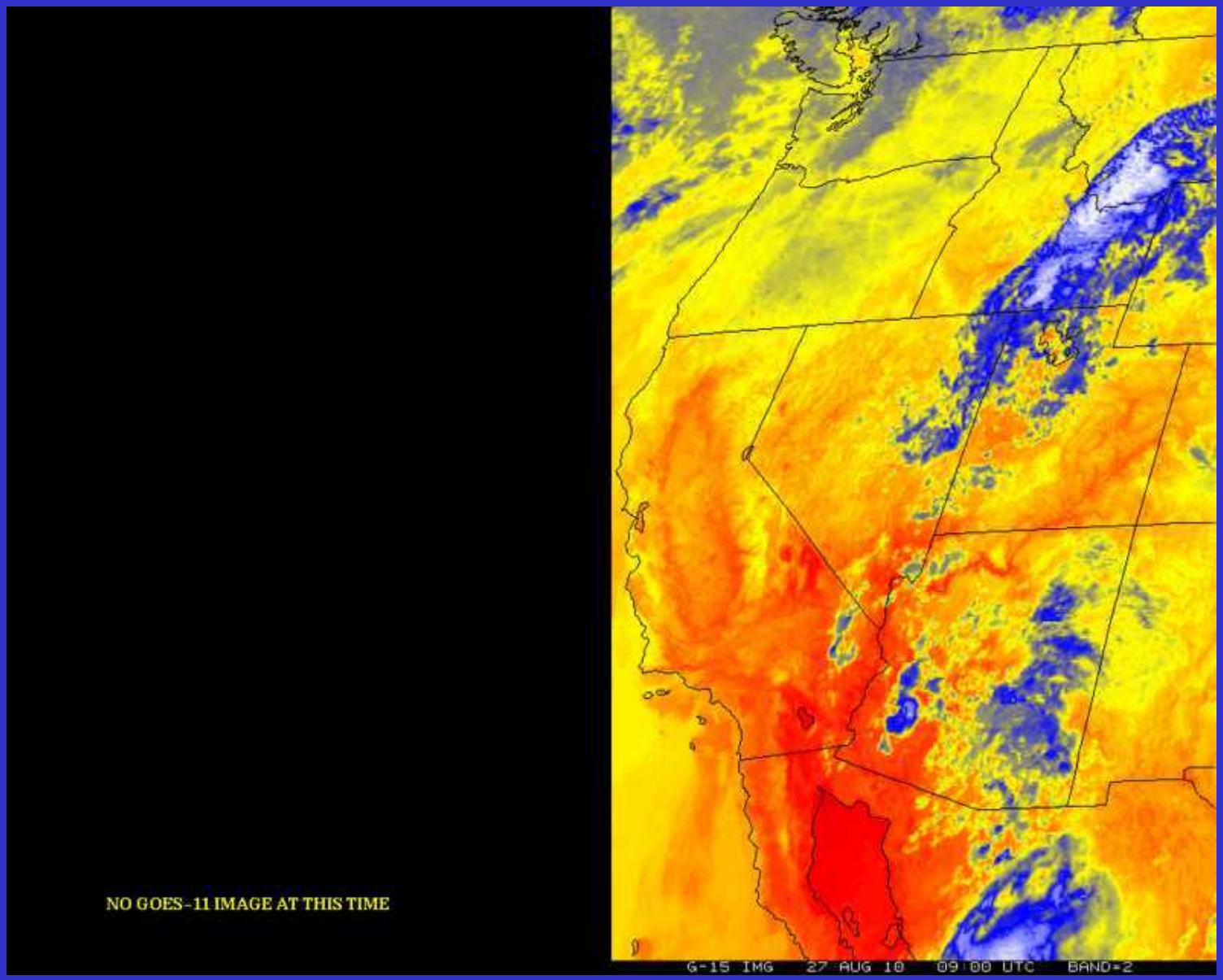
- Visible data from the GOES-14 NOAA Science Test, lead by Hillger and Schmit
- Can these type loops validate meso-scale models?

GOES-15: Sample “1-min” imagery



Visible data from the GOES-15 NOAA Science Test, lead by Hillger and Schmit

GOES-12/15 (Around eclipse period)



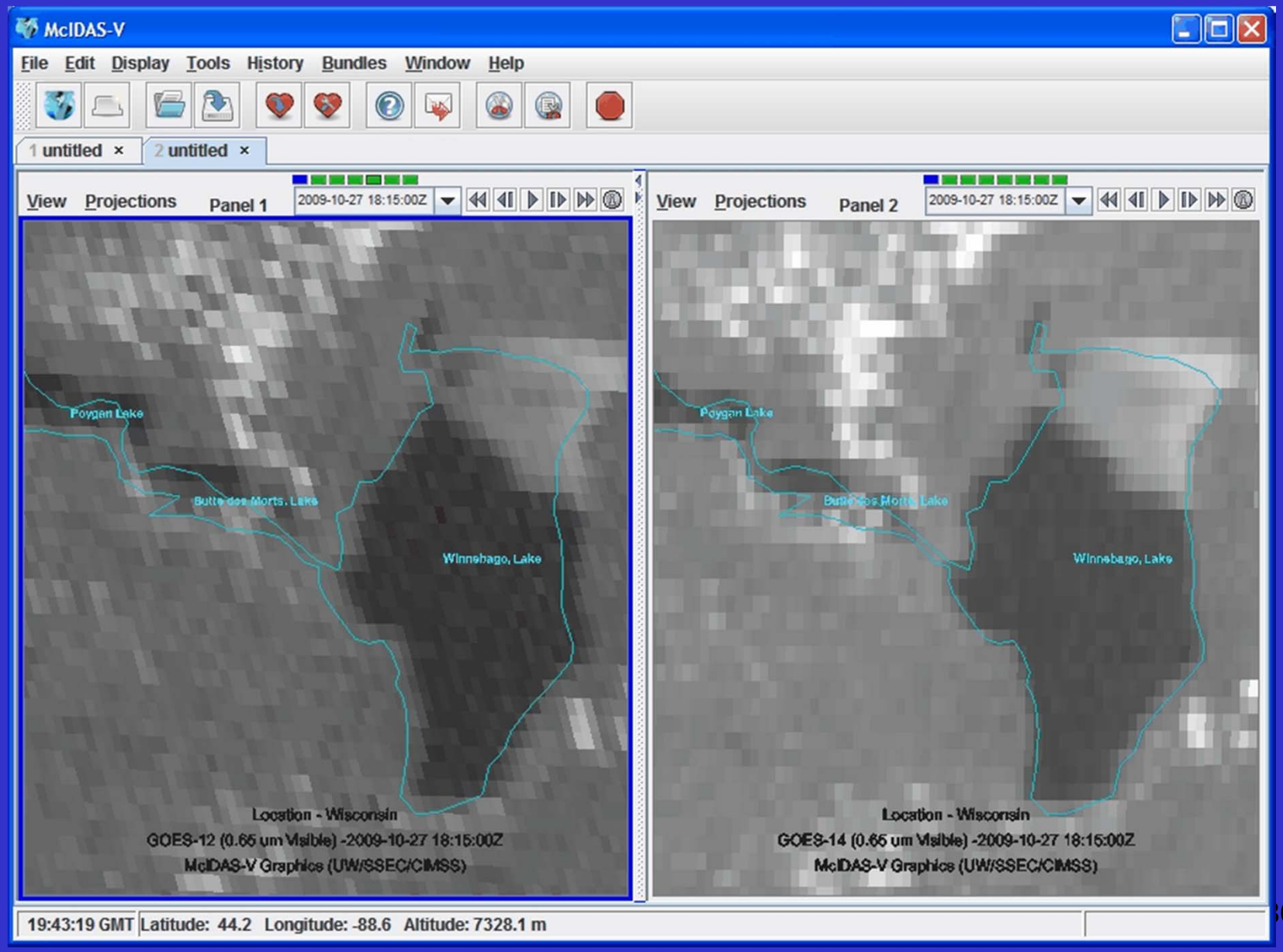
GOES-11 **GOES-15**

GOES Outages
-- approximate hours/year

Satellite Series	KOZ, Eclipse and Stray Light (spring and fall)	Housekeeping, SEM calibration, Maneuvers and Yaw-flip
GOES-8 thru -12	420	211
GOES-13/14/15 (may be reduced)	220	107
GOES-R ABI	~6 - 40	~2 - 6

Improved stray light performance with the ABI.

Improved Image Navigation and Registration



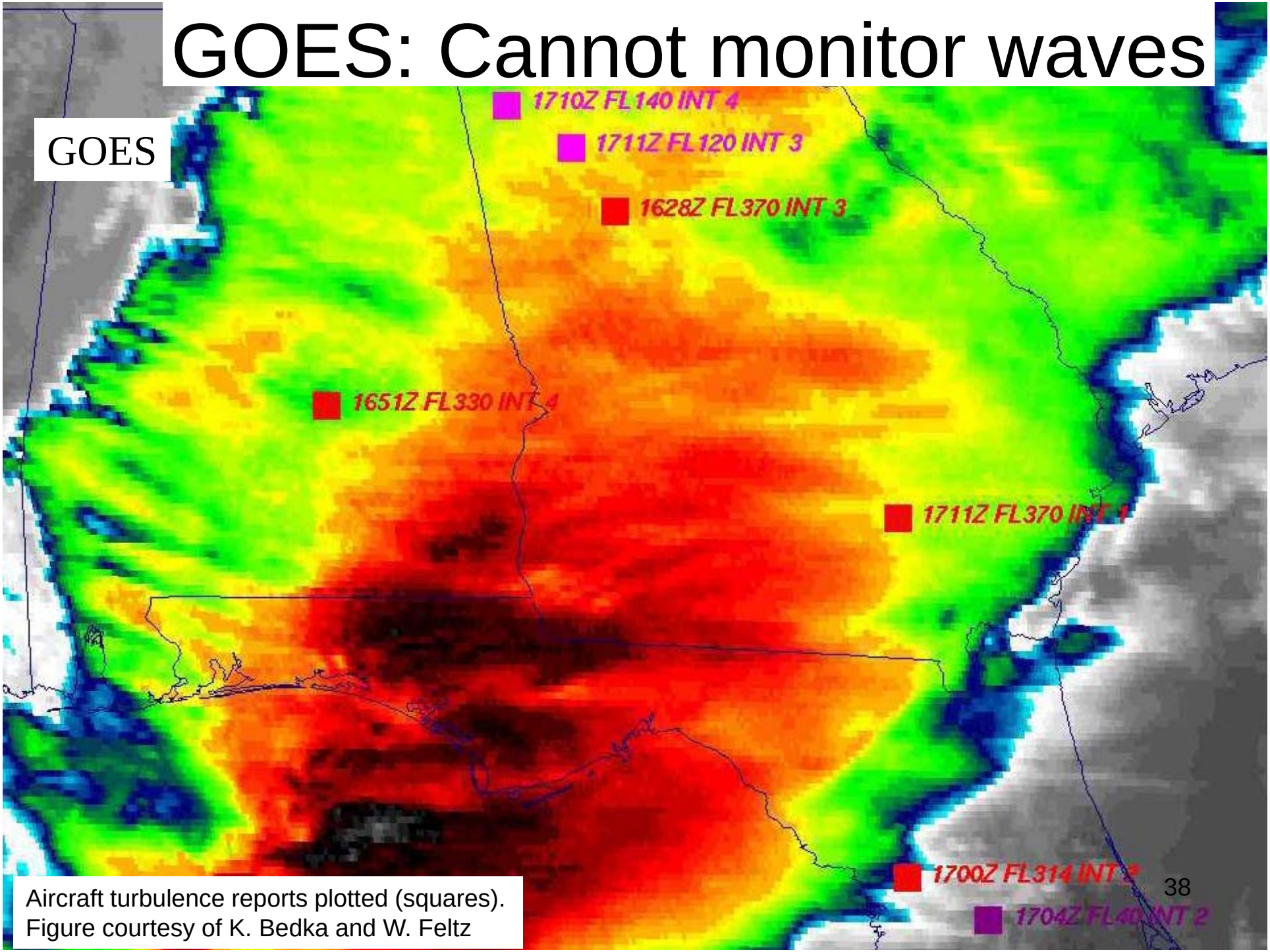
ABI to Imager Noise Comparison

* From ITT at GUC7

ABI				GOES			-12	-15
#	Freq. (um)	Spec	Worst Case Estimate*	#	Freq (um)	Spec	Measured (PLT)	Measured (PLT)
7	3.9	0.1	0.10	2	3.9	1.4	0.130	0.063
8	6.185	0.1	0.06					
9	6.95	0.1	0.09	3	6.x	1.0	0.15	0.17
10	7.34	0.1	0.11					
11	8.5	0.1	0.04					
12	9.61	0.1	0.04					
13	10.35	0.1	0.05					
14	11.2	0.1	0.04	4	10.7	0.35	0.11	0.06
15	12.3	0.1	0.05	5	12.0	0.35	-	-
16	13.3	0.3	0.14	6	13.3	0.32	0.19	0.13

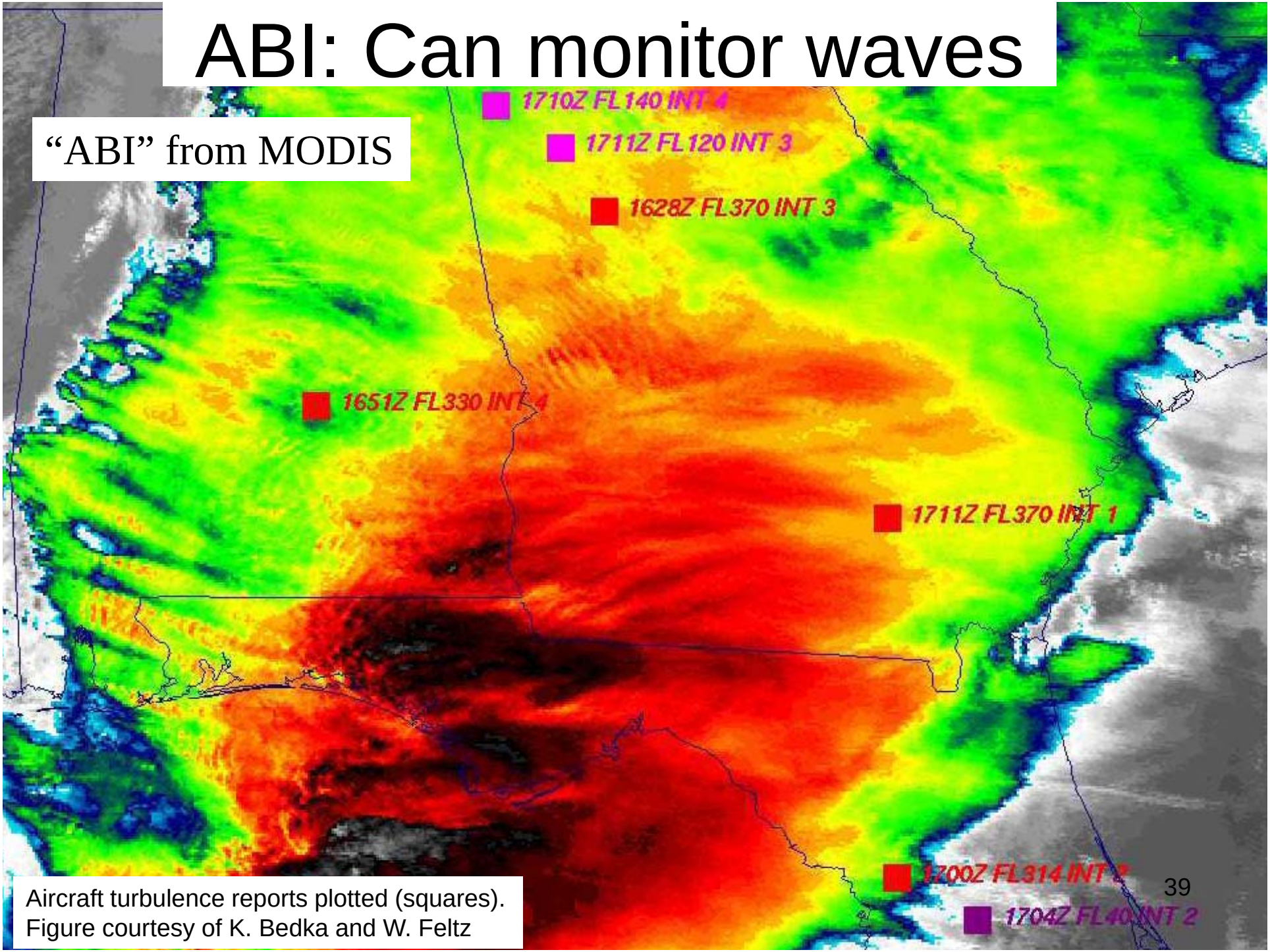
Similar instrument noise, even with 4-16 times finer spatial resolutions!

GOES: Cannot monitor waves



Aircraft turbulence reports plotted (squares).
Figure courtesy of K. Bedka and W. Feltz

ABI: Can monitor waves



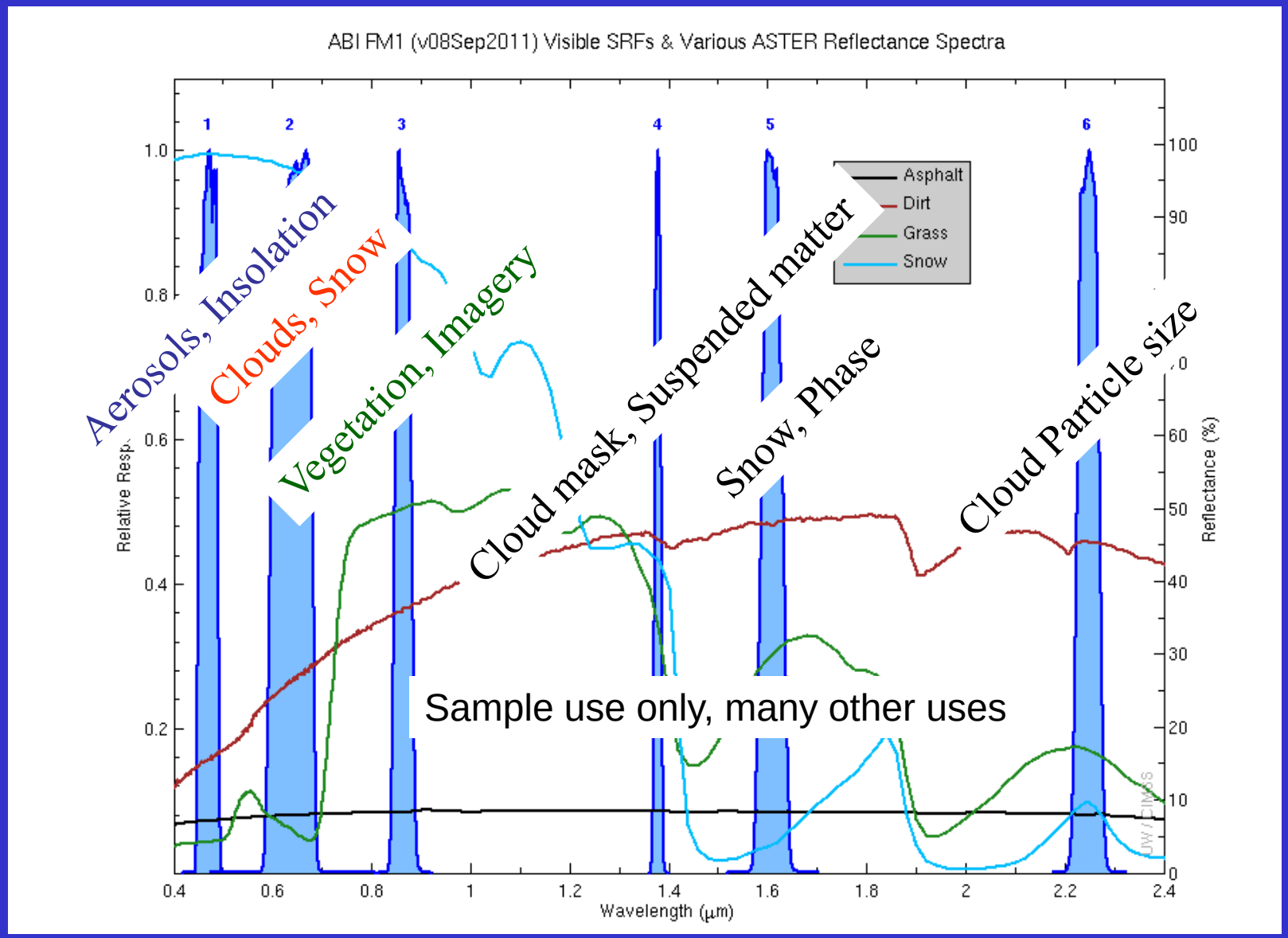
Aircraft turbulence reports plotted (squares).
Figure courtesy of K. Bedka and W. Feltz

ABI Visible/Near-IR Bands

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

Schmit et al, 2005

Visible and near-IR channels on the ABI



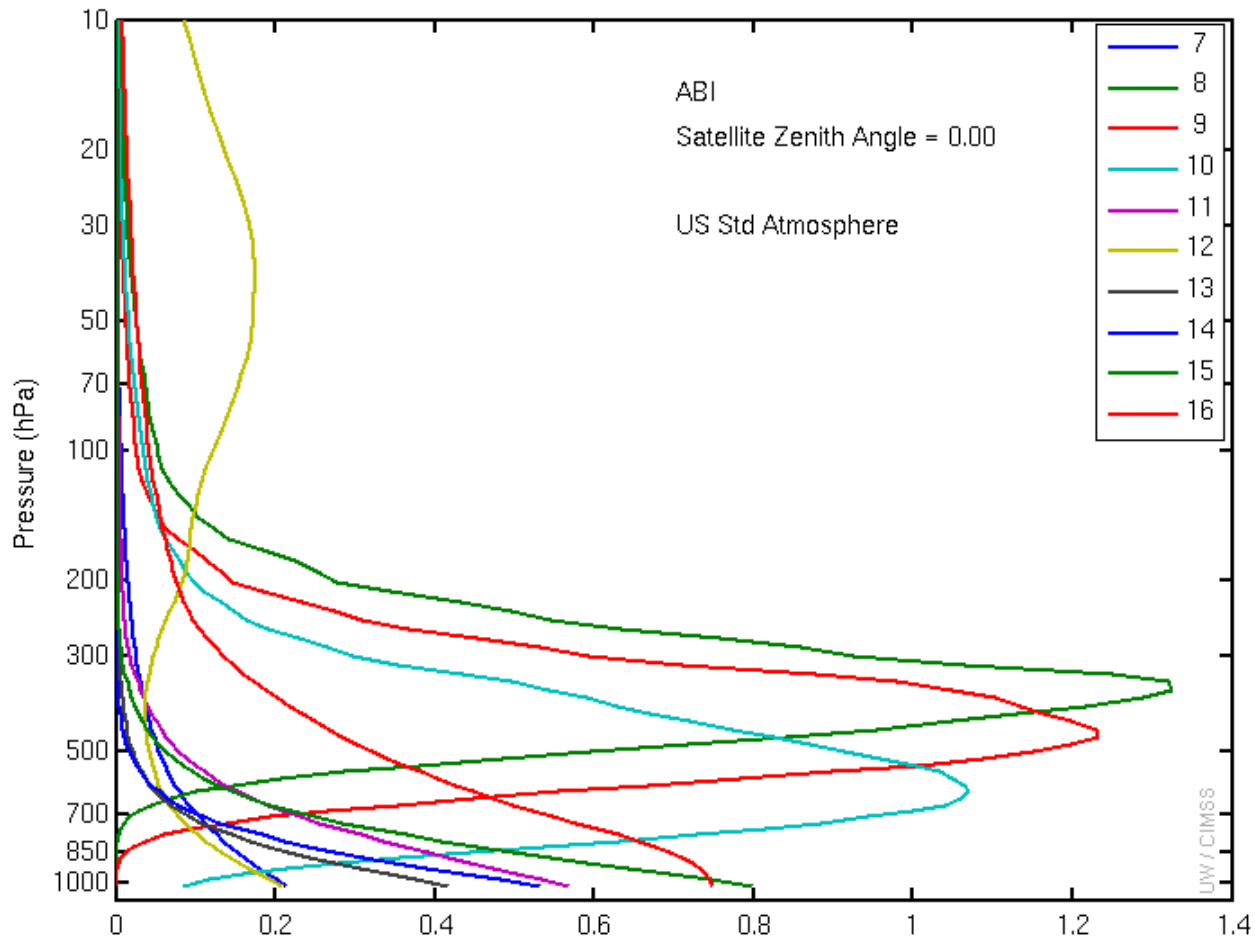
The ABI visible and near-IR bands have many uses.

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 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

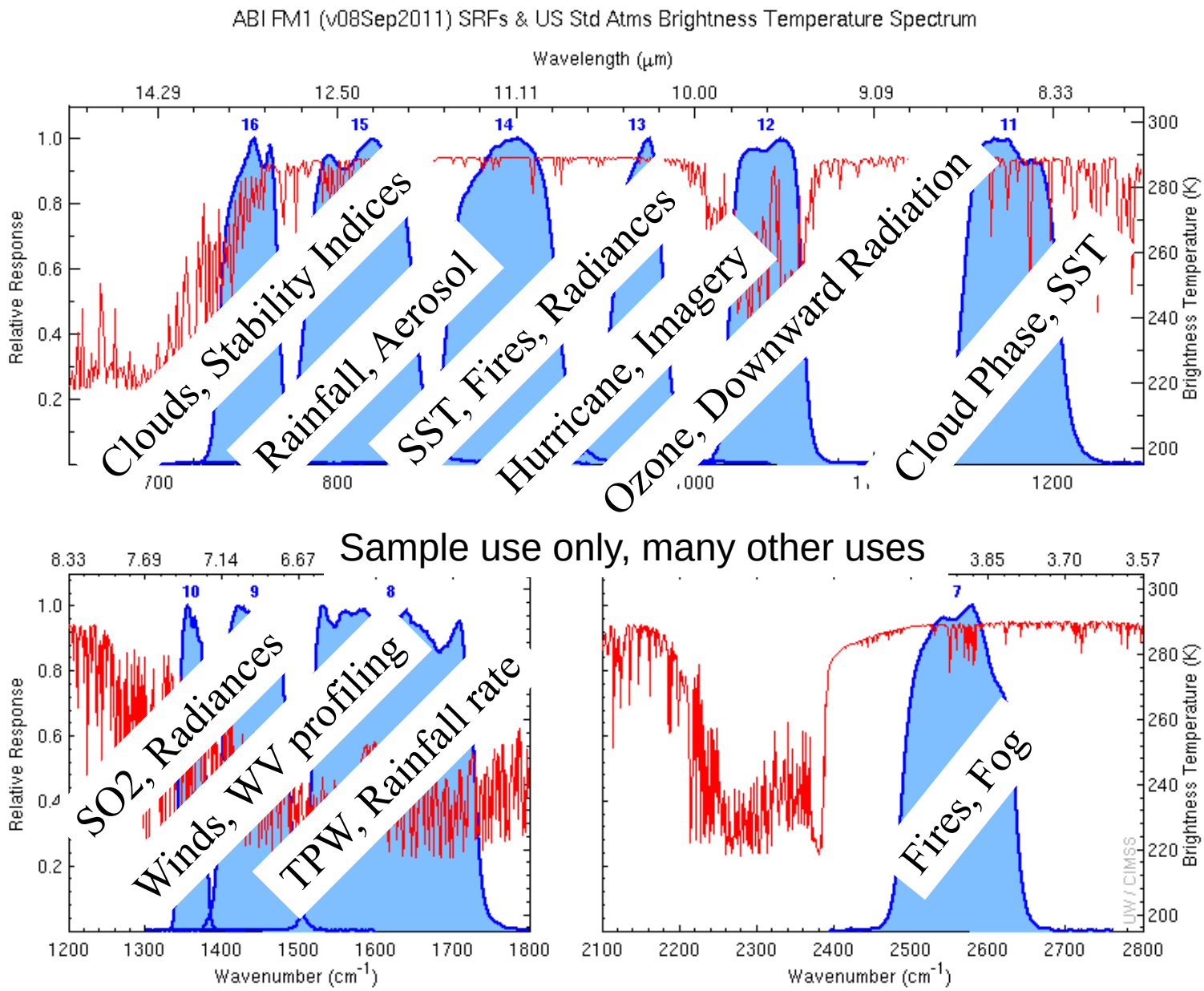
Schmit et al, 2005

ABI IR Weighting Functions

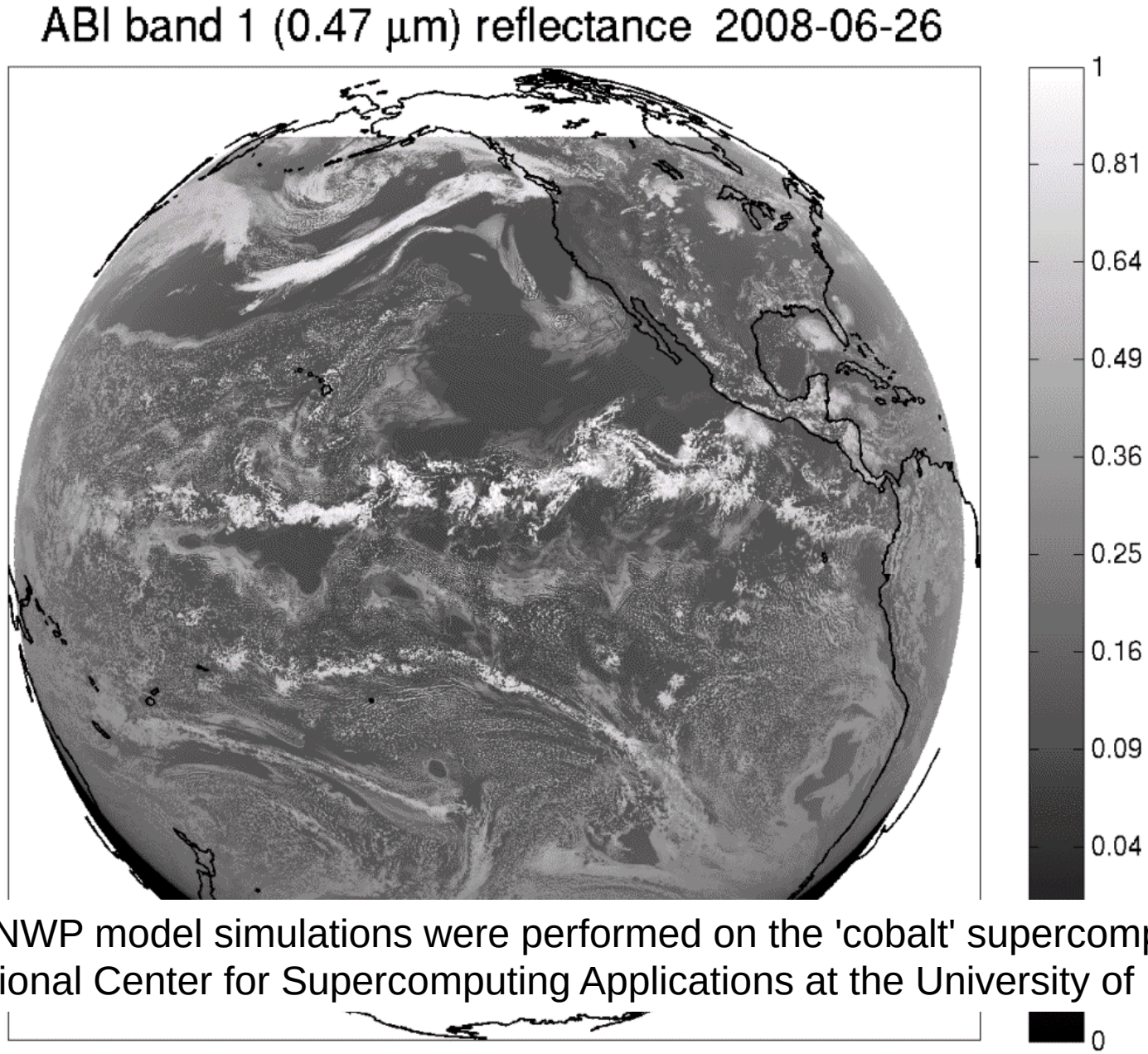


Clear-sky

The IR channels on the ABI

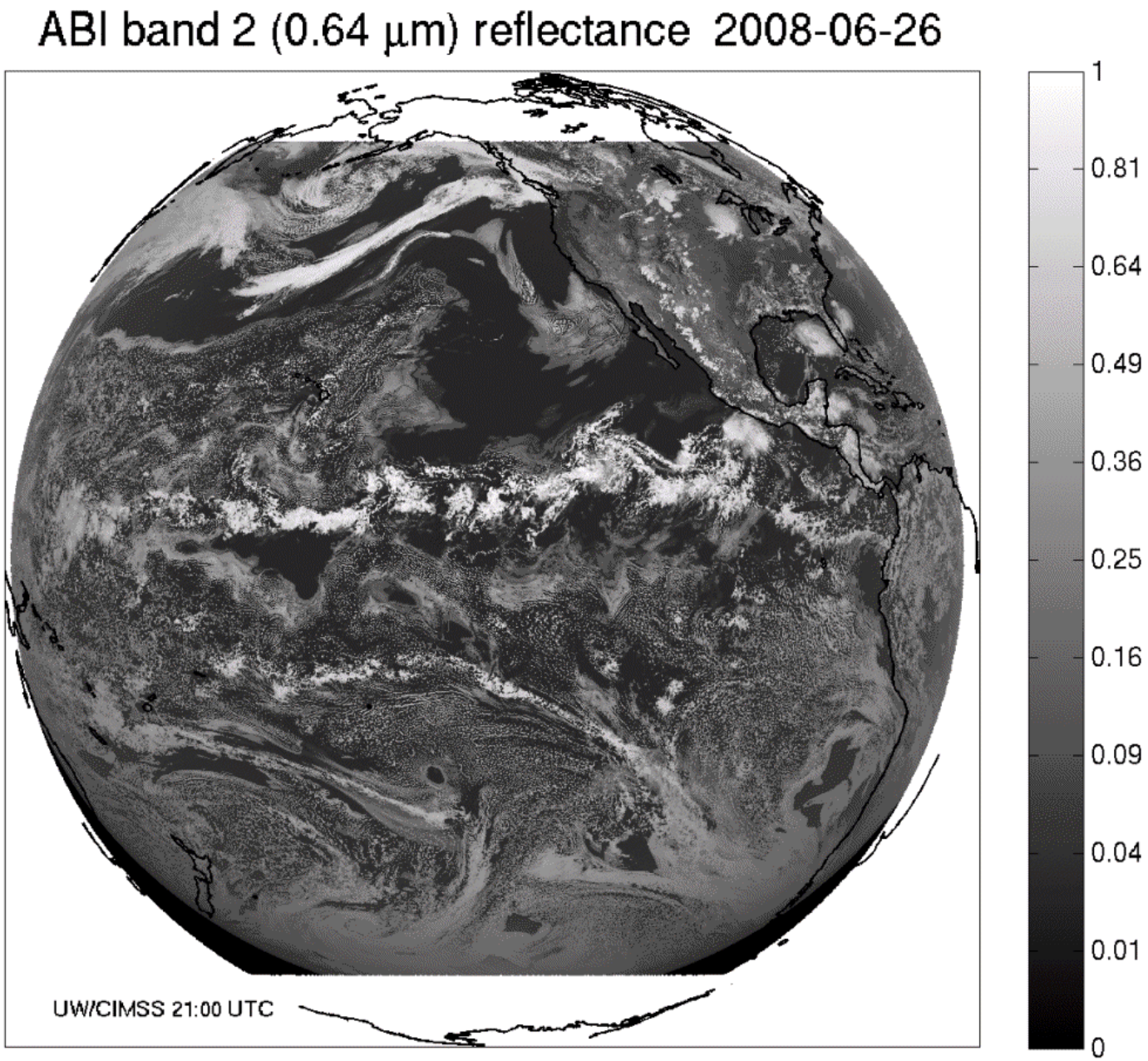


ABI has many more bands than the current operational GOES imagers.

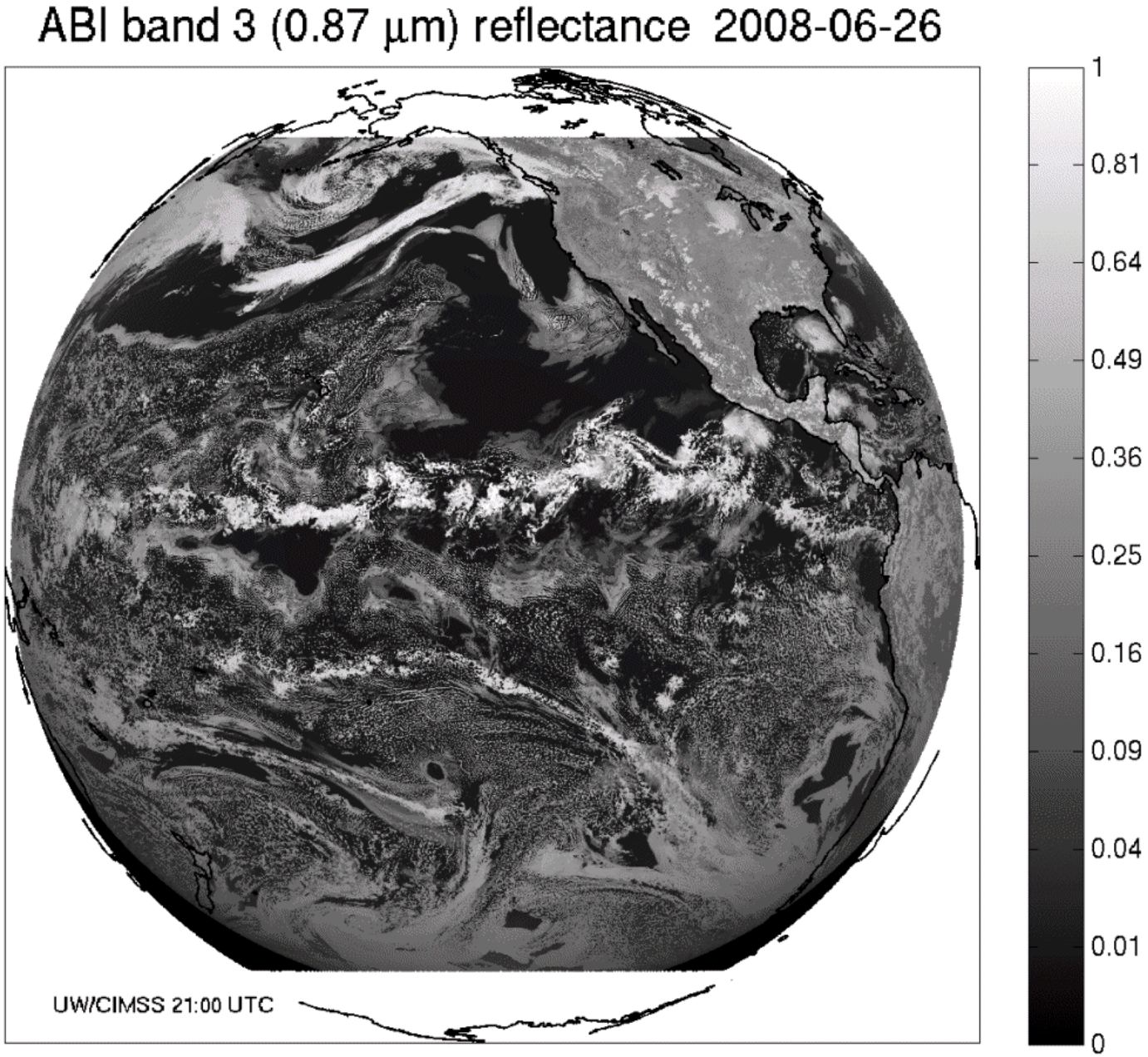


These NWP model simulations were performed on the 'cobalt' supercomputer at the National Center for Supercomputing Applications at the University of Illinois.

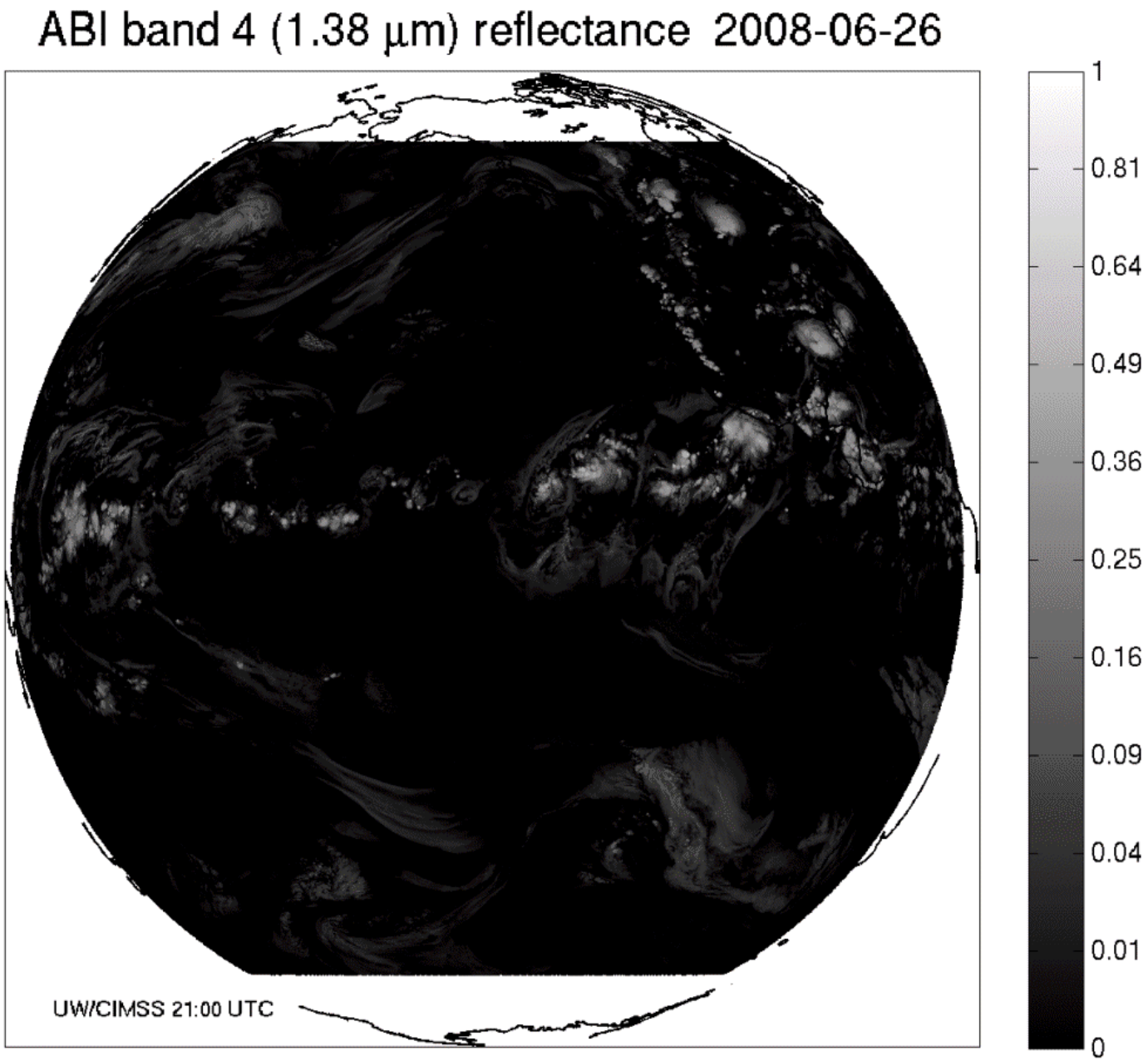
Band 1: Daytime “Blue” band – aerosols, solar insolation, snow cover



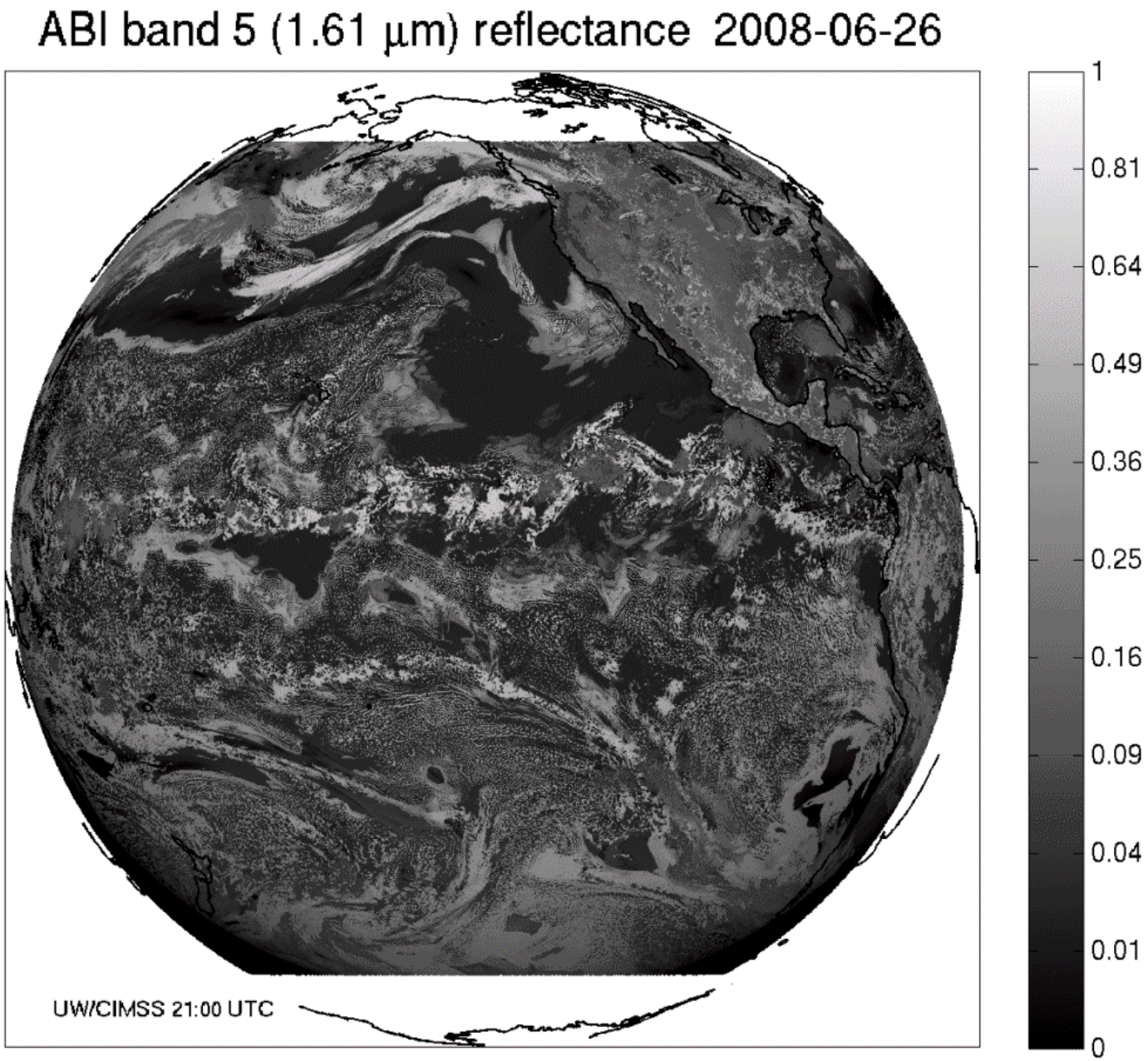
Band 2: Daytime “Red” band – clouds, cloud-mask, optical depth, winds, etc.



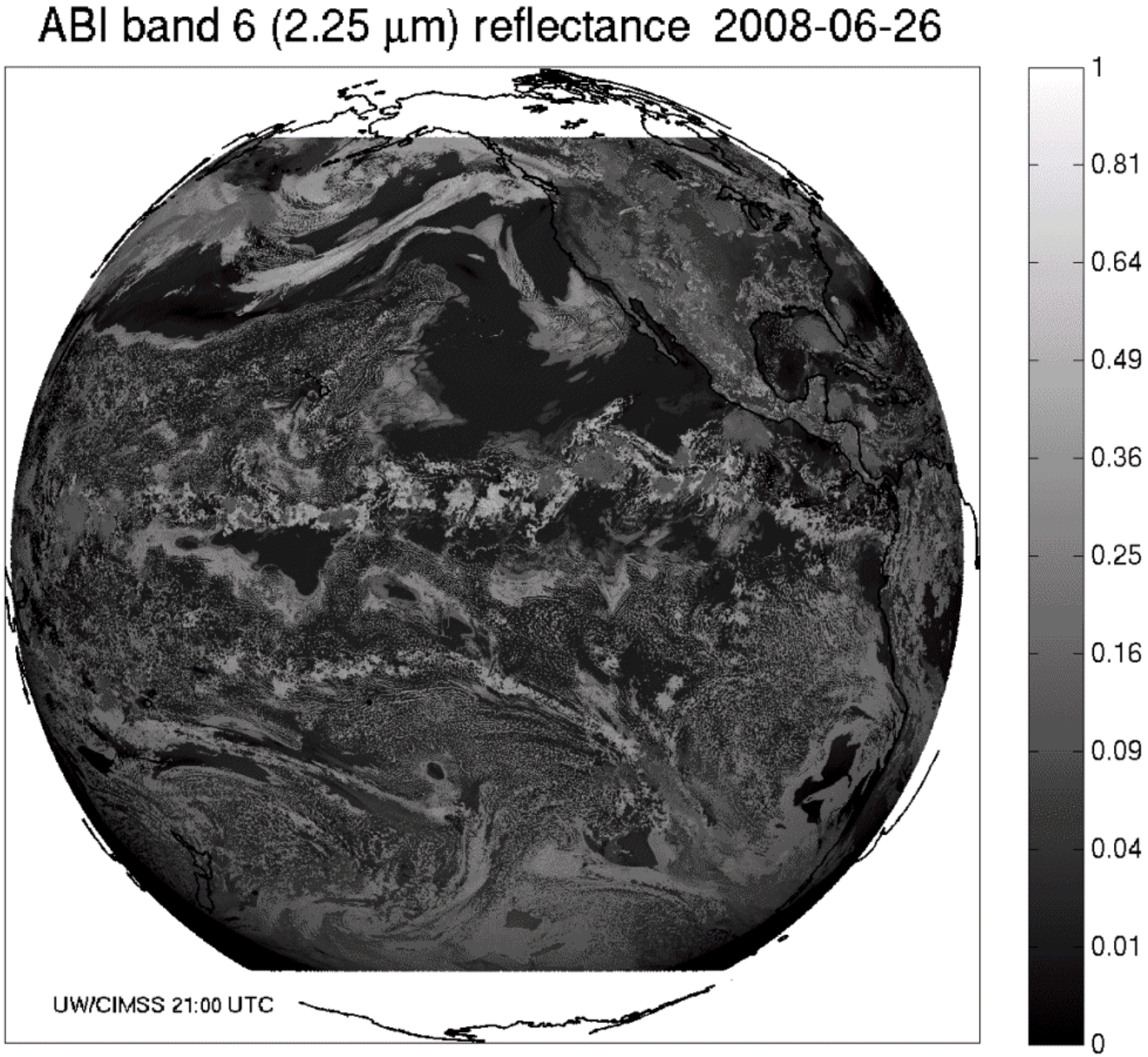
Band 3: Daytime “Veggie” band – NDVI, solar insolation, snow cover



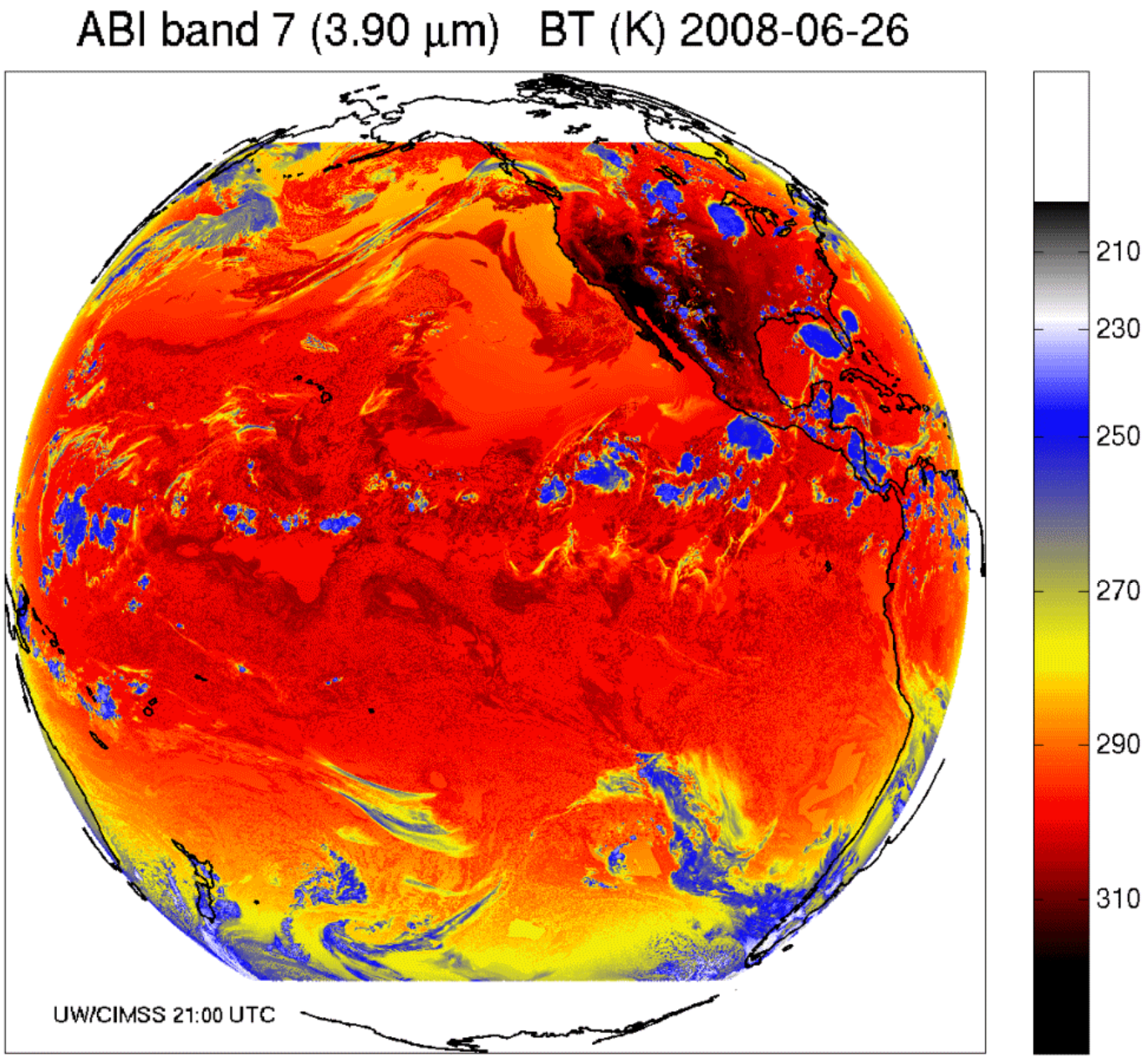
Band 4: Daytime “Cirrus” band – cloud mask, aerosol detection



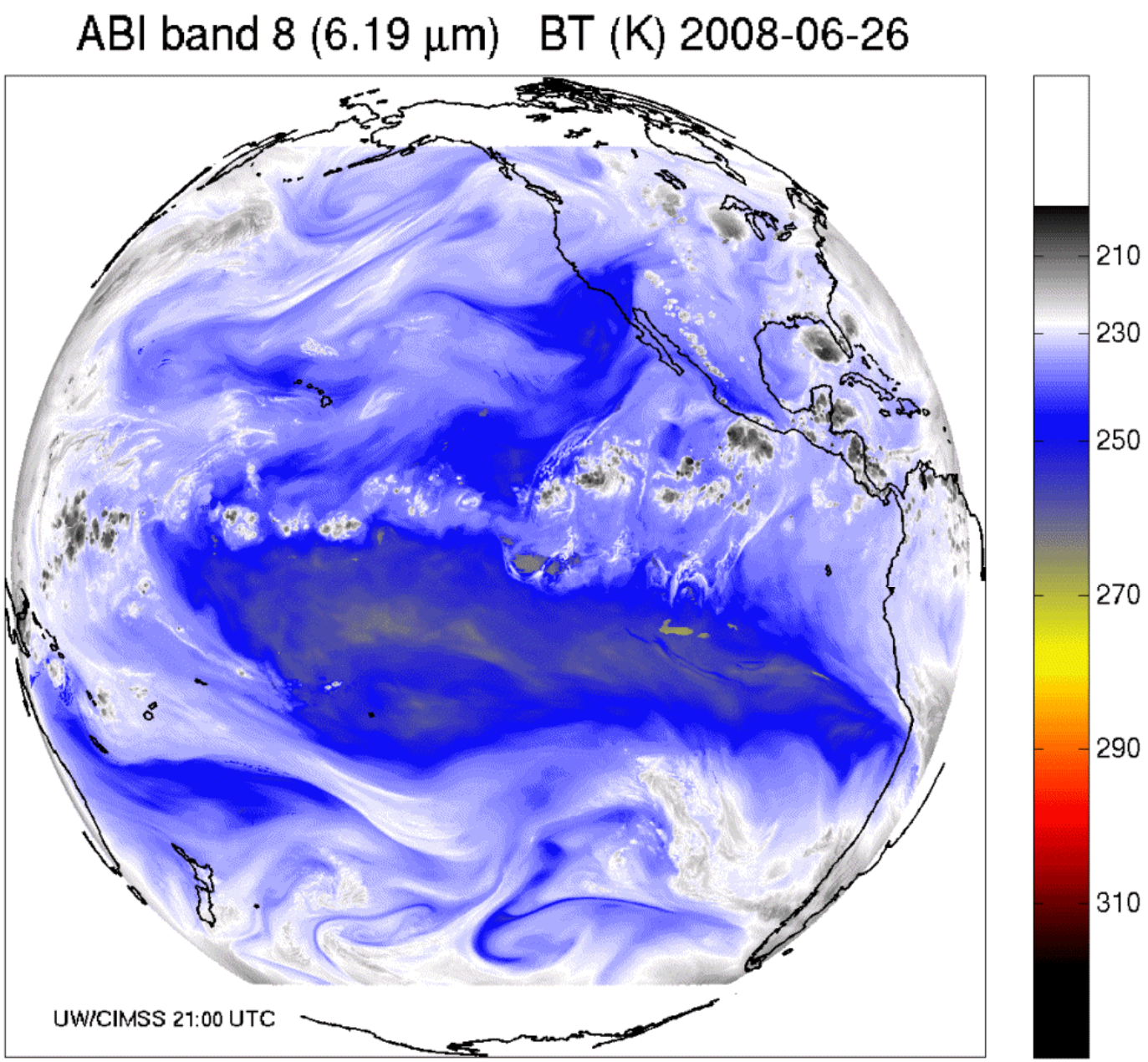
Band 5: Daytime “Snow” band – snow cover, cloud mask, etc.



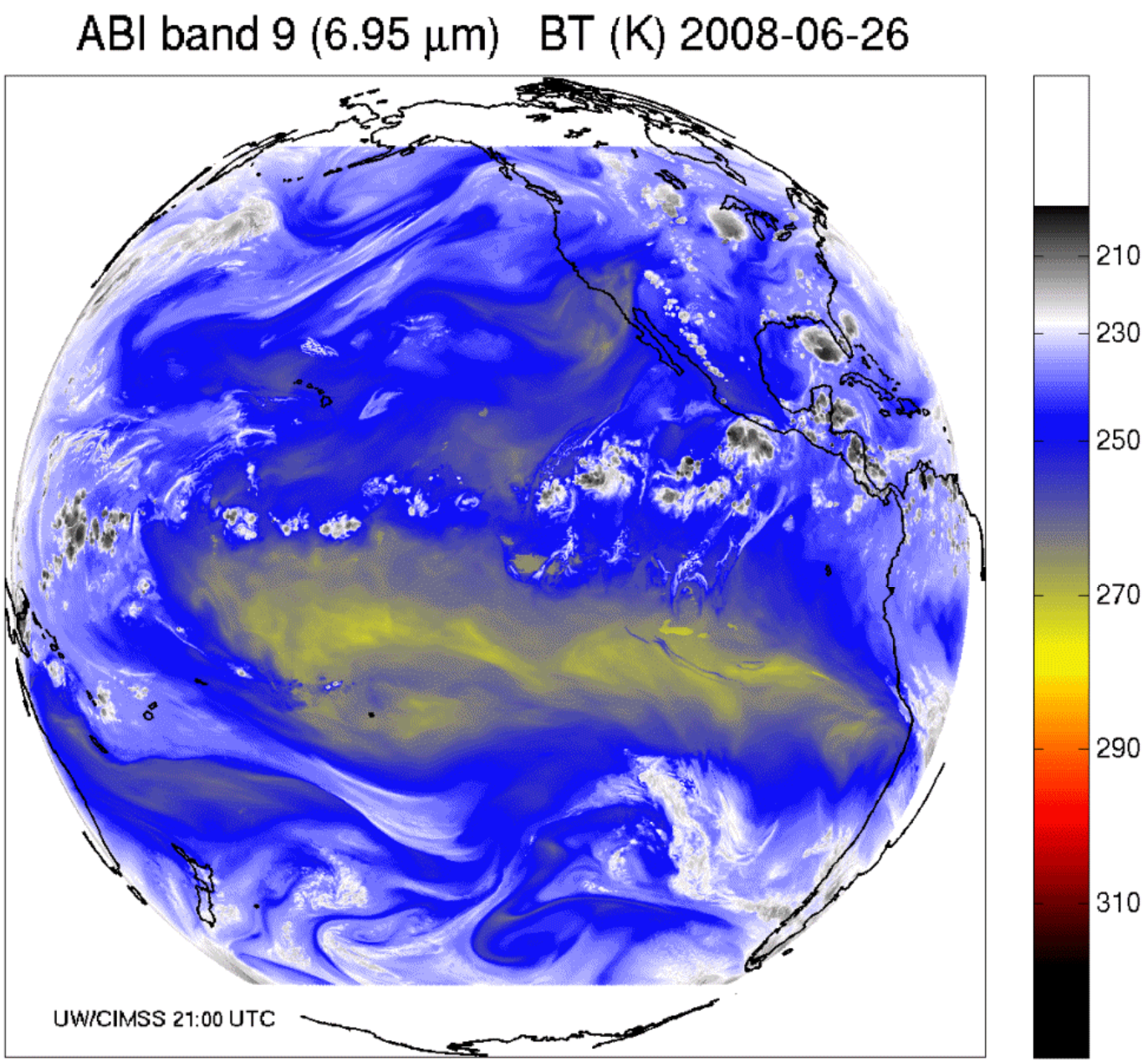
Band 6: Daytime “Cloud-top phase” band – cloud particle size, snow cover



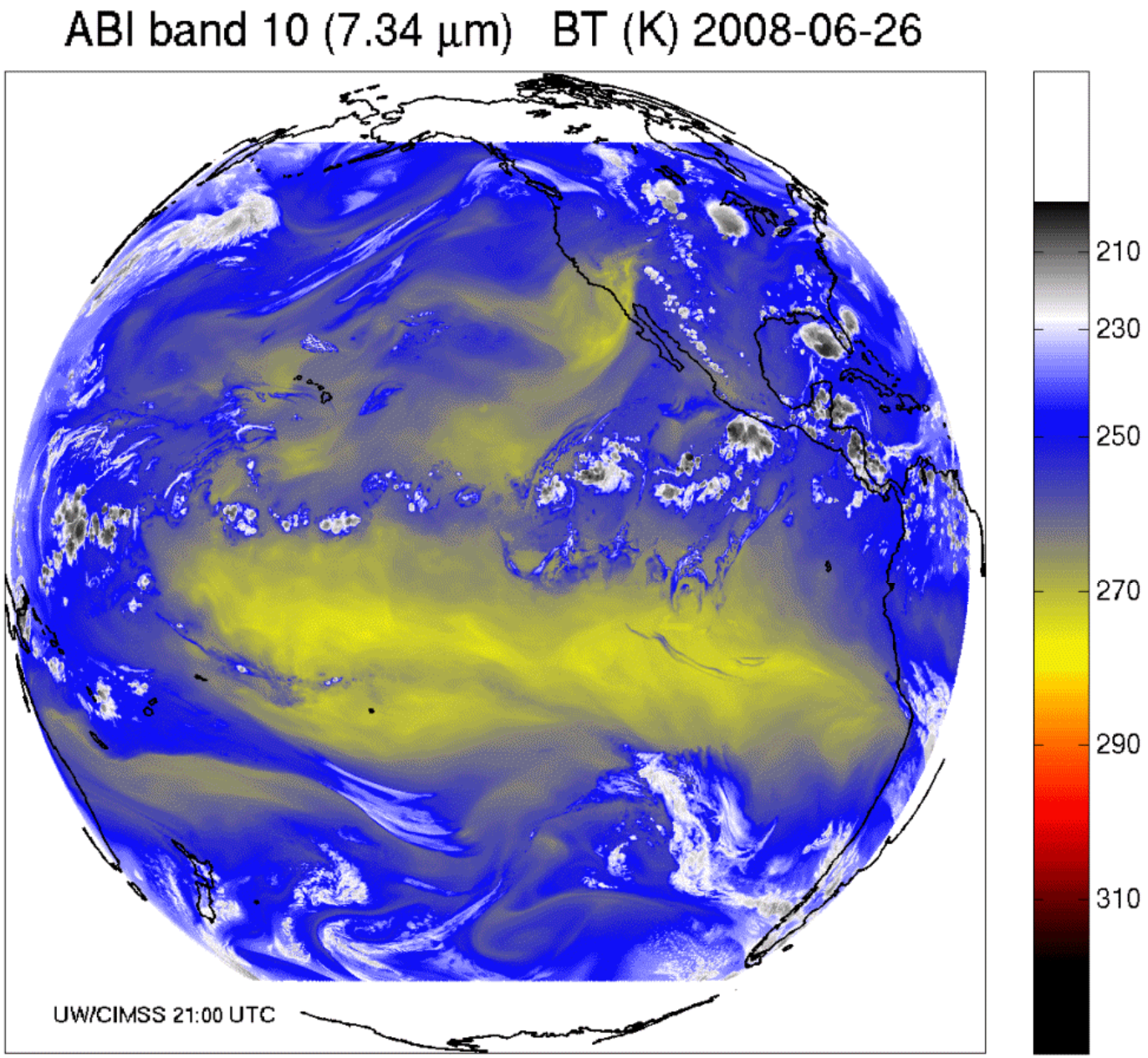
Band 7: Shortwave IR window band - fog, fires, winds, SST, etc.



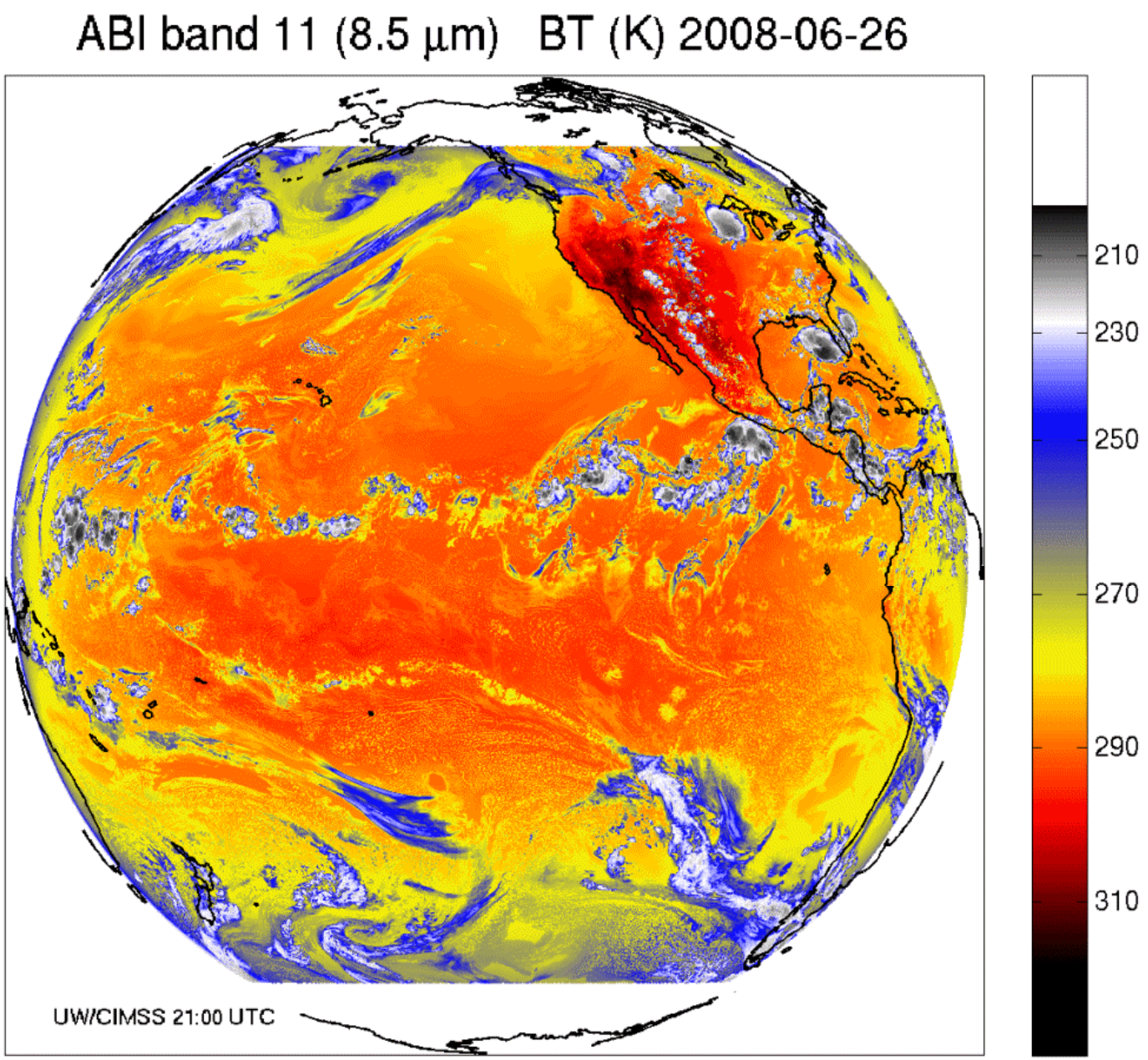
Band 8: Upper-level tropospheric water vapor band – moisture, flow, winds



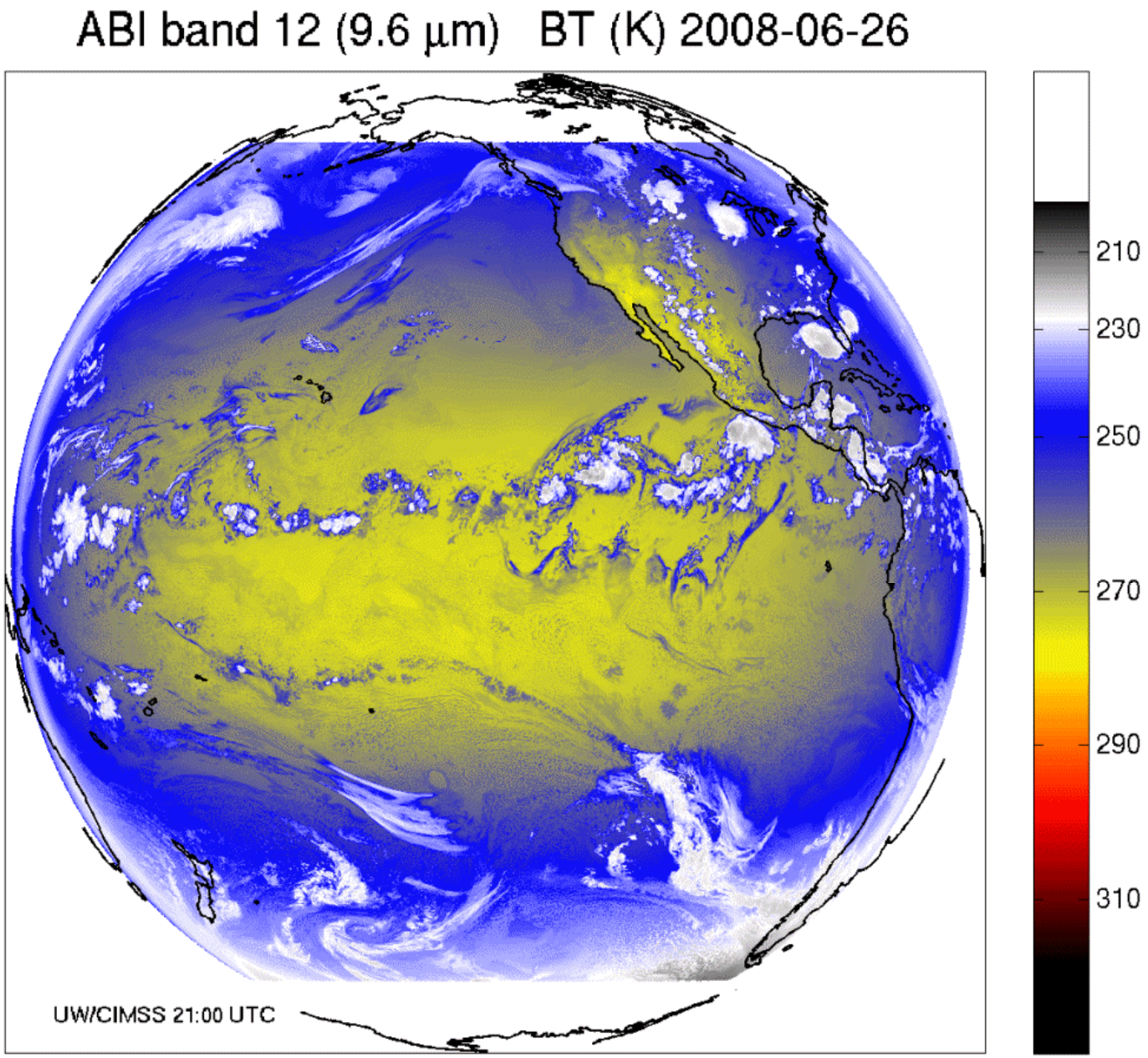
Band 9: Upper/mid-level tropospheric water vapor band – moisture, flow, winds



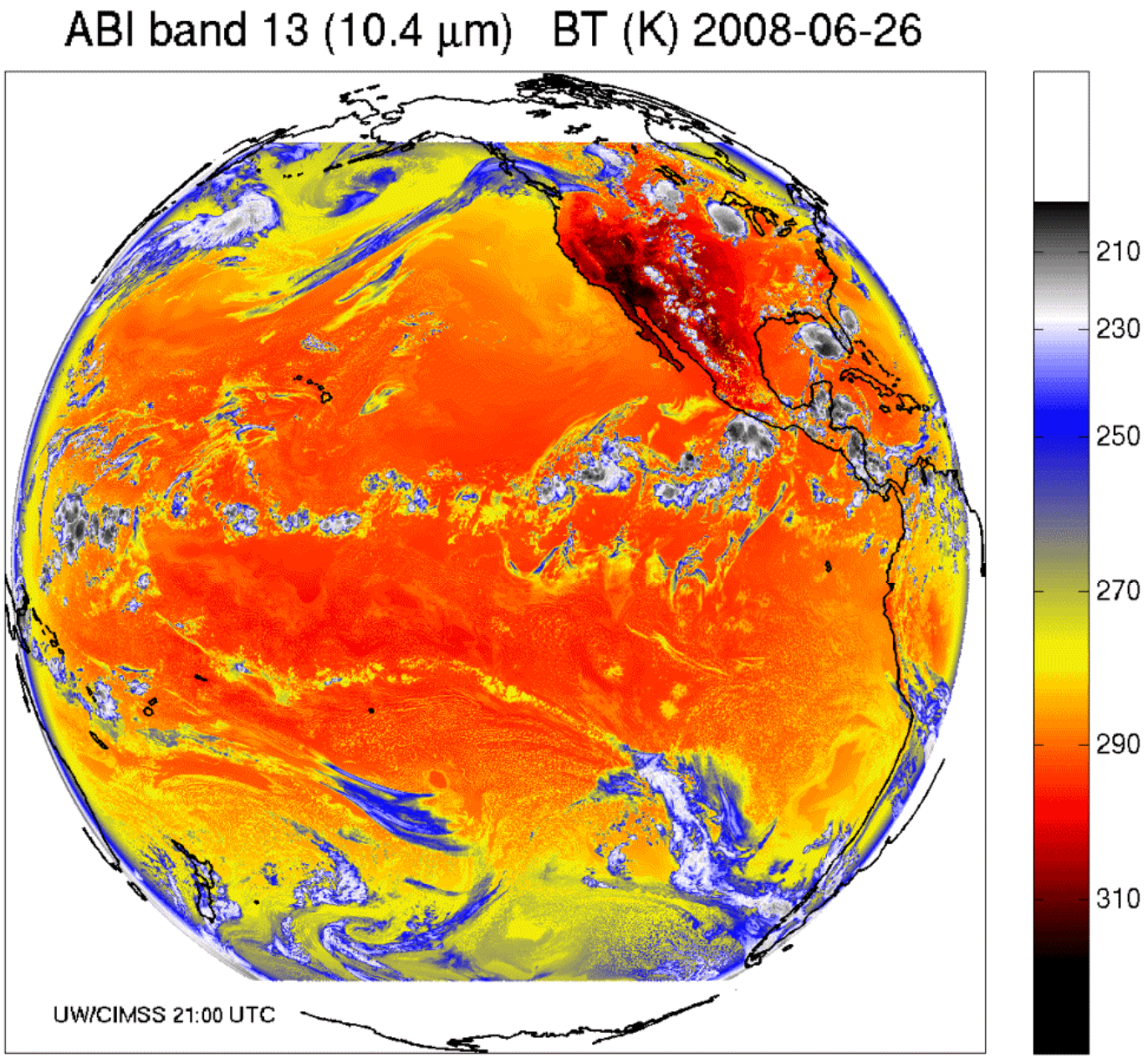
Band 10: Lower mid-level tropospheric water vapor band– moisture, flow, winds



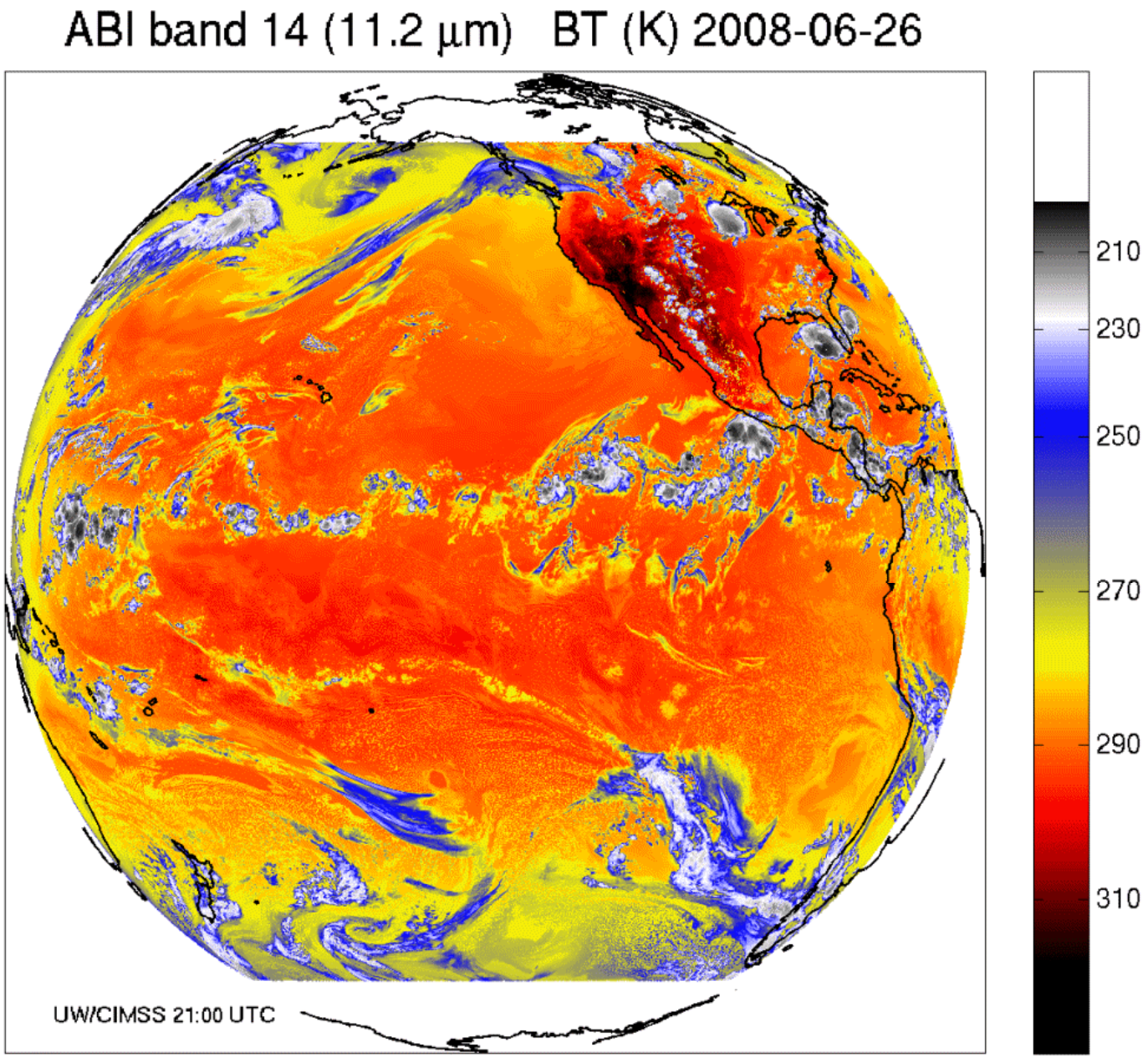
Band 11: “Cloud-top phase” band – SO_2, dust, SST, stability indices, etc.



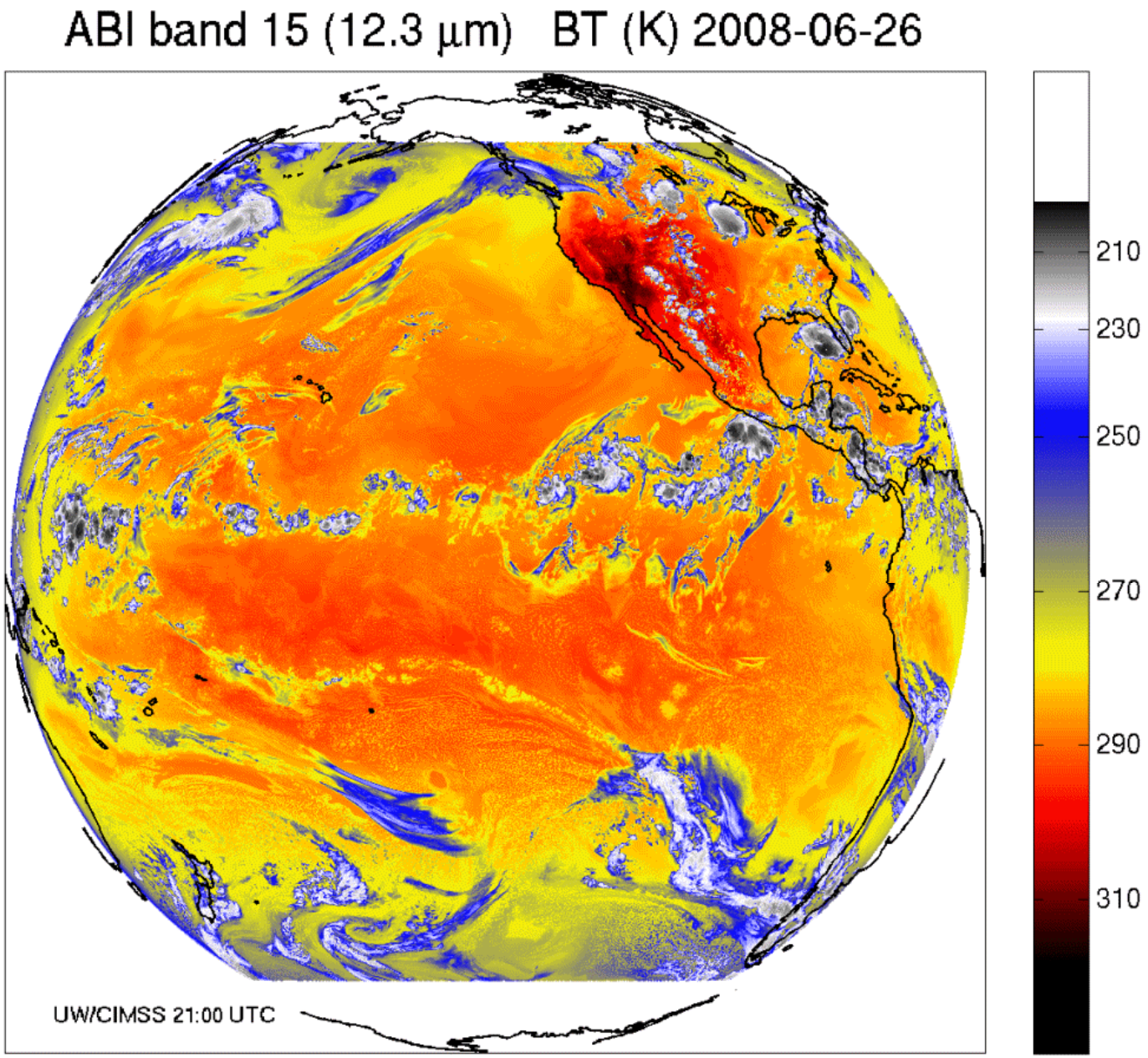
Band 12: “Ozone” band



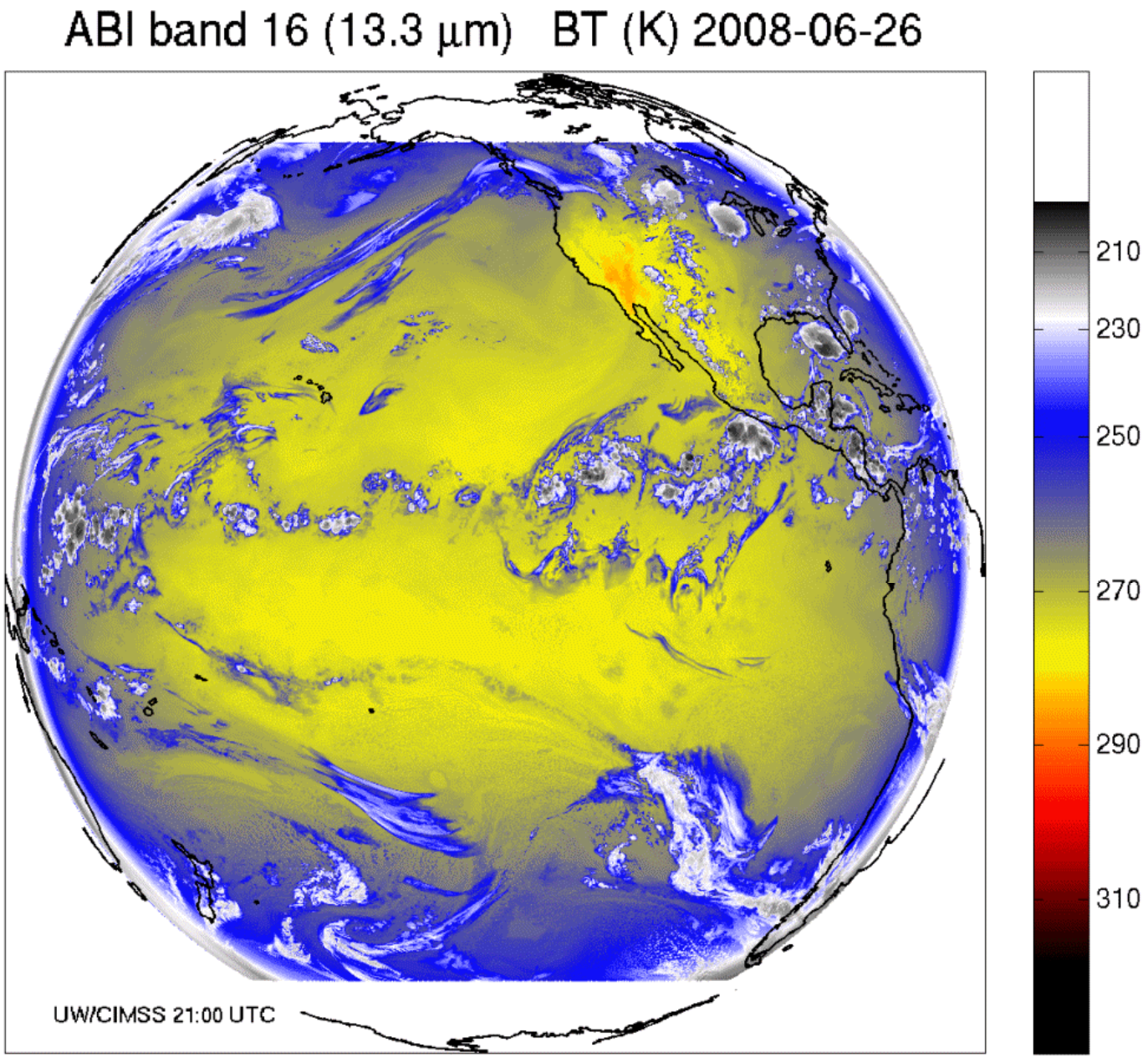
Band 13: “Clean” IR longwave window band – imagery, TPW, etc.



Band 14: IR longwave window band – many cloud parameters, SST, snow cover

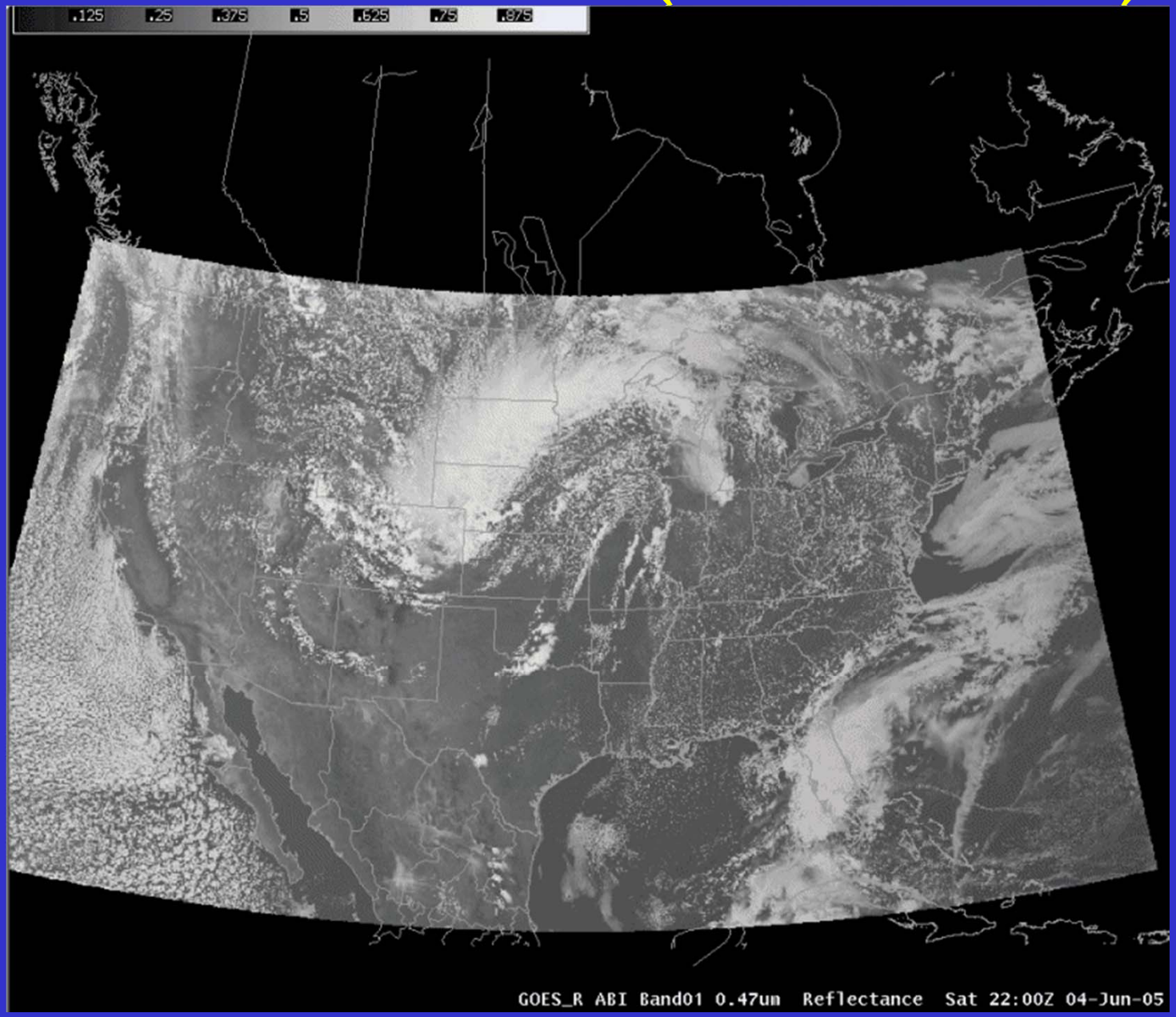


Band 15: “Dirty” IR longwave window band – many cloud parameters, TPW



Band 16: "CO2" longwave IR band – cloud height/pressure, stability indices

ABI in AWIPS (via netCDF)

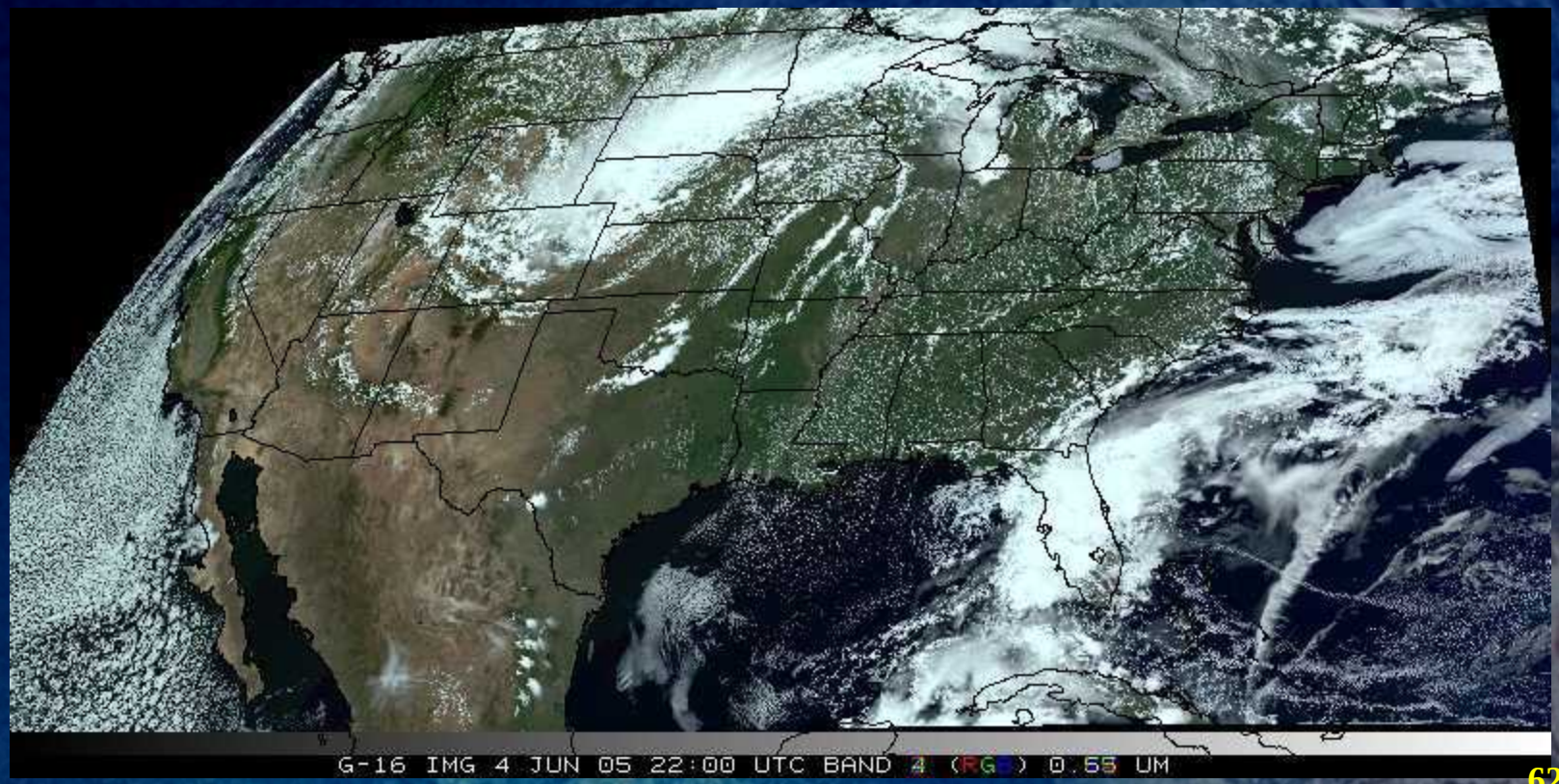


Simulated Advanced Baseline Imager (ABI) bands shown; in the legacy AWIPS.

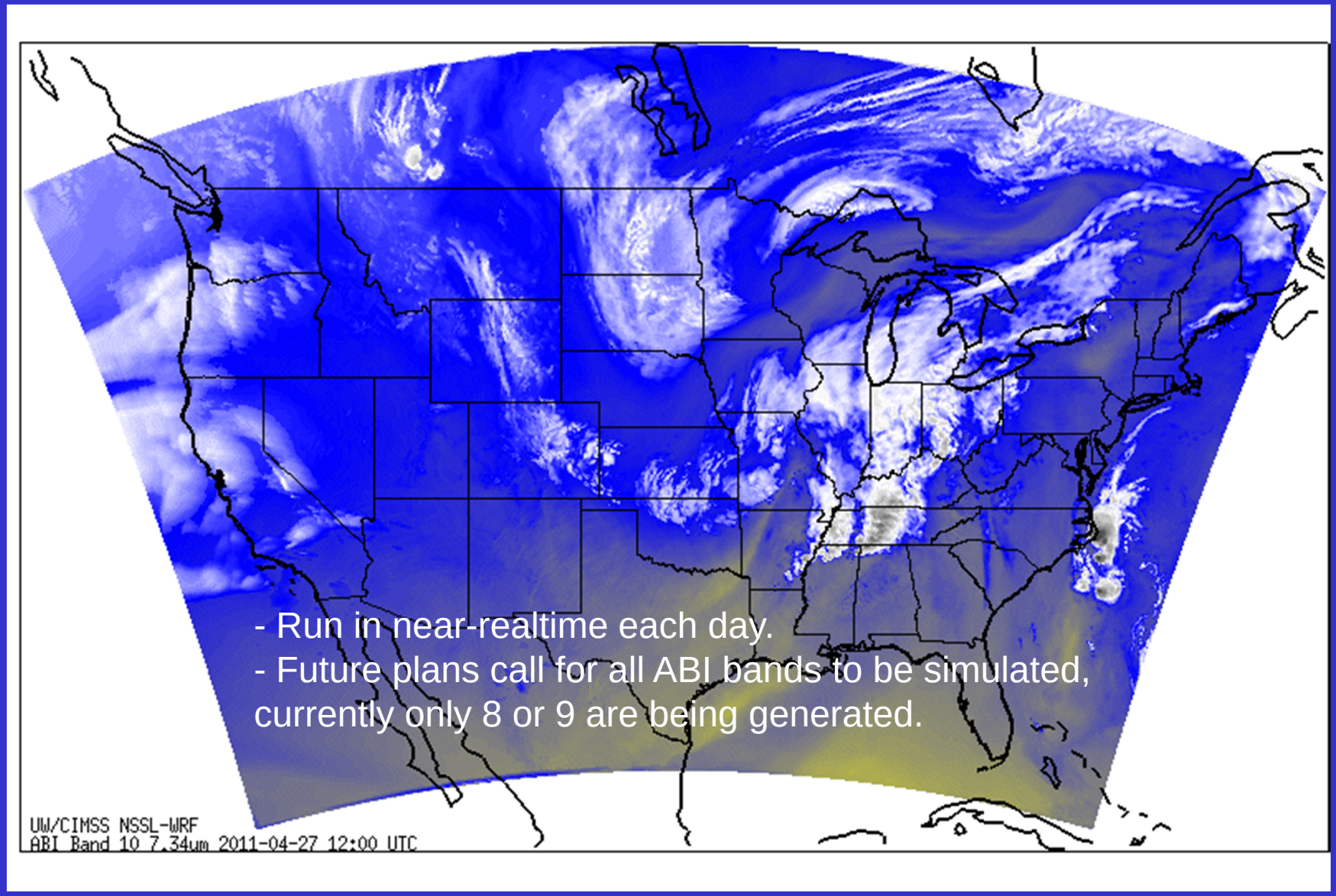
J. Oktin et al., CIMSS

Visualization ("decision aid")

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



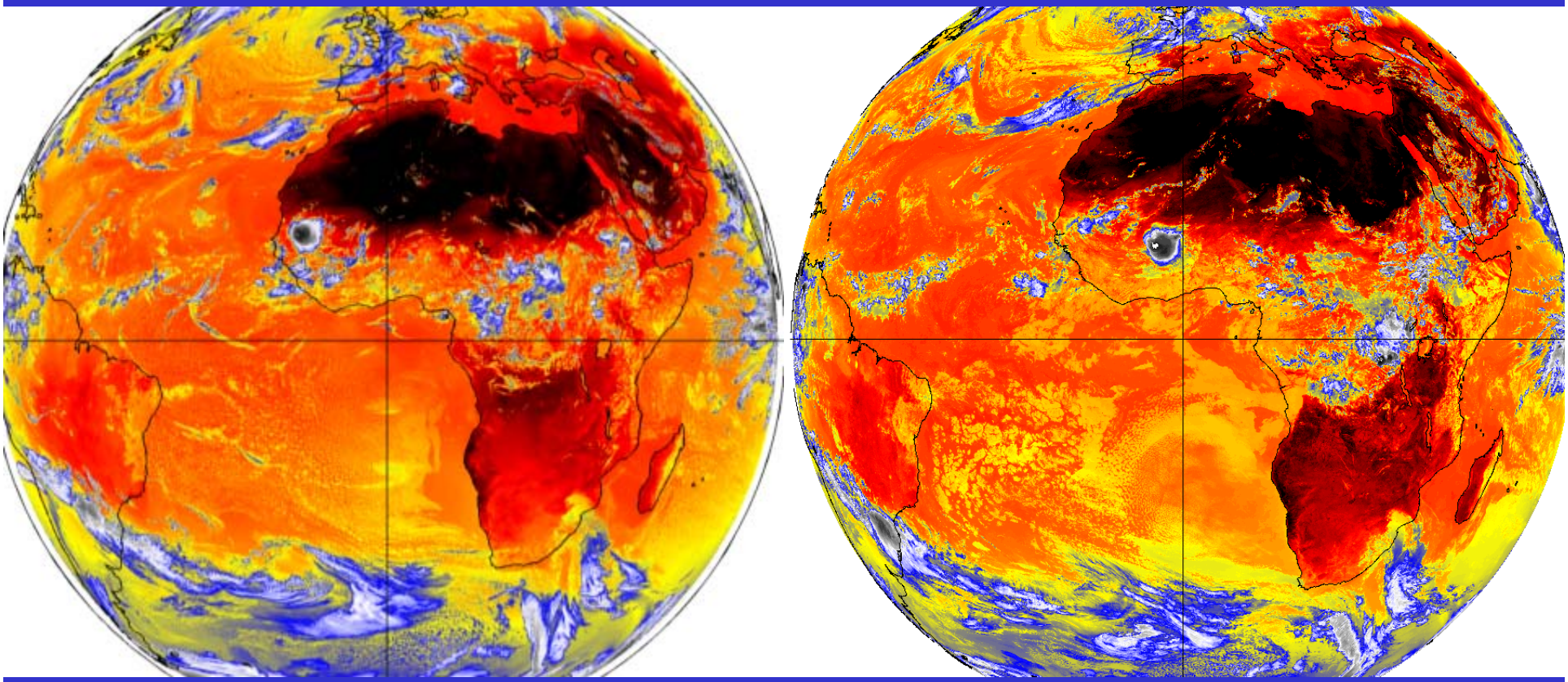
Simulated ABI band – NSSL WRF



- Run in near-realtime each day.
- Future plans call for all ABI bands to be simulated, currently only 8 or 9 are being generated.

http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/nssl_wrf_goes.html

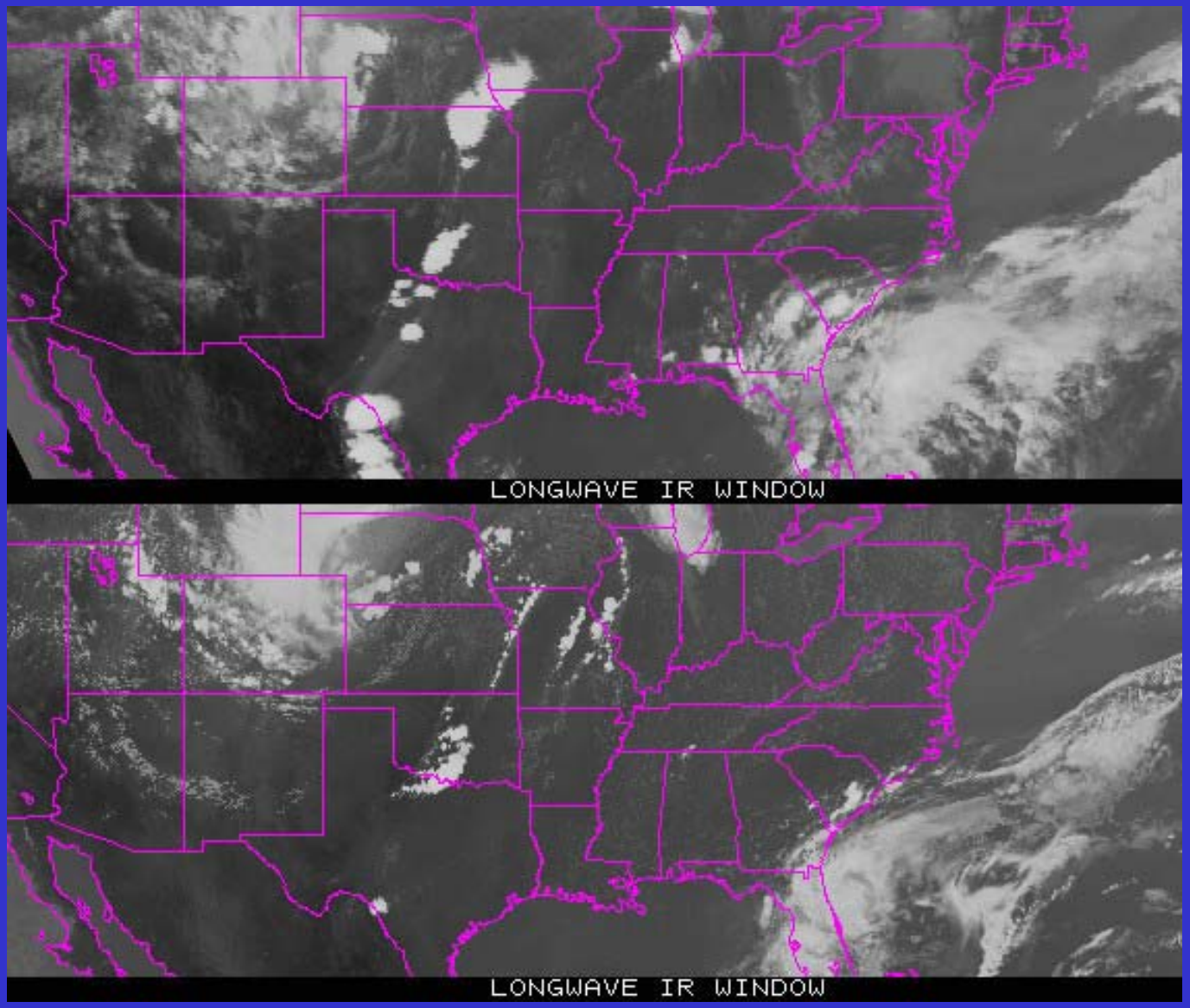
WRF Model-Derived Proxy Radiance Datasets
(UW CIMSS)



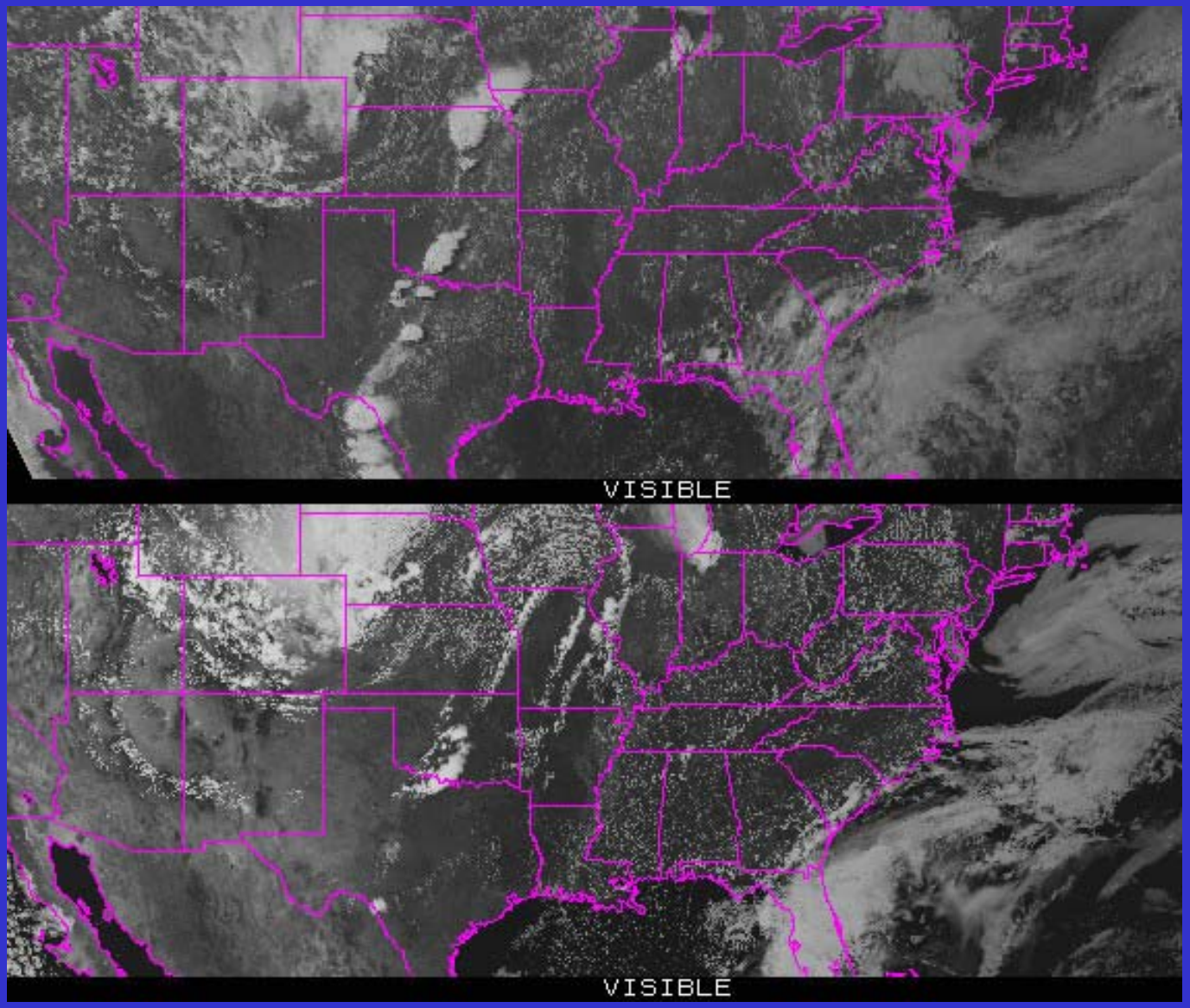
- Which is which – Proxy/Observed or Observed/Proxy SEVIRI 10.8 μm Tb?

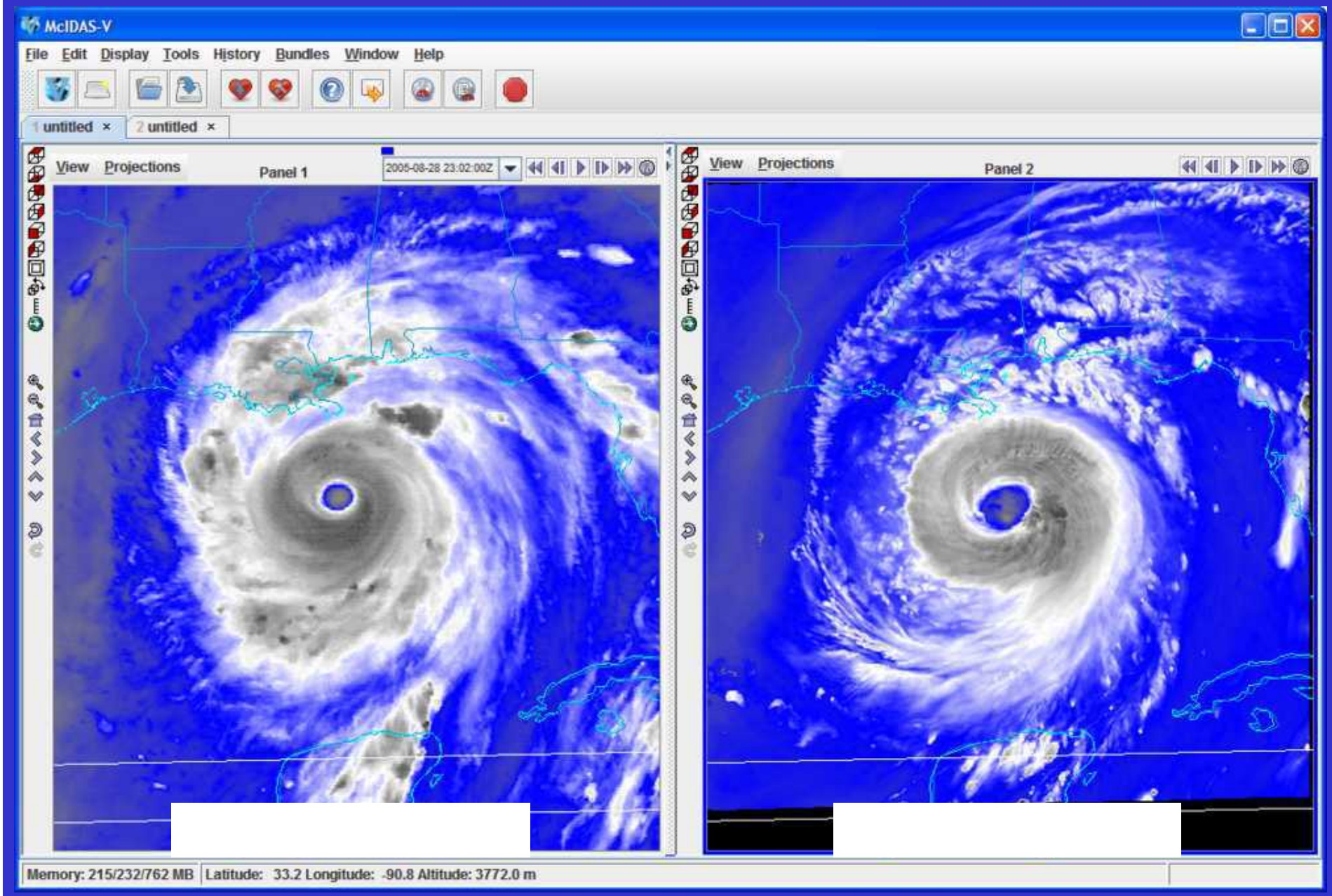
J. Oktin et al., CIMSS

Real, Simulated



Real, Simulated





One is from a McIDAS AREA, while the other (simulated image) is from a netCDF.

Outline

- History
- Current GOES Imager and Sounder
  - GOES-14/15
- ABI (Advanced Baseline Imager)
  - Temporal
  - Spatial
  - Spectral
- Select Products
- High Spectral res.
- Summary
  - More information
  - Questions

Photo courtesy of ITT Geospatial Systems

GOES-R Products

Baseline Products

Advanced Baseline Imager (ABI)

- Aerosol Detection (Including Smoke and Dust)
- Aerosol Optical Depth (AOD)
- 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

Geostationary Lightning Mapper (GLM)

- Lightning Detection: Events, Groups & Flashes

Space Environment In-Situ Suite (SEISS)

- Energetic Heavy Ions
- Magnetospheric Electrons & Protons: Low Energy
- Magnetospheric Electrons: Med & High Energy
- Magnetospheric Protons: Med & High Energy
- Solar and Galactic Protons

Magnetometer (MAG)

- Geomagnetic Field

Extreme Ultraviolet and X-ray Irradiance Suite (EXIS)

- Solar Flux: EUV
- Solar Flux: X-ray Irradiance

Solar Ultraviolet Imager (SUVI)

- Solar EUV Imagery

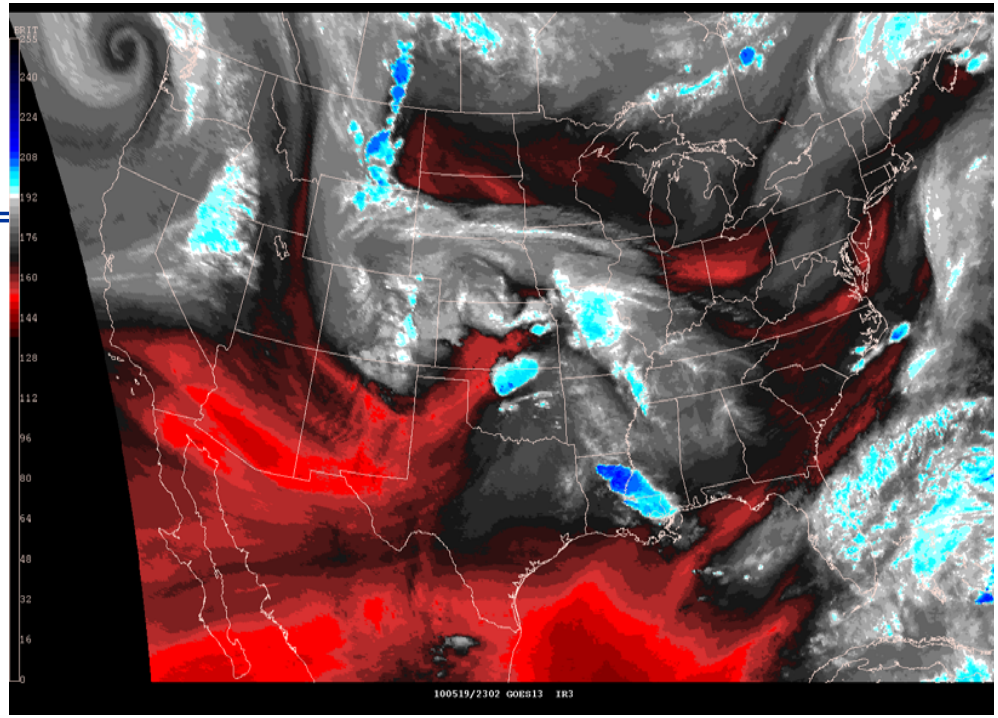
Future Capabilities

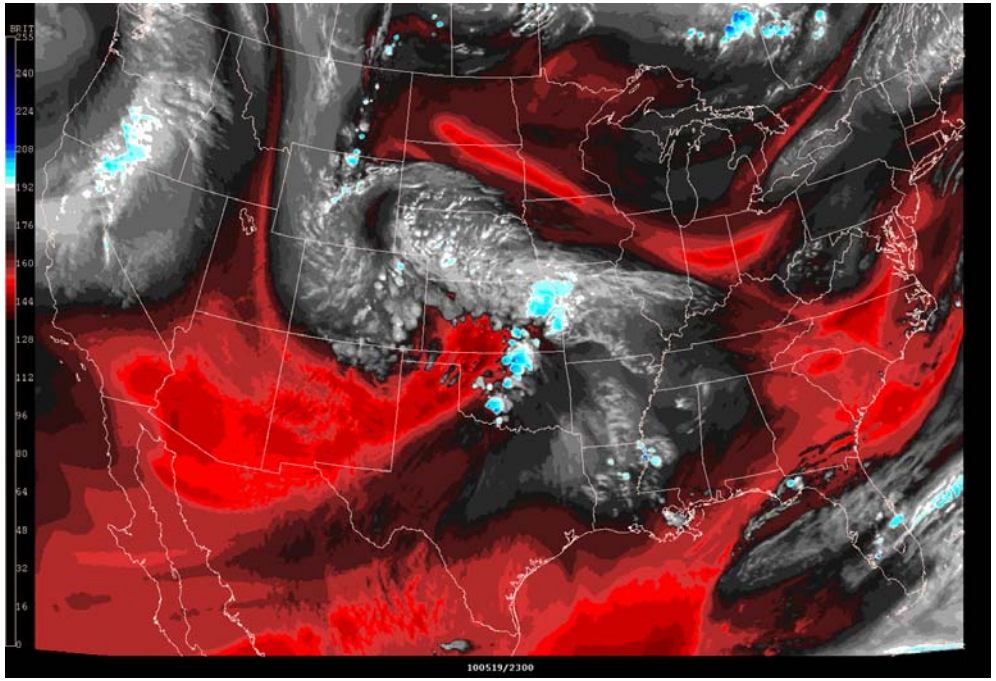
Advanced Baseline Imager (ABI)

- Absorbed Shortwave Radiation: Surface
- Aerosol Particle Size
- Aircraft Icing Threat
- Cloud Ice Water Path
- Cloud Layers/Heights
- Cloud Liquid Water
- Cloud Type
- Convective Initiation
- Currents
- Currents: Offshore
- Downward Longwave Radiation: Surface
- Enhanced “V”/Overshooting Top Detection
- Flood/Standing Water
- Ice Cover
- Low Cloud and Fog
- Ozone Total
- Probability of Rainfall
- Rainfall Potential
- Sea and Lake Ice: Age
- Sea and Lake Ice: Concentration
- Sea and Lake Ice: Motion
- Snow Depth (Over Plains)
- SO_2 Detection
- Surface Albedo
- Surface Emissivity
- Tropopause Folding Turbulence Prediction
- Upward Longwave Radiation: Surface
- Upward Longwave Radiation: TOA
- Vegetation Fraction: Green
- Vegetation Index
- Visibility

Imagery

- Imagery for nowcasting
  - Clouds
  - Input for products
  - Channel differences
  - RGB
  - General Users
  - Etc.
- Radiances for NWP
  - Clear-sky
  - Cloudy-sky
  - Validations
  - Monitoring
  - Etc.





Clear Sky Mask
("Cloud Detection")

- **Automatic Cloud Mask (ACM)**

- **Algorithm Highlights**
  - Designed to maximize flexibility and use
  - Mask built with multiple individual tests that could be turned on and off by the downstream applications.
  - Uses new ABI Bands (1.38um, 1.6um)
  - Design allows for additional of new tests easily as warranted.
  - Determination of test thresholds accomplished through the use and analysis of CALIPSO data.

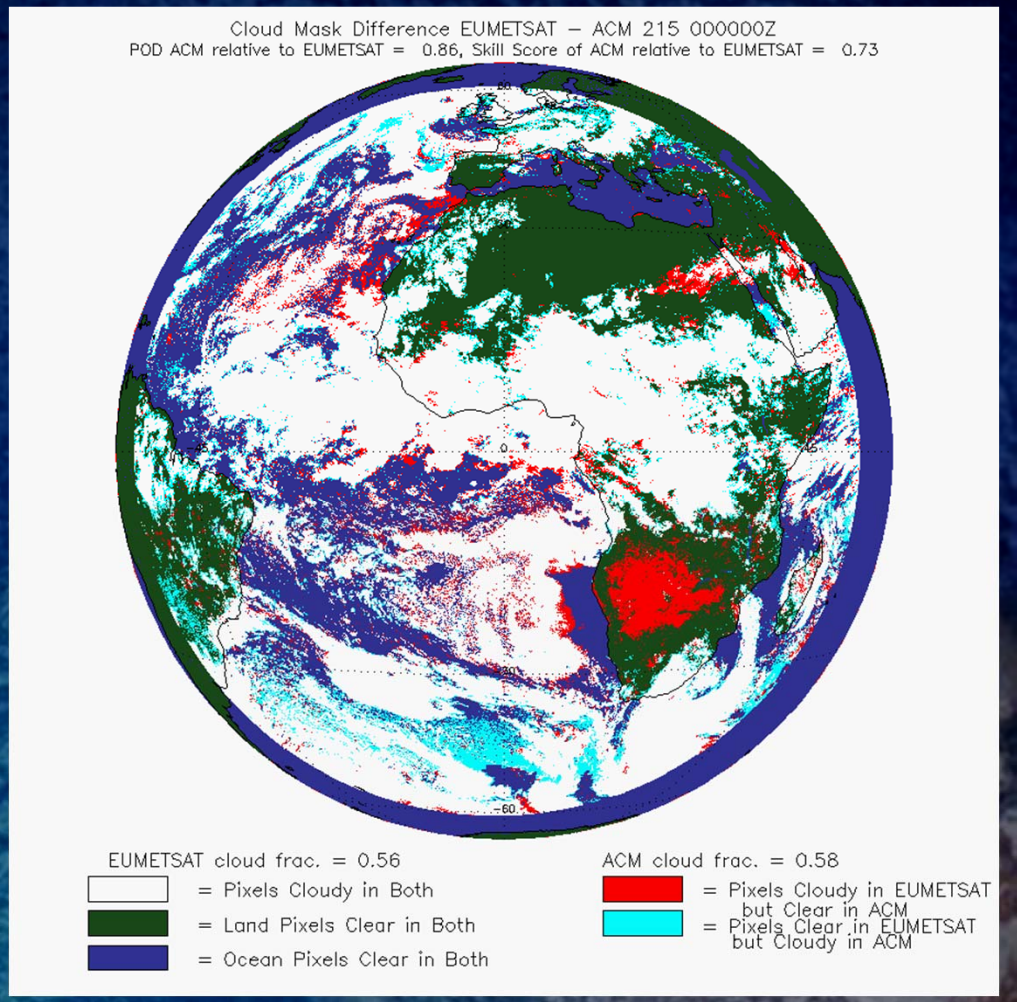
- **Operational Applications**
  - Used extensively by downstream level-2 product algorithms
  - Identifies clear pixel radiances for NWP data assimilation

Inter-satellite ACM Comparison

- *The EUMETSAT Meteorological Product Extraction Facility (MPEF) Cloud Mask cloud mask provides a well-characterized mask designed for the imagery used as proxy*

- *The animation on the right shows a comparison of the ACM run on data from SEVIRI as compared to the EUMETSAT cloud mask from that scene.*

- *Inter-satellite comparisons of cloud mask (and other products) can provide insight as to deficiencies and improvement in both products (next slide)*

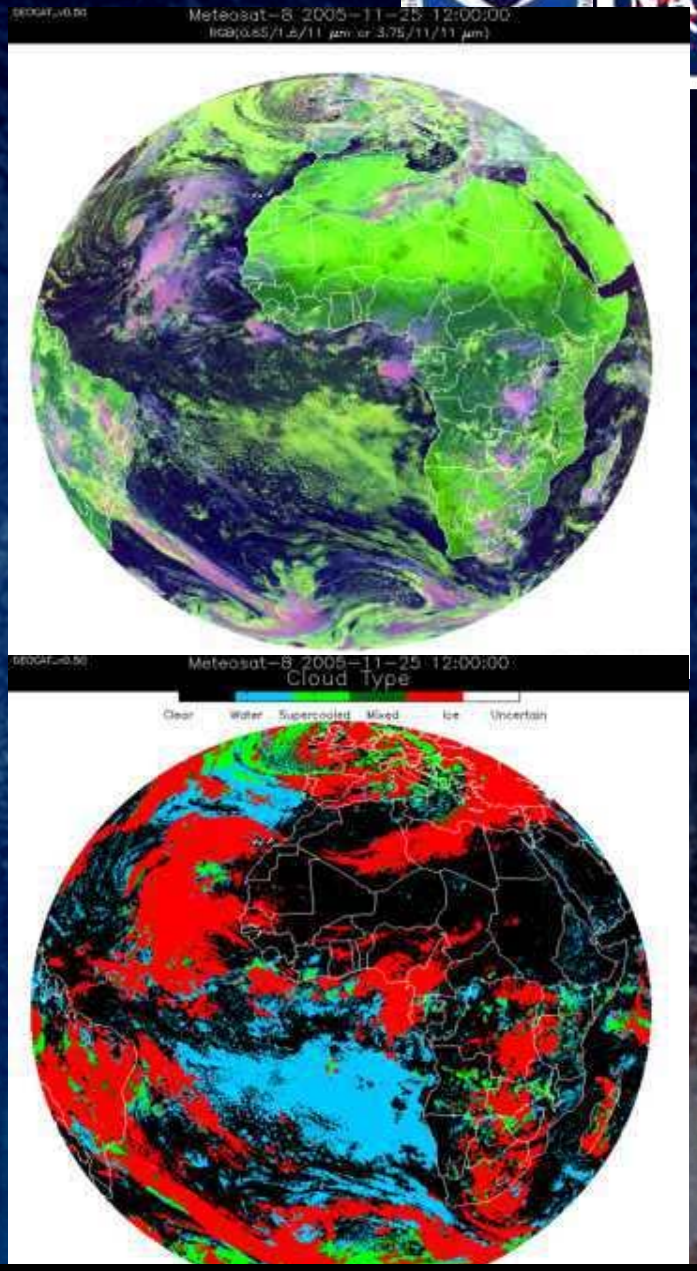


A. Heidinger, ASPB

Cloud Phase

- **Algorithm Highlights**
  - An Infrared only algorithm that exploits the rich IR information (7.4, 8.5, 11.2, and 12.3 μm) provided by the ABI
  - Algorithm determines the cloud top (layer that the radiometer senses) thermodynamic phase of the highest cloud layer
  - Exploits recent improvements in fast clear-sky radiative transfer models and ancillary data (land cover, surface emissivity
  - Makes advanced use of spatial information

- **Operational Applications**
  - Prerequisite for other cloud property retrievals (height, temp)
  - Climate prediction
  - Aviation forecasting (Aircraft icing)

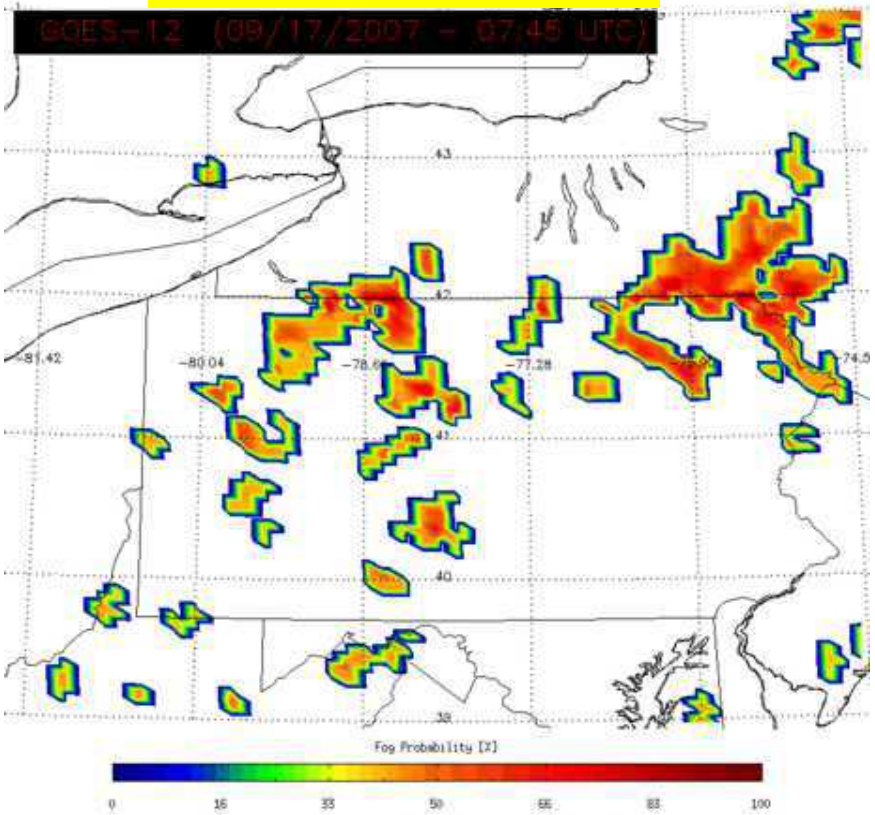


Water, Supercooled Water, Mixed Phase, Ice

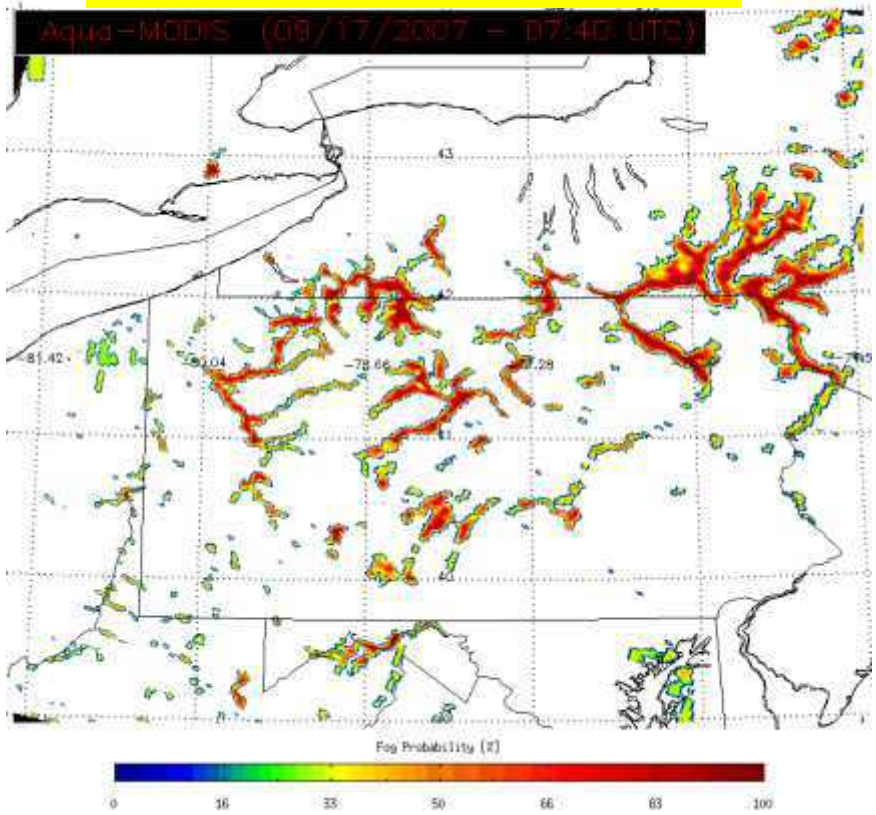
M. Pavolonis

The “Future Capabilities” Fog Product

GOES

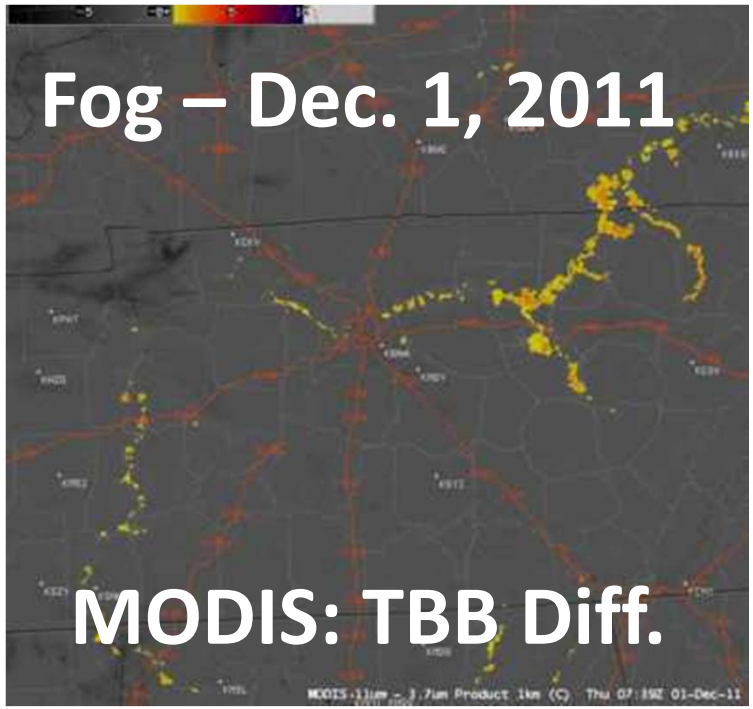


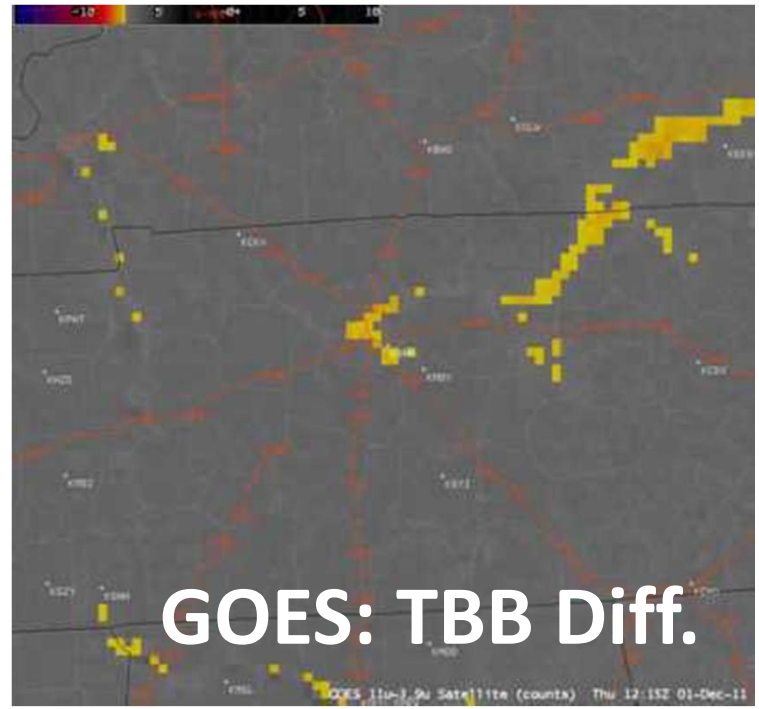
GOES-R alg.

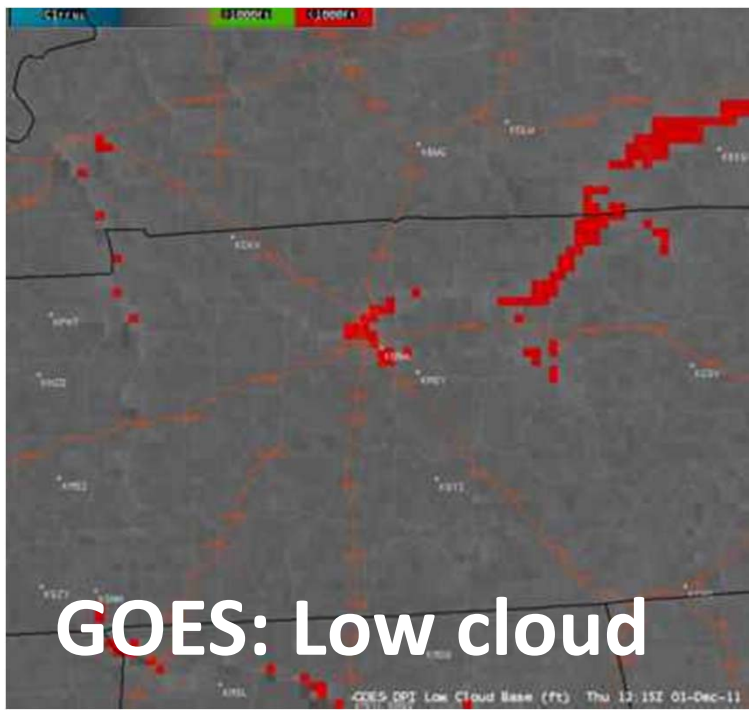


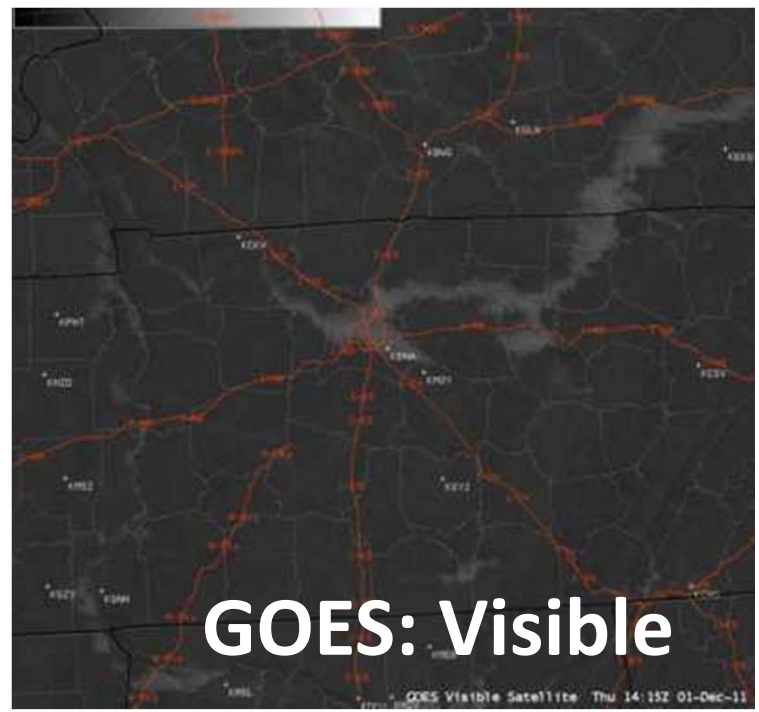
M. Pavolonis

Fog – Dec. 1, 2011









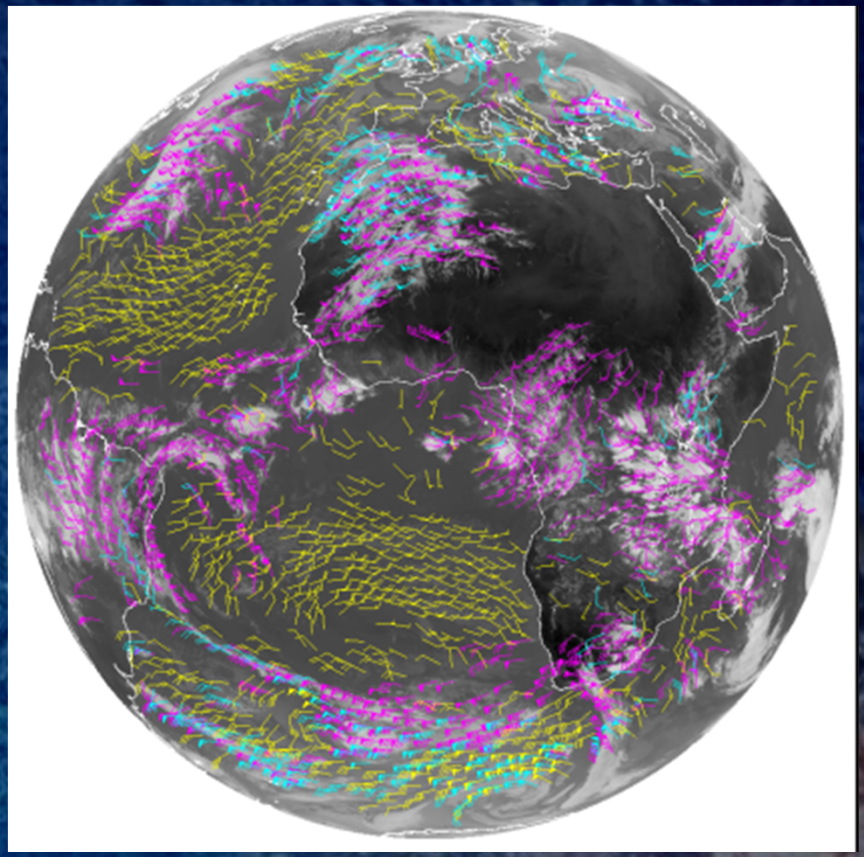
Bachmeier, CIMSS

Derived Motion Winds

- **Algorithm Highlights**
  - Heritage in targeting, tracking, and QC algorithms lie with current NESDIS operational winds algorithms
  - New nested tracking algorithm introduced that makes use of a two-dimensional clustering algorithm to capture the dominant motion in each target scene
  - Utilizes clear sky mask product
  - Wind height assignment will rely on utilization of pixel level cloud heights generated upstream via algorithms delivered by AWG cloud application team
  - Leverages ABI's higher spatial and temporal resolution data

- **Operational Applications**
  - Weather Forecasting
  - Assimilation into mesoscale and global NWP models
  - Aviation (flight routing)

Cloud-drift Winds derived from a Full Disk Meteosat-8 SEVERI 10.8 μm image triplet centered at 1200 UTC 01 February 2007



High Level 100-399 mb Mid-Level 400-699 mb Low-Level >700 mb

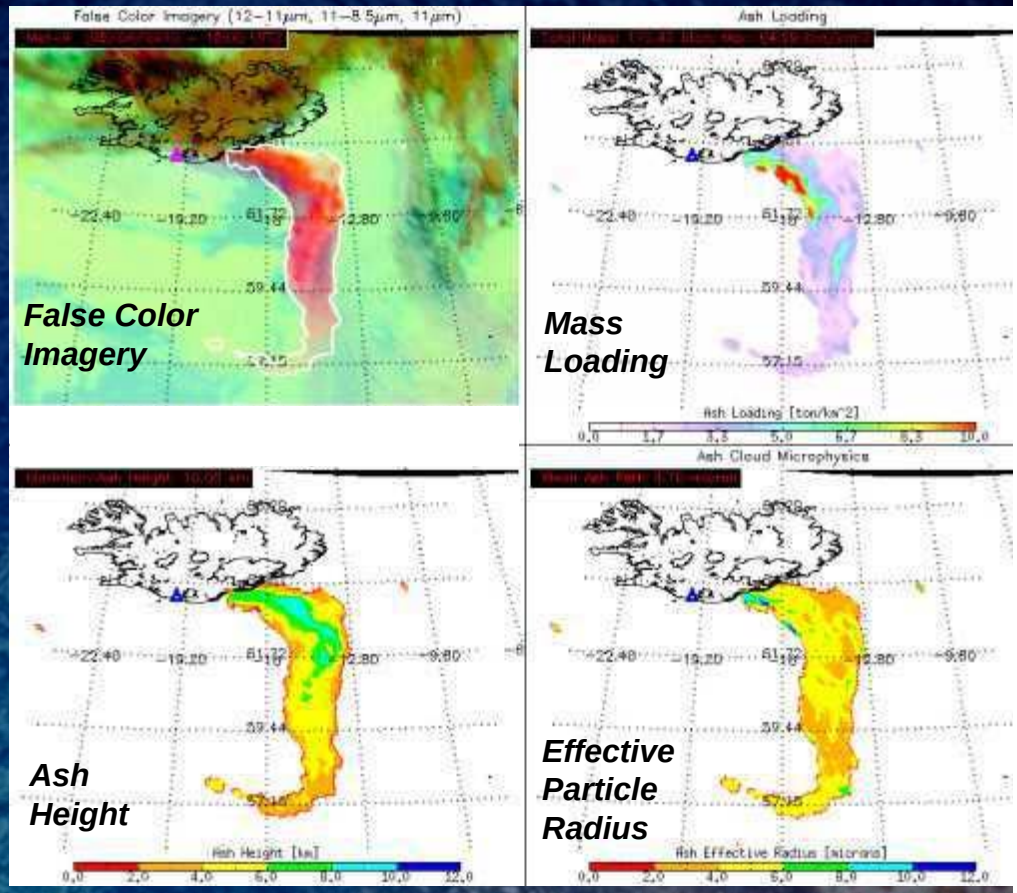
Courtesy J. Daniels: NOAA-STAR

Volcanic Ash

- **Algorithm Highlights**
  - Detects volcanic ash and estimates its height and mass loading
  - Leverages the new ABI 8.5 μm band, The 8.5 μm, 11.2 μm, and 12.3,11.2 μm channel pairs are used to detect volcanic ash
  - An optimal estimation approach is used to estimate ash cloud temperature, emissivity and microphysical index.
  - Ash cloud height determined from NWP profiles.
  - Mass loading estimated from computed optical depth and effective particle size
  - Leverages ABI's new 8.5 μm channel, along with 11.2 μm and 12.3 μm for sensitivity to cloud microphysics (including composition)

- **Operational Applications**
  - Aviation safety
  - Health safety
  - Climate studies

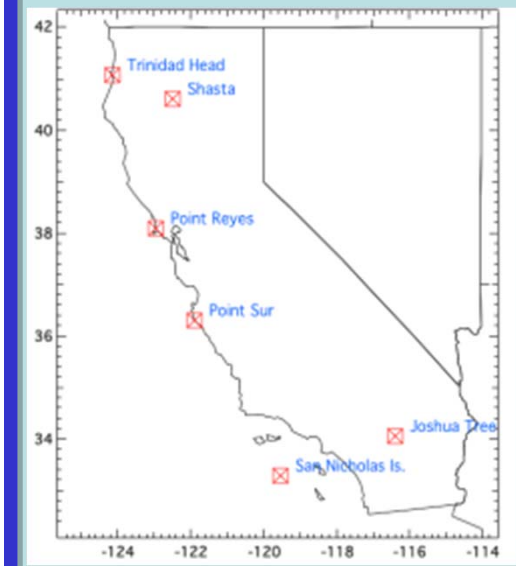
Iceland's Eyjafjallajökull Volcano



M. Pavolonis

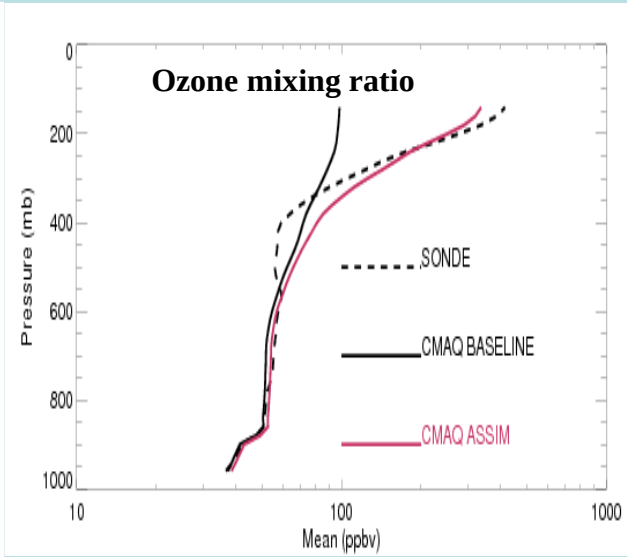
Geostationary Total Column Ozone (TCO) Assimilation

CalNex Ozonesonde

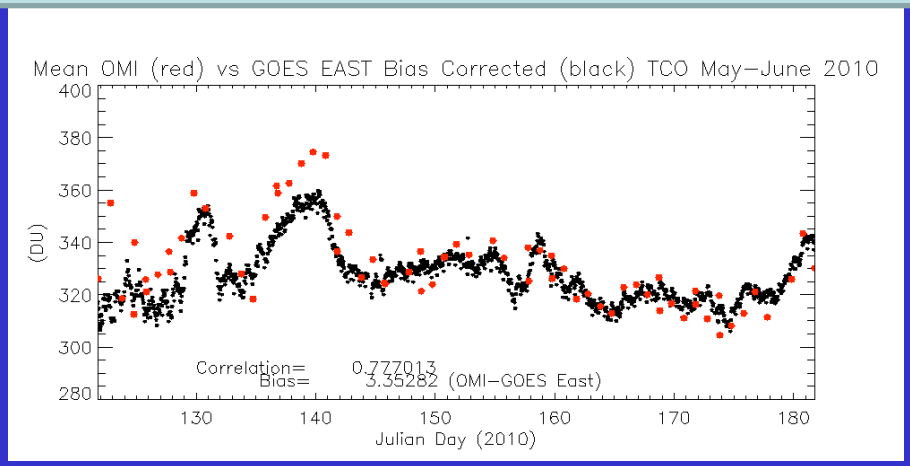


GOES TCO Assimilation

(GFS UT/LS and background errors)

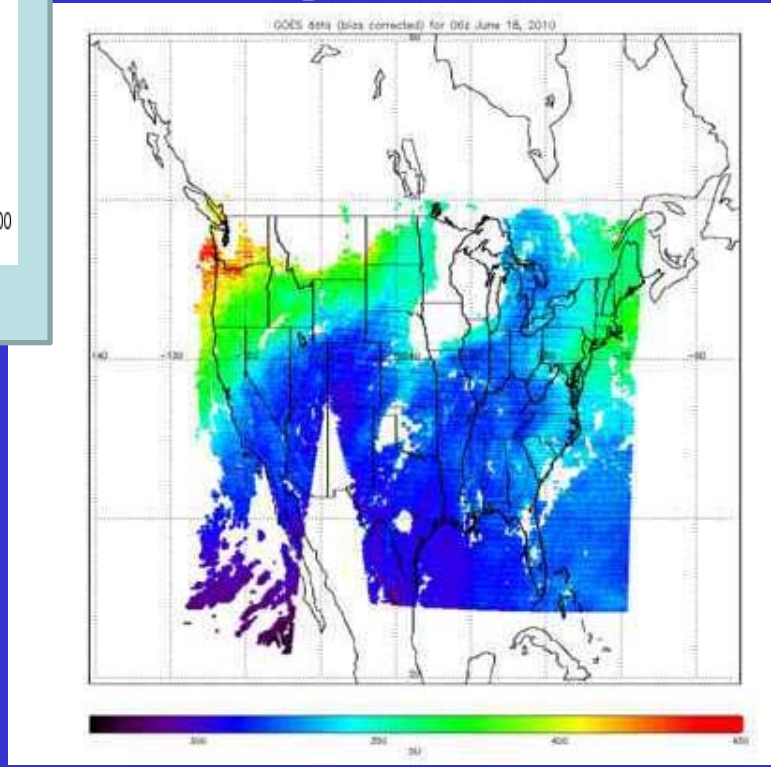


Significant improvement in upper troposphere



Continuous day/night sampling

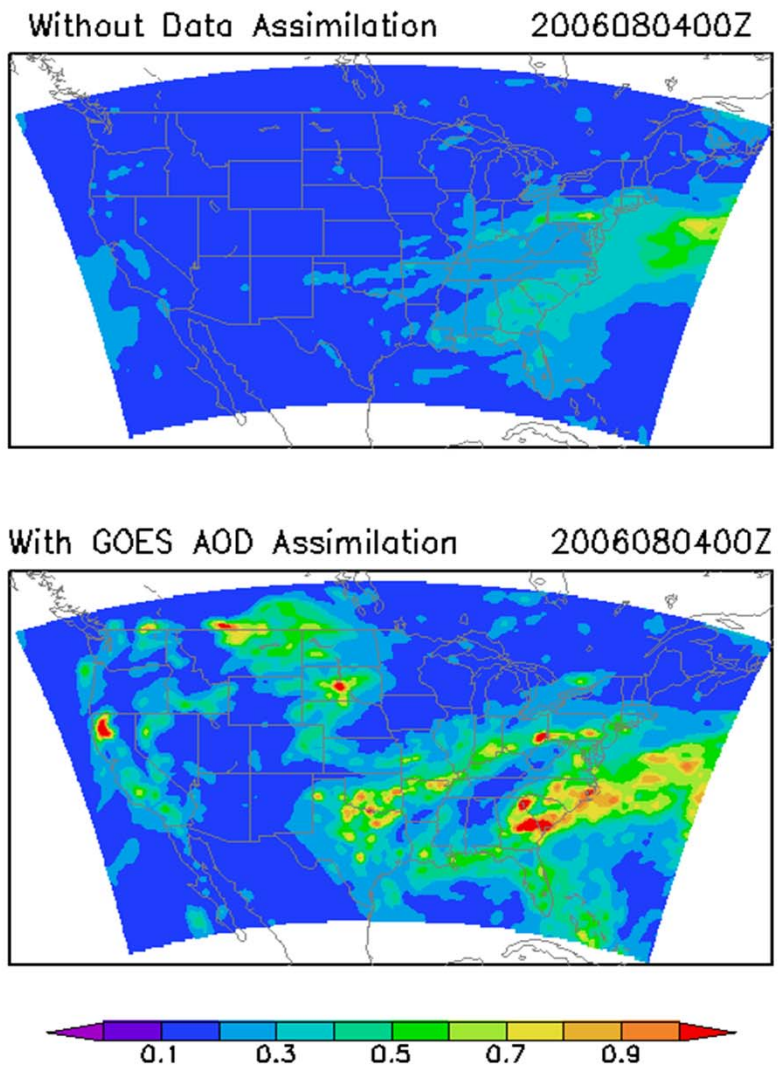
The National Air Quality Forecasting Capability (NAQFC) uses the Community Multi-scale Air Quality (CMAQ) to provide air quality forecast guidance. Capabilities to assimilate Geostationary Sounder TCO within CMAQ are currently under development at JCSDA



Improved Cloud free sampling

Brad Pierce (NESDIS/STAR)

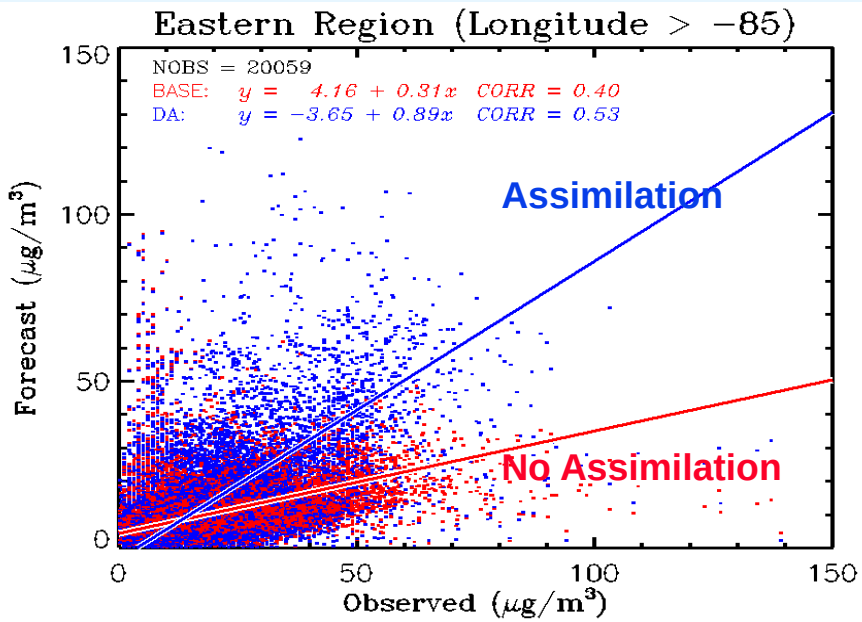
Improved Aerosol Predictions with Satellite Data Assimilation



AOD

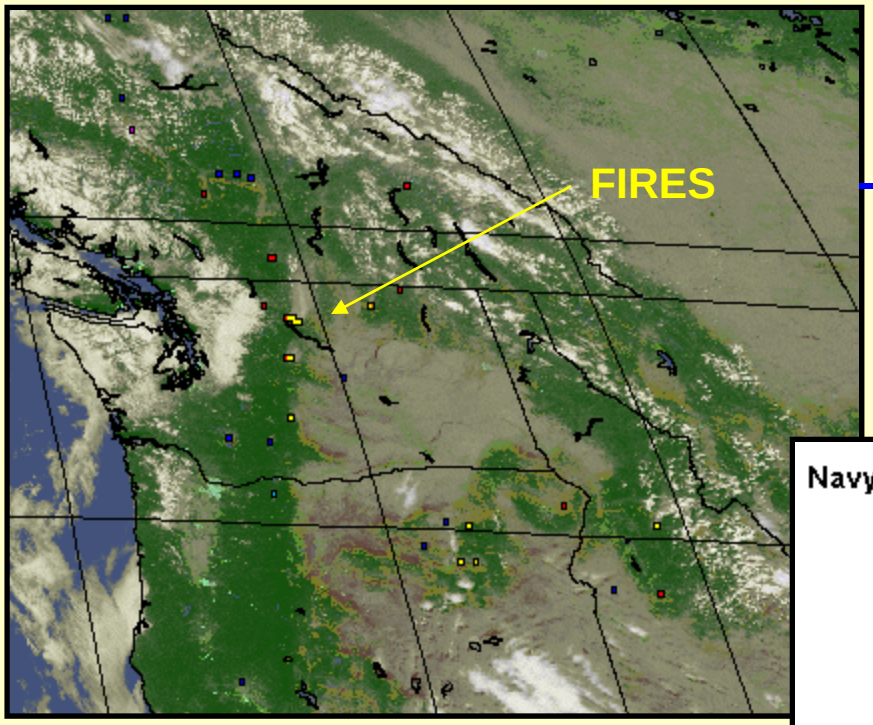
- **Assimilation (Cressman analysis) of GOES Aerosol Optical Depth (AOD) in a NOAA-EPA Weather and Research (WRF)/Community Multiscale Air Quality (CMAQ) model shows improved aerosol predictions for an east coast pollution episode**

Observed vs Predicted Surface PM2.5 (µg/m^3) Concentrations

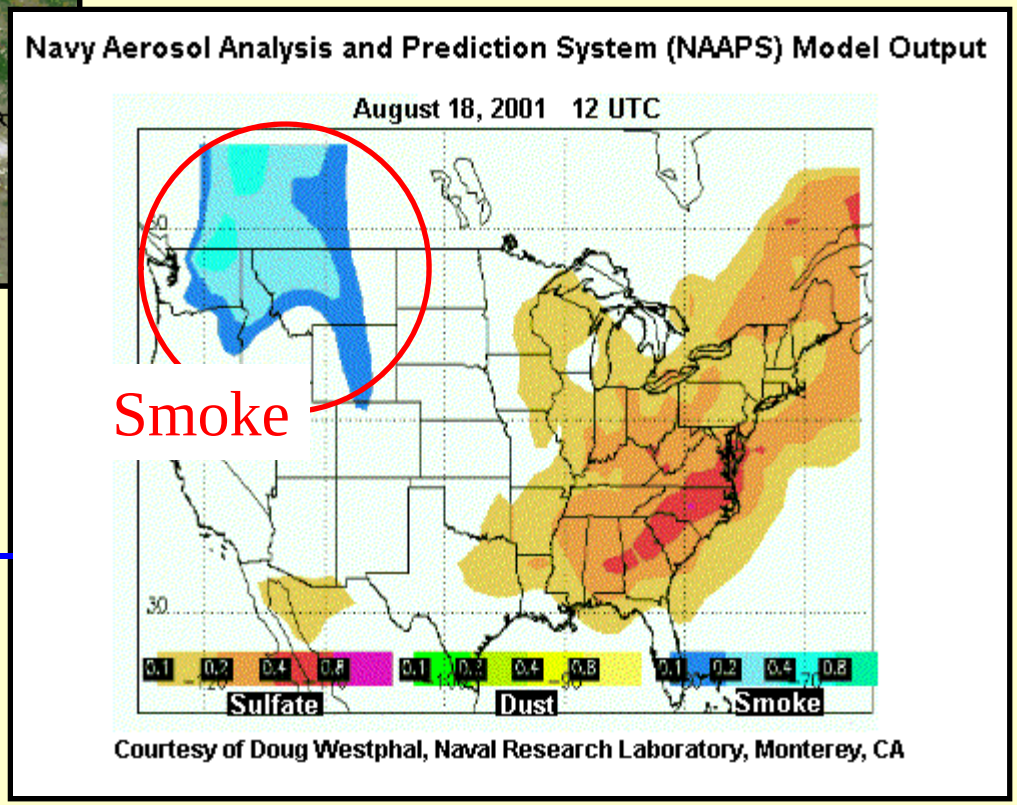


Shobha Kondragunta, STAR

Aerosol Transport Model Assimilation of the Wildfire ABBA Fire Product Using the Navy Aerosol Analysis and Prediction System



GOES-8 Wildfire ABBA fire product for the Pacific Northwest
Date: August 17, 2001
Time: 2200 UTC



NAAPS Model Aerosol Analysis for the continental U.S.
Date: August 18, 2001
Time: 1200 UTC

Elaine Prins, formerly of STAR

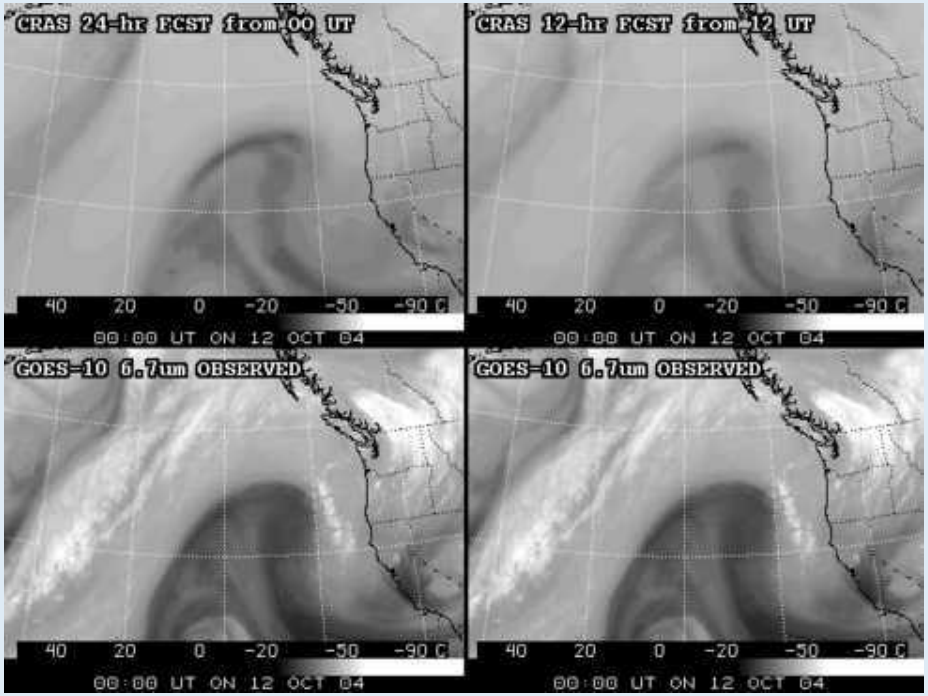
GOES data was used to develop improved moist physics in CRAS

SATELLITE VALIDATION

CRAS generates forecast 11um and 6.5um satellite images and are validated using actual GOES imagery.

CRAS 24hr forecast 6.7um satellite image at 40km resolution (clear sky)

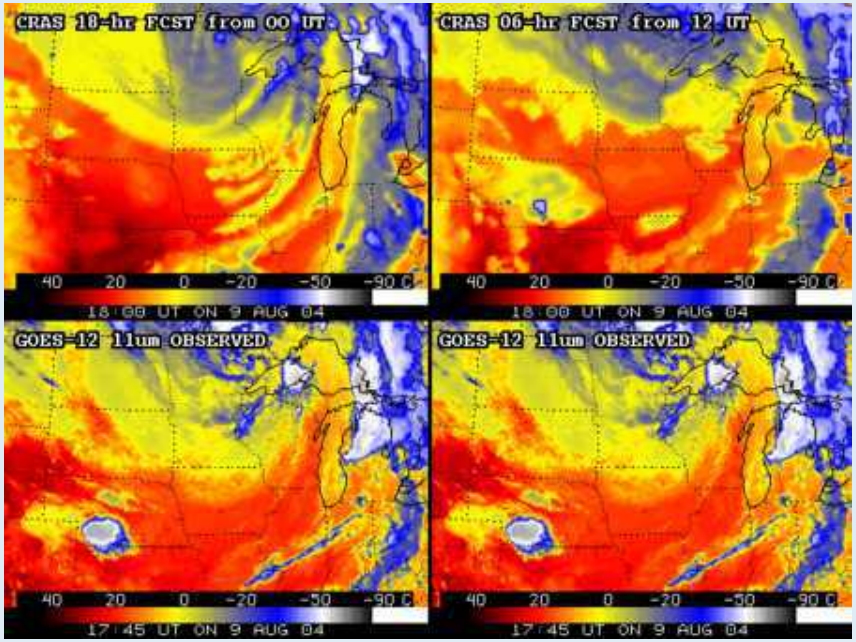
CRAS 12hr forecast 6.7um satellite image at 40km resolution (clear sky)



6.7 um water vapor image from GOES-10 valid 00UTC, October 12, 2004

CRAS 18hr forecast 11um image at 20km resolution

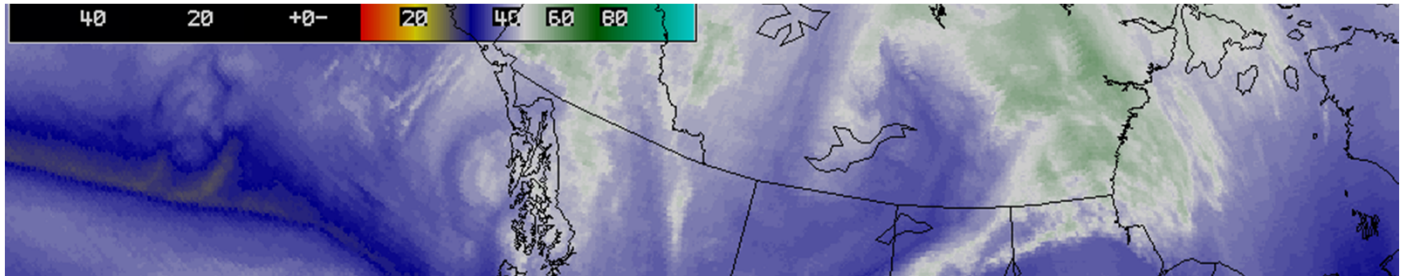
CRAS 06hr forecast 11um image at 20km resolution



11um image from GOES-12 valid 18UTC August 9, 2004

Images courtesy of G. Wade

Simulated WV imagery in AWIPS (since 2006)



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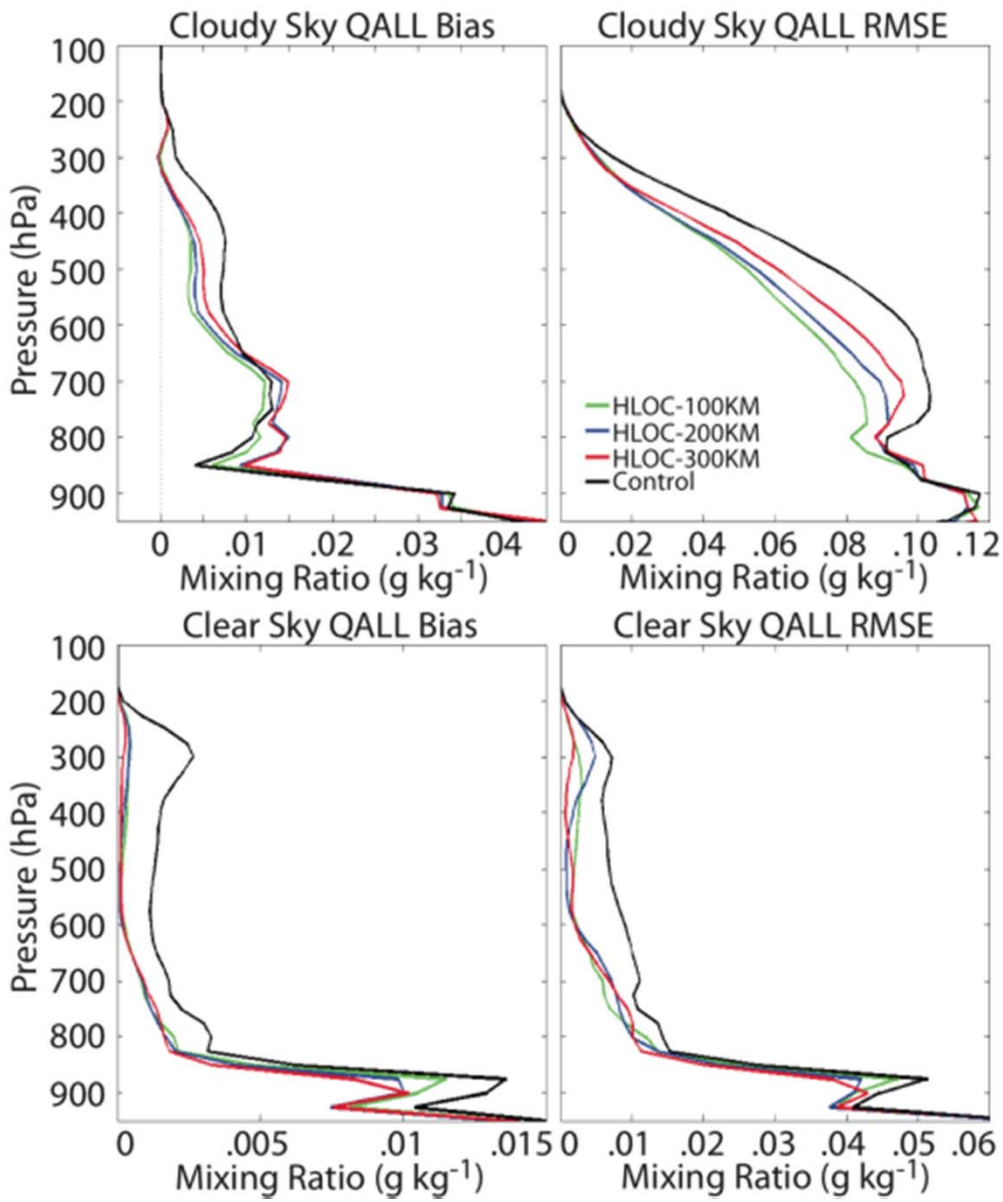
FXUS63 KMKX 301935
AFDMKX

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE MILWAUKEE/SULLIVAN WI
230 PM CDT WED AUG 30 2006

.DISCUSSION...FORECAST FOCUS ON LINGERING UPPER LOW AND STRONGER UPPER LOW FOR NEXT WEEK.

IN THE NEAR TERM FIRST LOOK AT CRAS MODEL SATELLITE IMAGERY IS VERY IMPRESSIVE. SO MUCH MODEL INFORMATION IS BEING PRESENTED IN ONE IMAGE THAT CAN BE EASILY DIGESTED. ESPECIALLY WITH SAY 700MB NAM HEIGHT OVERLAYED. CLOUD COVER AND CLOUD HEIGHTS...EASILY IDENTIFIED STRATOCUMULUS SHIELDS. ALSO EASY TO CONVERT TO CONCEPTUAL MODEL OF SYSTEM TYPE. …

Cloud Errors After Last Assimilation Cycle



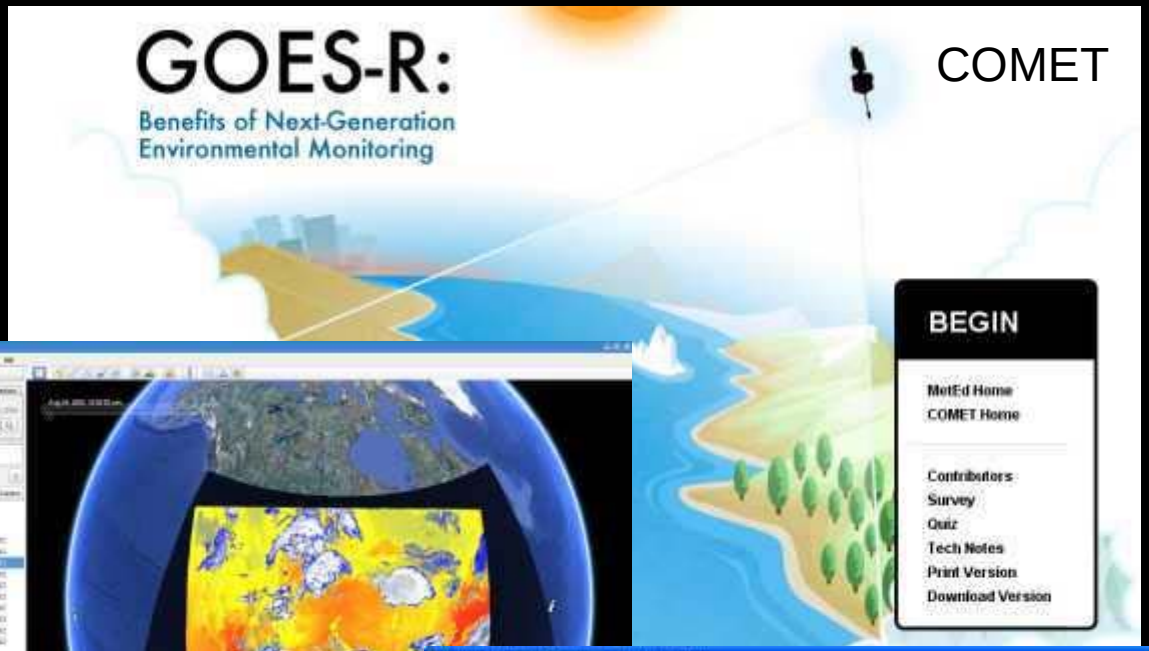
Jason Otkin, CIMSS

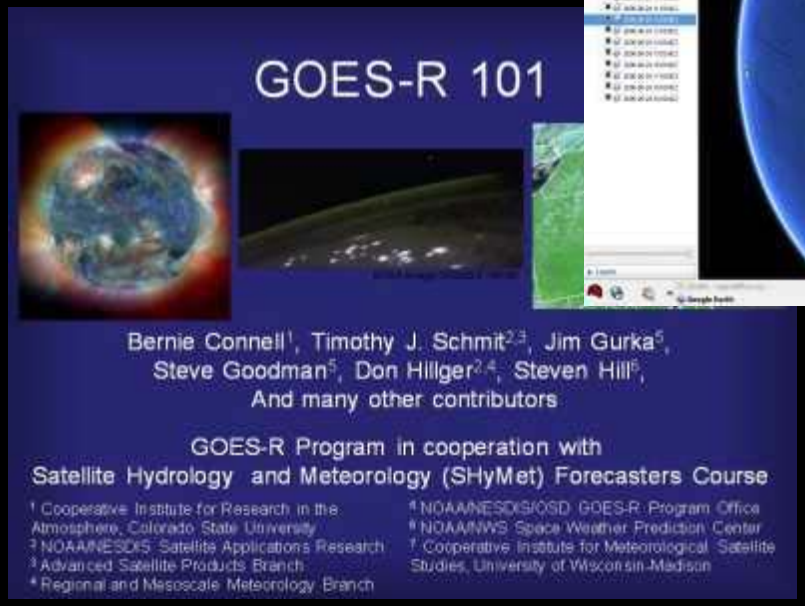
- Total cloud condensate (QALL) errors over the entire model domain after the last assimilation cycle

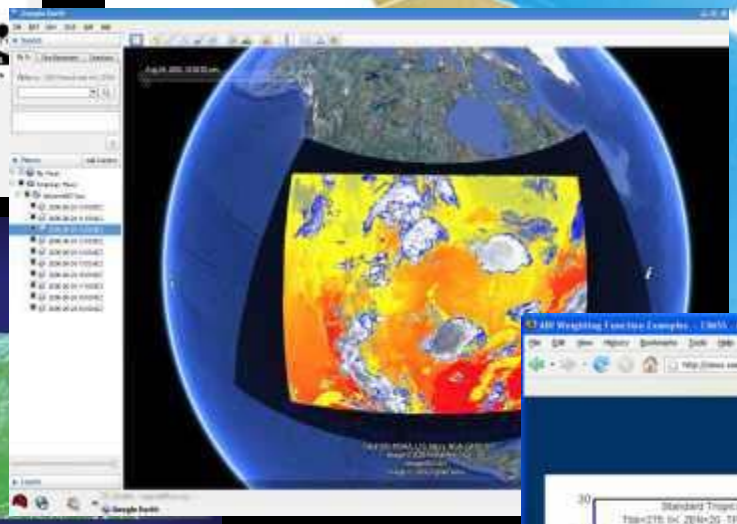
- Overall, the cloud analysis was greatly improved when 8.5 micrometer brightness temperatures were assimilated simultaneously with the conventional observations.

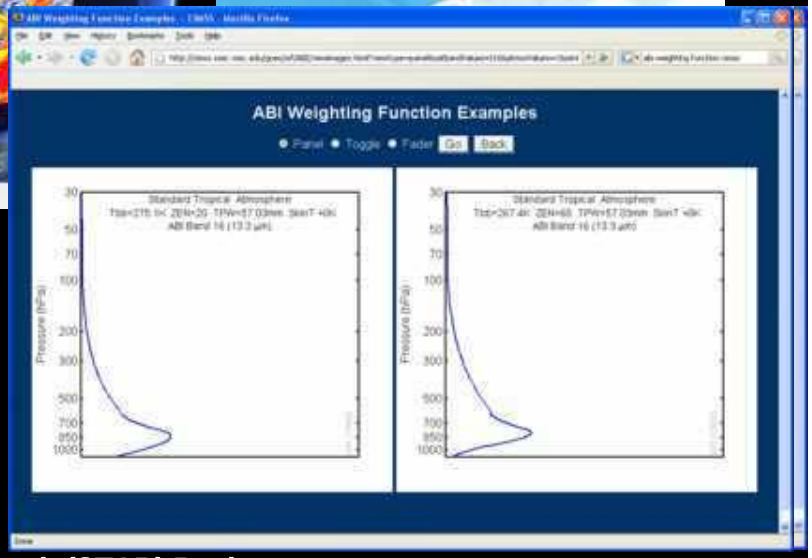
- Clear observations may be more representative of larger scales whereas cloudy observations are more representative of smaller scale features.

Training and Education



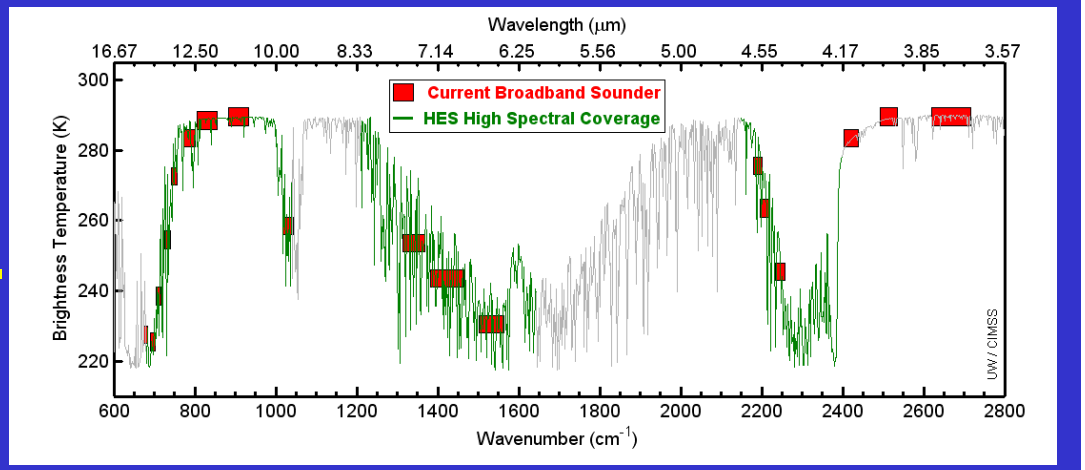






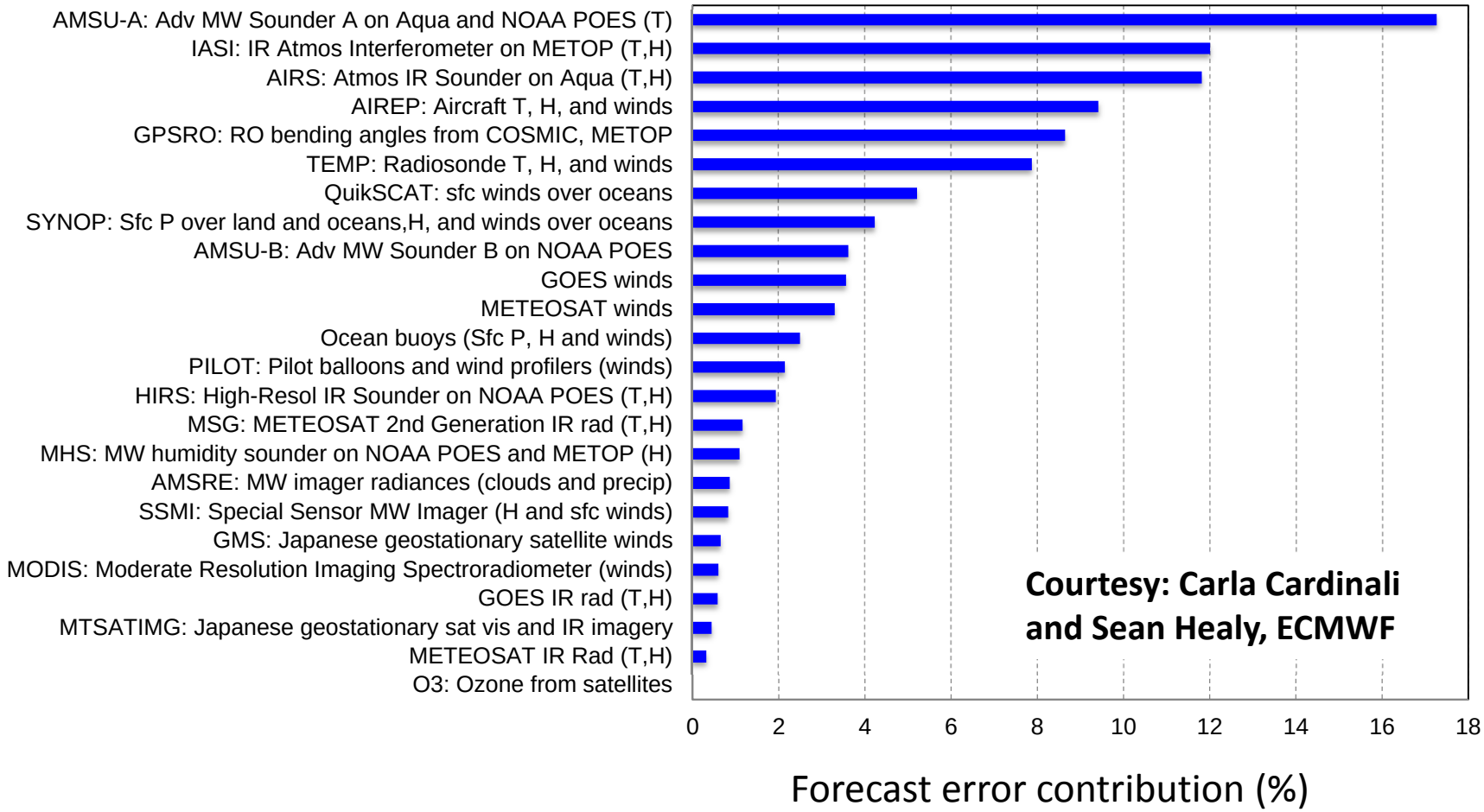
Outline

- History
- Current GOES Imager and Sounder
  - GOES-14/15
- ABI (Advanced Baseline Imager)
  - Temporal
  - Spatial
  - Spectral
- Select Products
- High Spectral res.
- Summary
  - More information
  - Questions



Operational ECMWF system

Averaged over all model layers and entire global atmosphere. % contribution of different observations to reduction in forecast error.

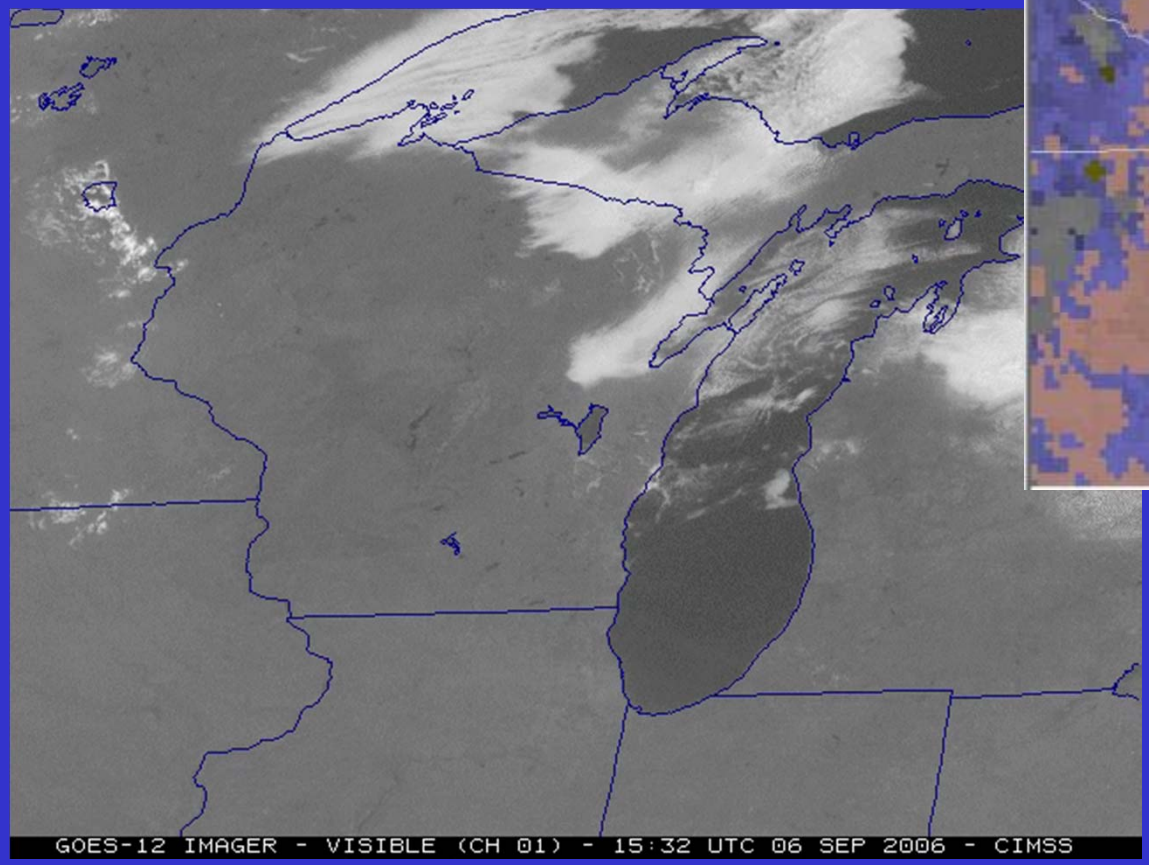


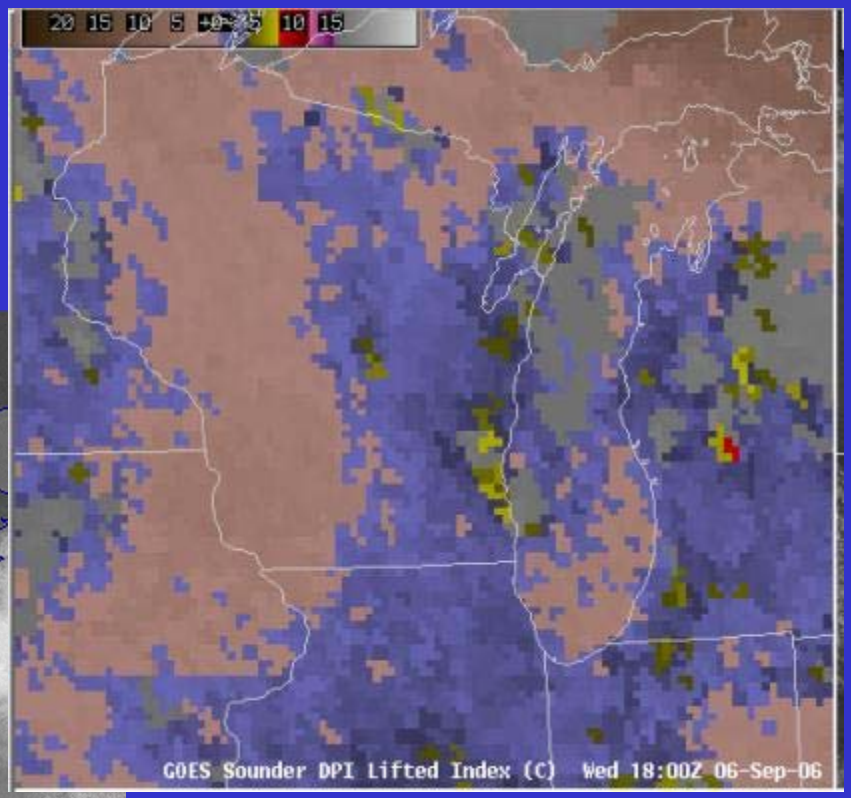
Infrared High Spectral resolution Sounders reduce forecast error the most (for a given instrument)

High-Spectral, combined with High-Temporal Resolution is the key

- Water Vapor and Carbon Dioxide absorption lines within the infrared window are sensitive to changes in the lower tropospheric thermodynamic state
  - current GOES sounders are spectrally too broad to resolve these lines
- High-time information obtained from a high spectral resolution IR GEO sounder would be very useful for monitoring pre-convective clear sky regions
- GOES-R previously had an advanced sounder (HES), which was removed in 2006
  - requirements remain unmet

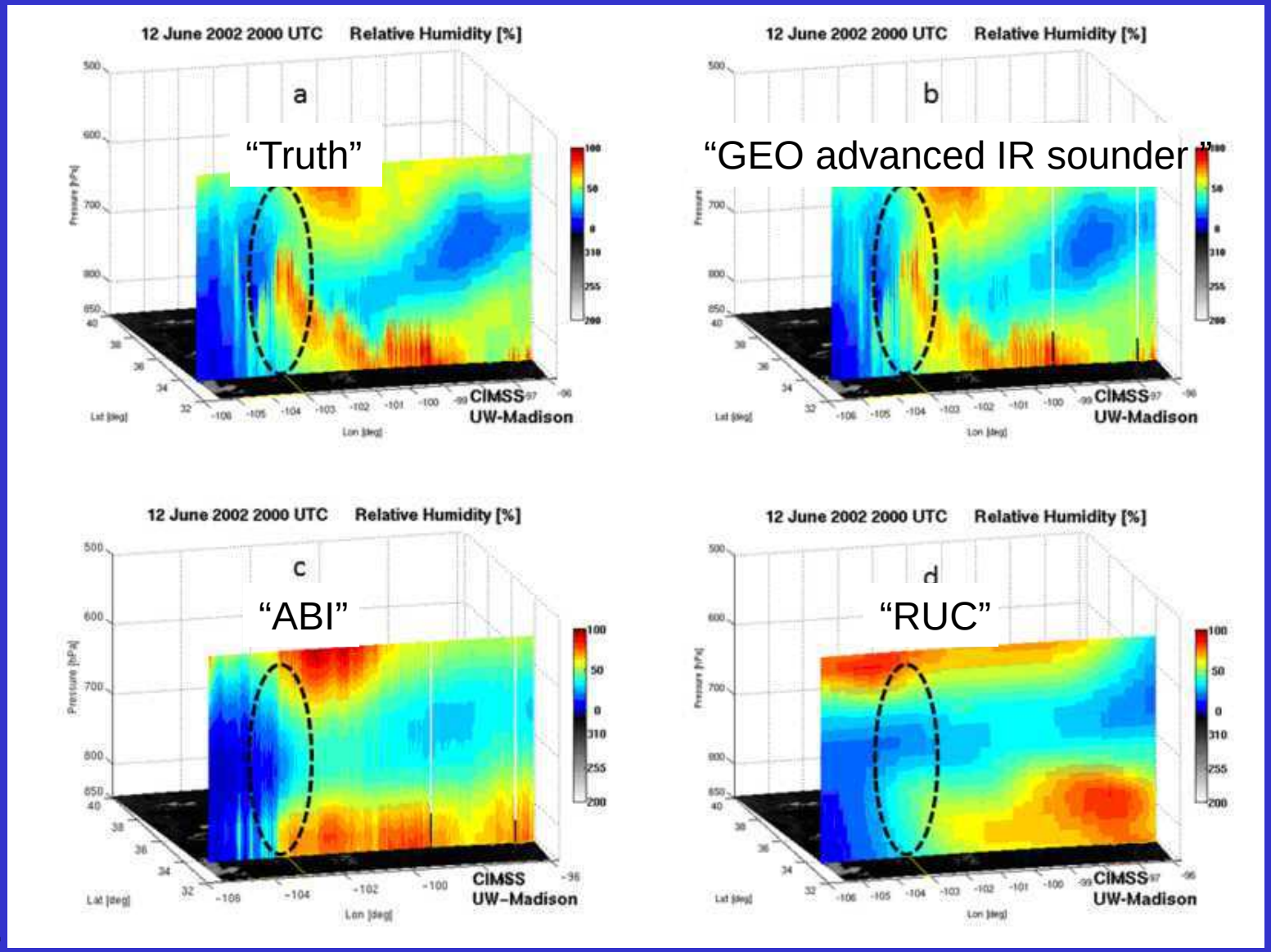
Need to monitor rapidly evolving situations





Evolution of the Vertical Moisture is the Key!

Simulated Relative humidity cross-section at 20 UTC 12 June 2002



Li et. al.

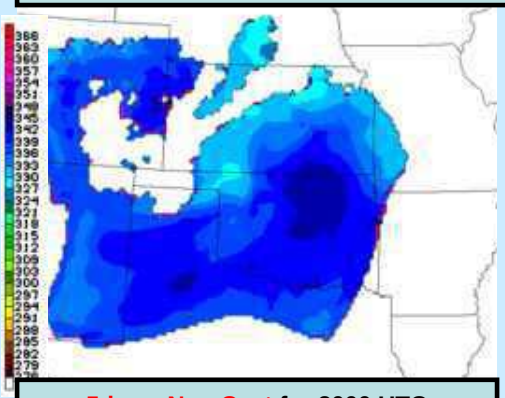
A Hyper-Spectral Geo-Sounder Could Near-cast Severe Weather

An Observing System Simulation Experiment

Robert Aune (NESDIS)

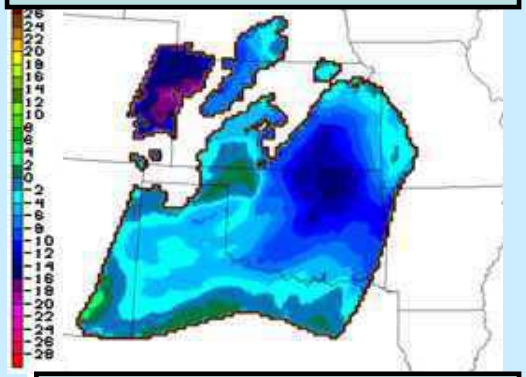
Simulated ABI

Weak gradients of low-level Theta-E are indicated by ABI which has only two water vapor channels.



5-hour NearCast for 2000 UTC
Low level Theta-E

Negative vertical Theta-E differences indicate where convection is likely.

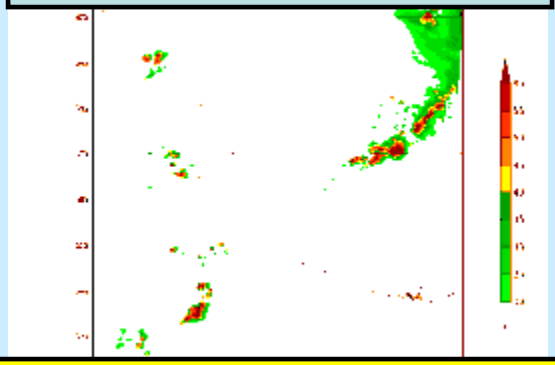


5-hour NearCast for 2000 UTC
Low to Mid level Theta-E Differences

A WRF model simulation of the June 12, 2002 IHOP case was used to generate simulated radiances from a GOES-R Advanced Baseline Imager (ABI) and a geostationary Hyper-spectral Environmental Sounder (HES). Simulated radar reflectivity was also generated

Temperature and moisture profiles were retrieved from the simulated radiance datasets and assimilated by the CIMSS Near-casting Model and compared.

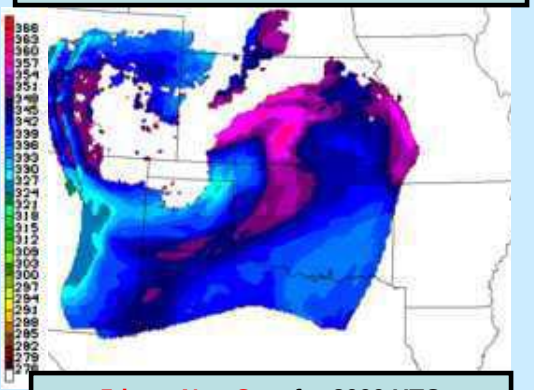
Simulated composite reflectivity indication the formation of convection.



Rapid Development of Convection over Texas and Nebraska between 2000 and 2100 UTC 12 June 2002

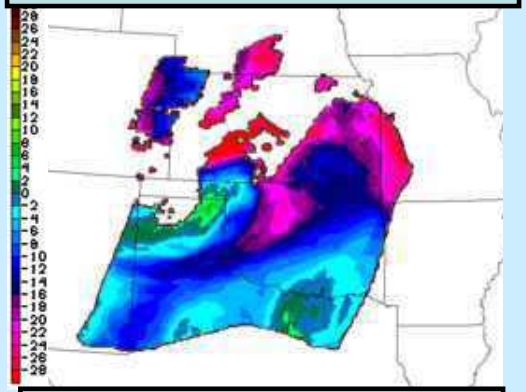
Simulated HES

Strong low-level Theta-E gradients are indicated by HES which has the ability to detect low-level moisture.



5-hour NearCast for 2000 UTC
Low level Theta-E

Negative vertical Theta-E differences indicate where convection is likely.



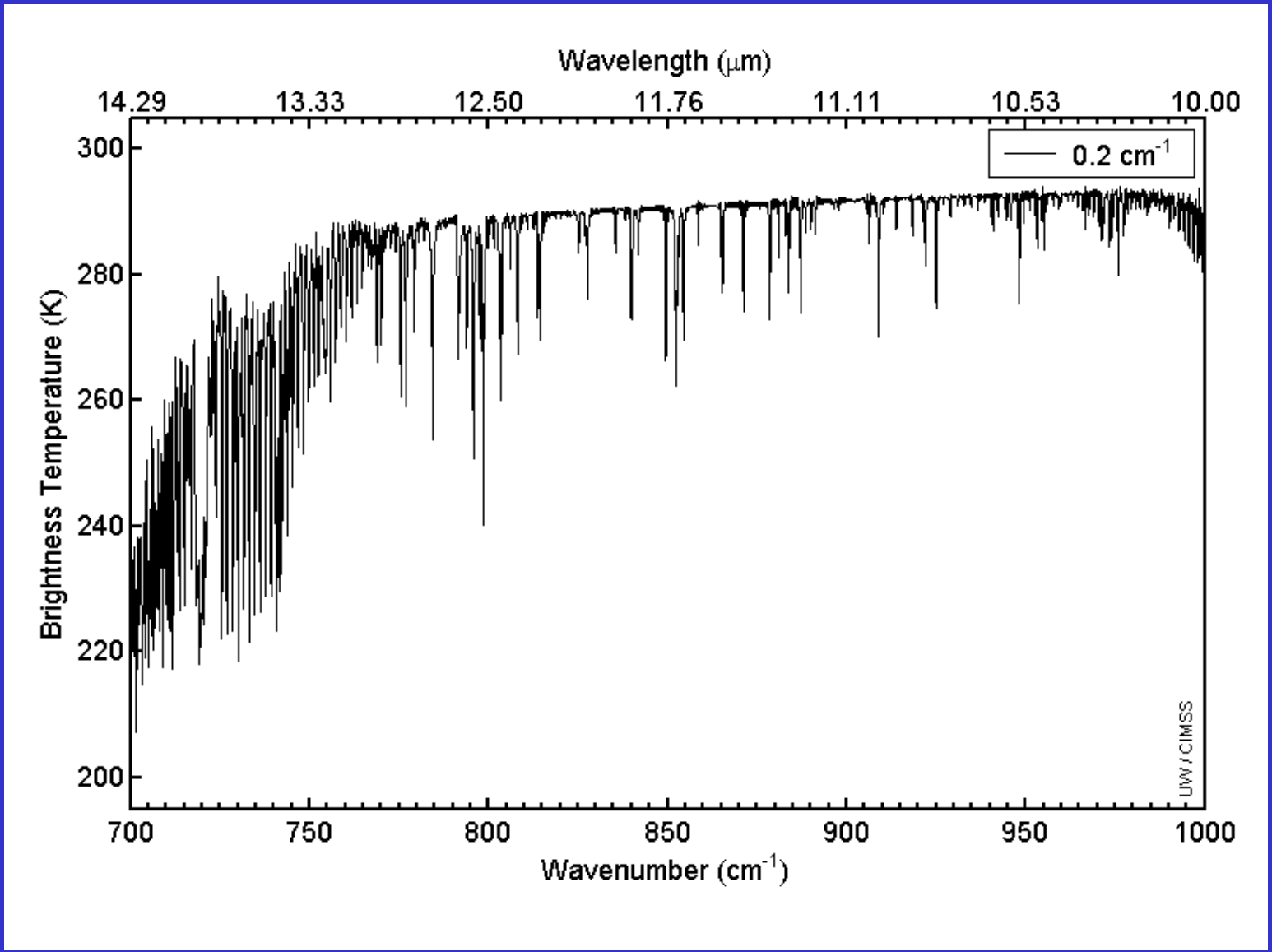
5-hour NearCast for 2000 UTC
Low to Mid level Theta-E Differences

Various Infrared spectral resolutions

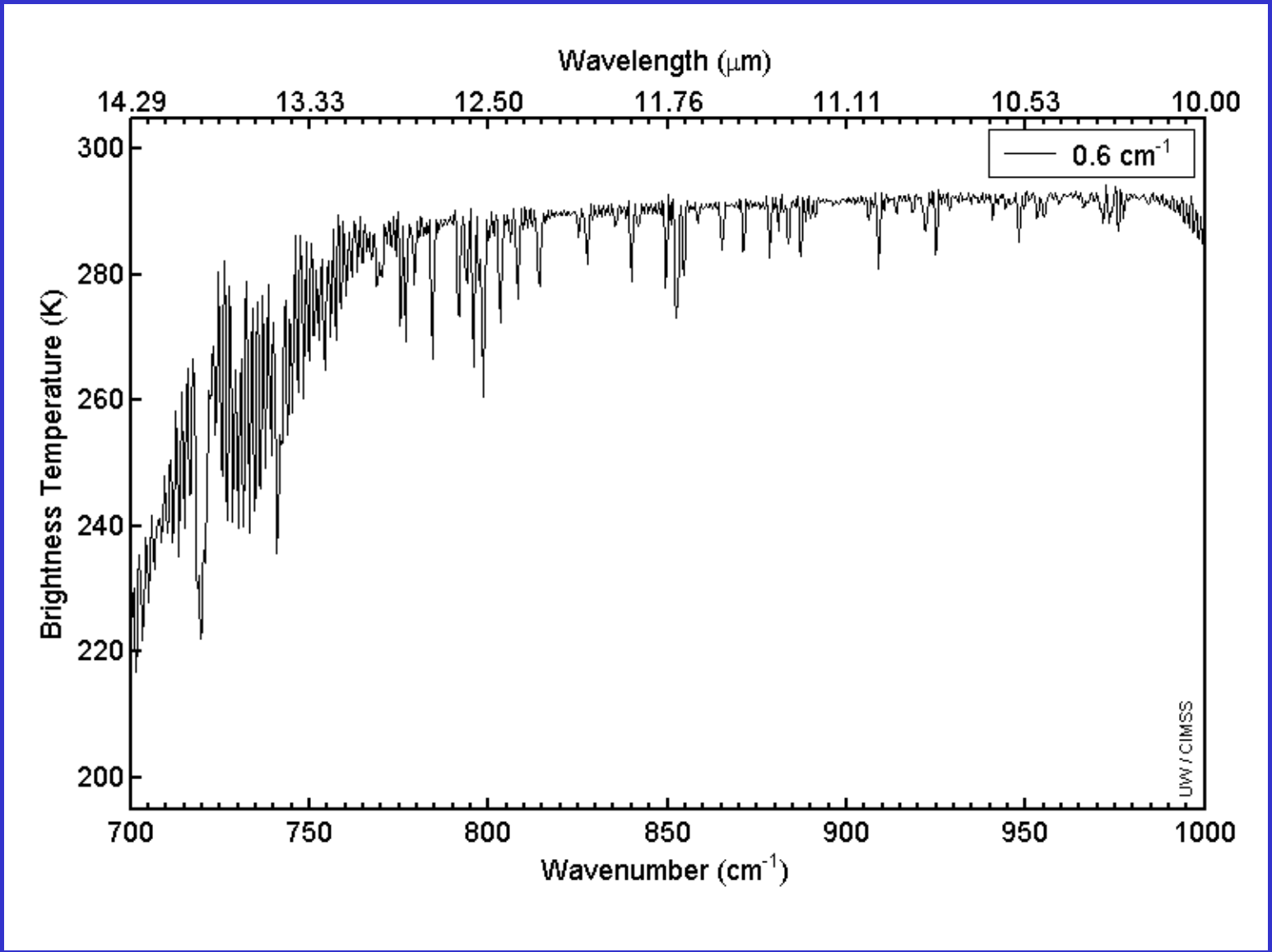
Standard Atmosphere:

0.2 cm^{-1} (NAST-I-like)
0.6 cm^{-1} (HS from polar-like)
1.2 cm^{-1} (HS from polar-like)
4.8 cm^{-1}
19.2 cm^{-1} (current sounder-like)
38.4 cm^{-1} (imager-like)

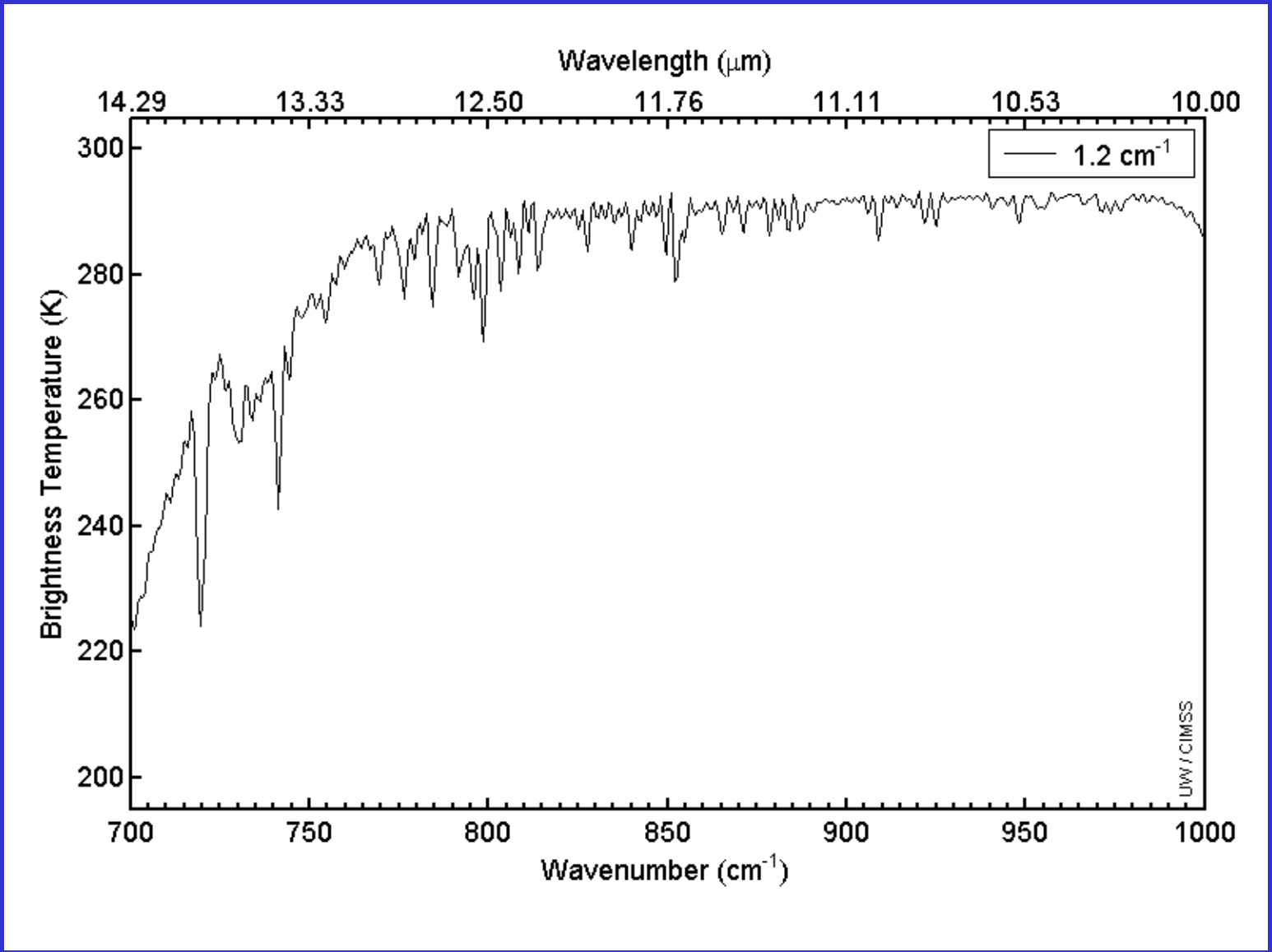
Jun Li, Mat Gunshor and Allen Huang



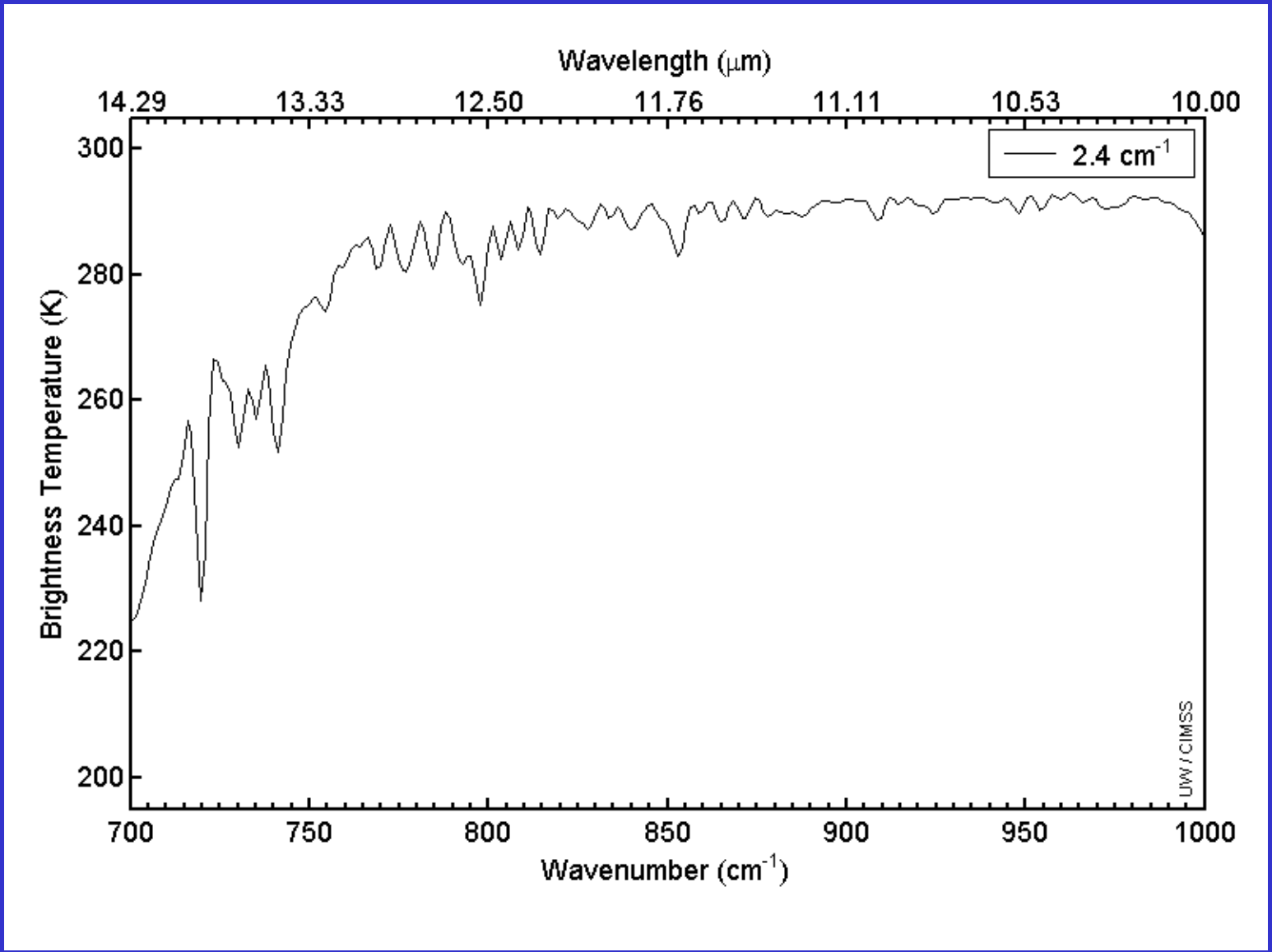
Longwave window region



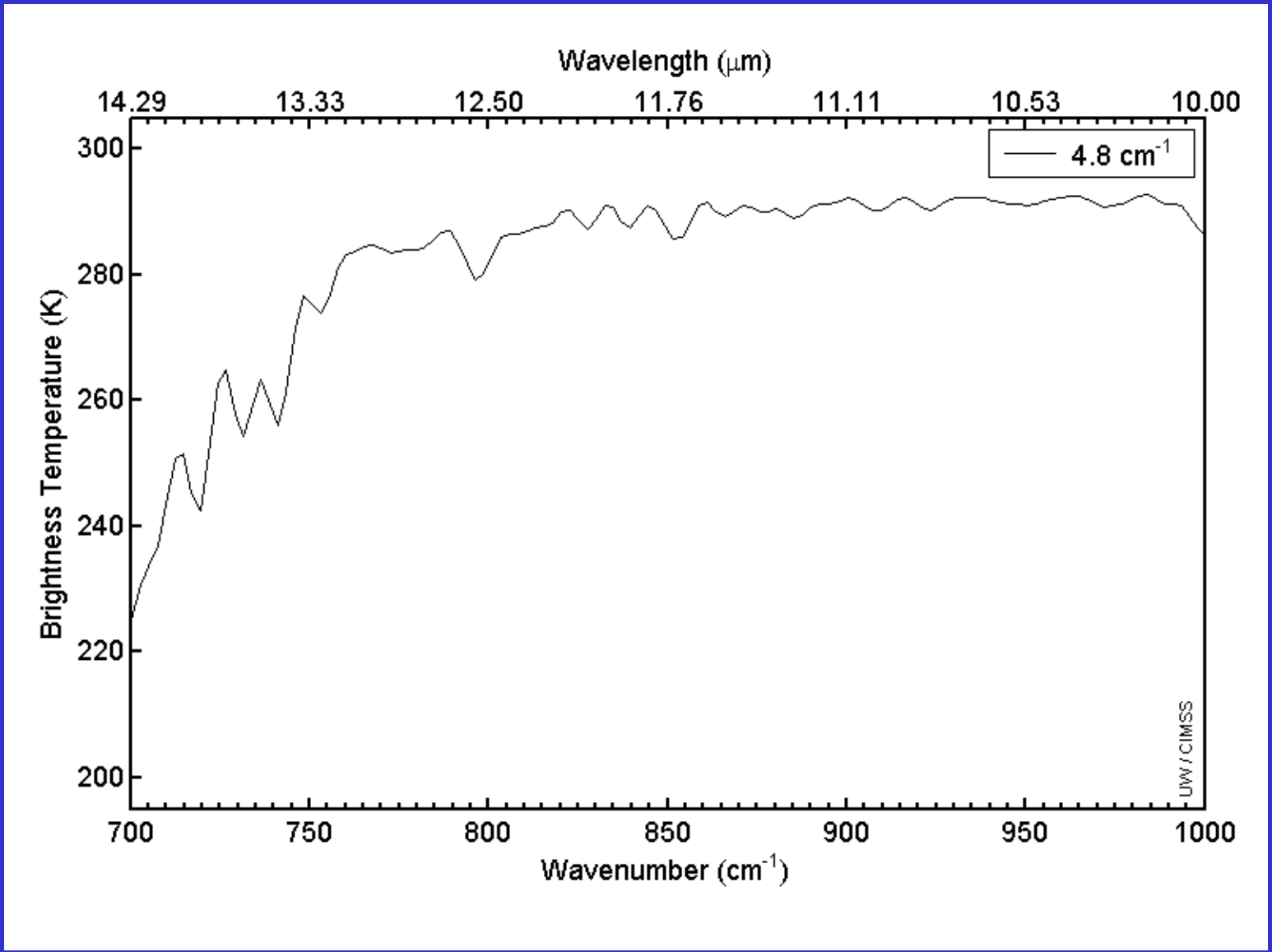
Longwave window region



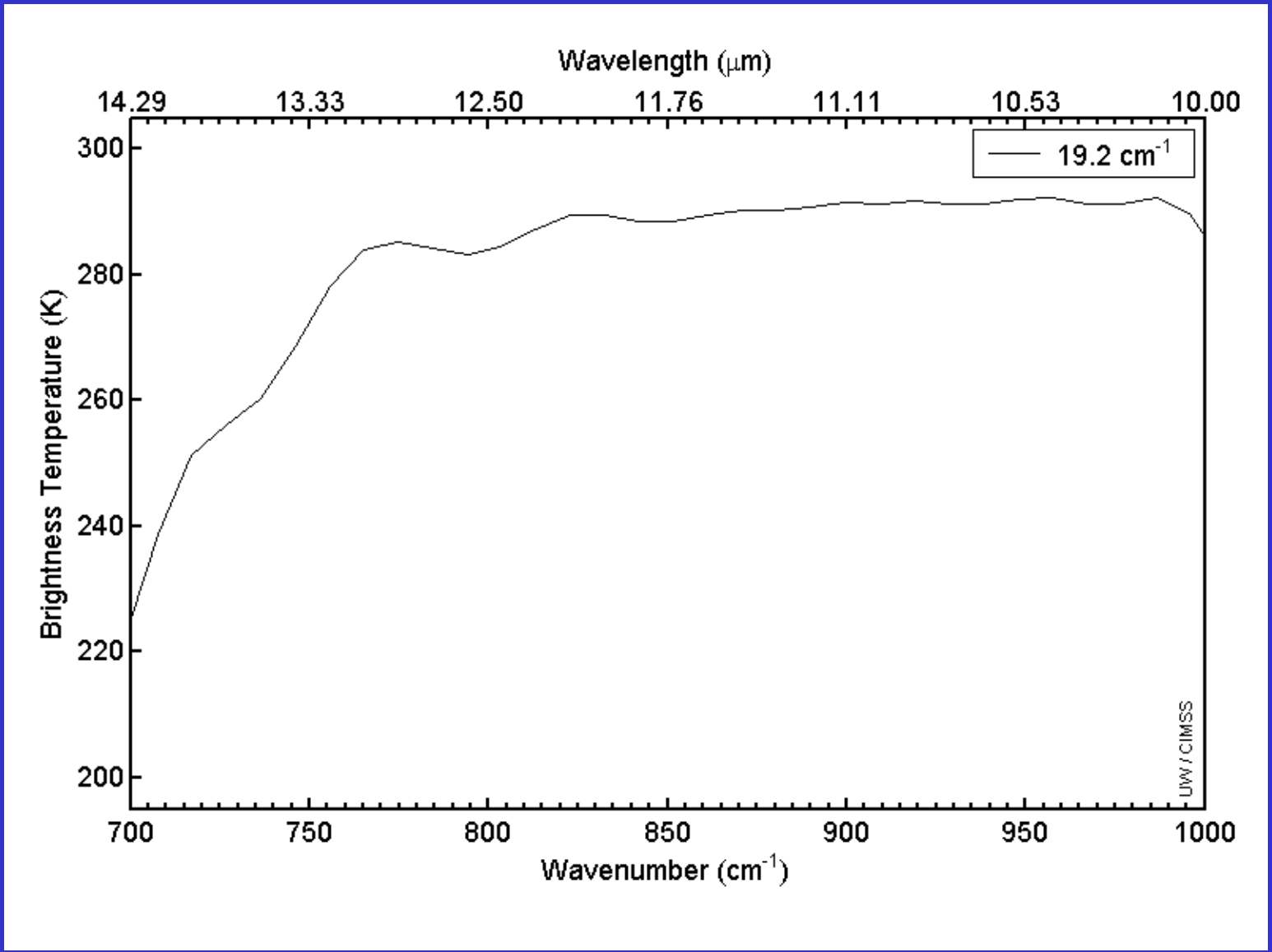
Longwave window region



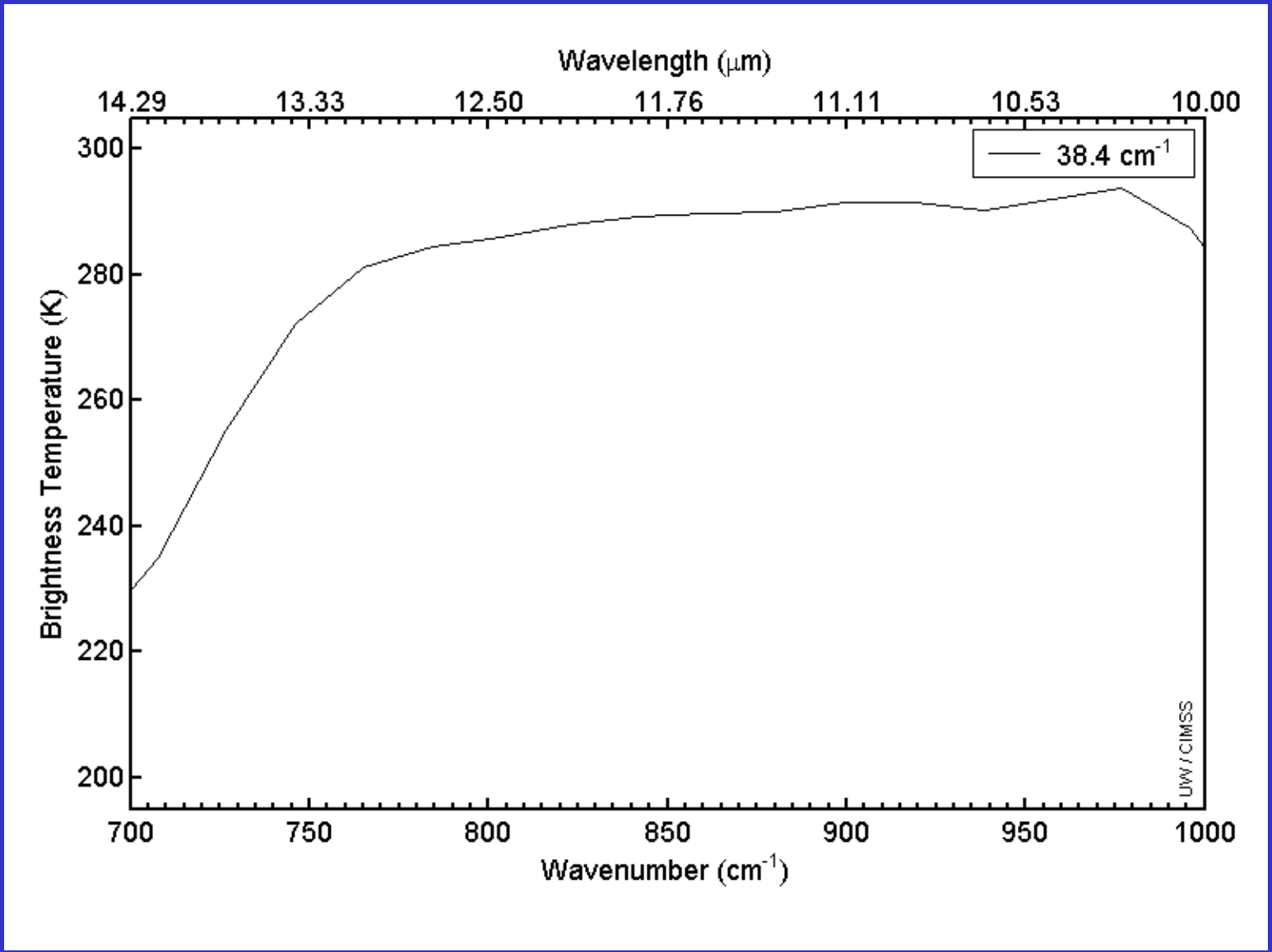
Longwave window region



Longwave window region

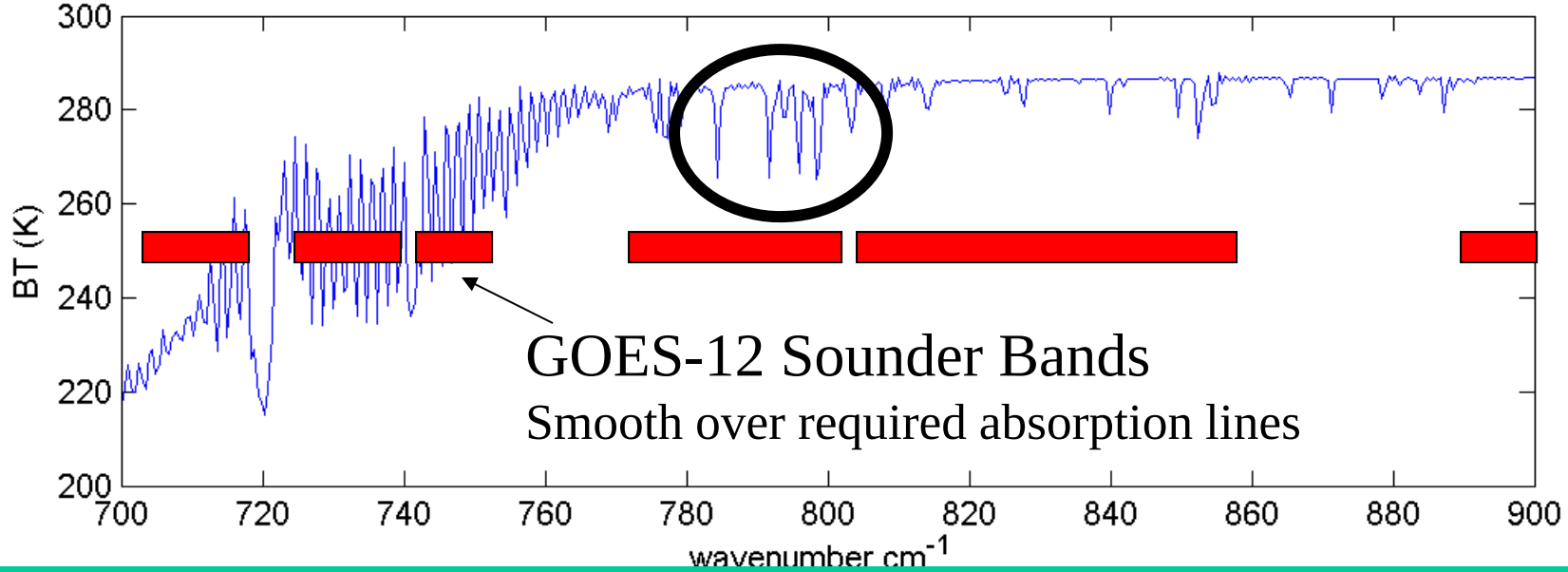


Longwave window region



Longwave window region

Why do we need a high spectral resolution sounder?



Analysis courtesy of Justin Sieglaff, CIMSS.

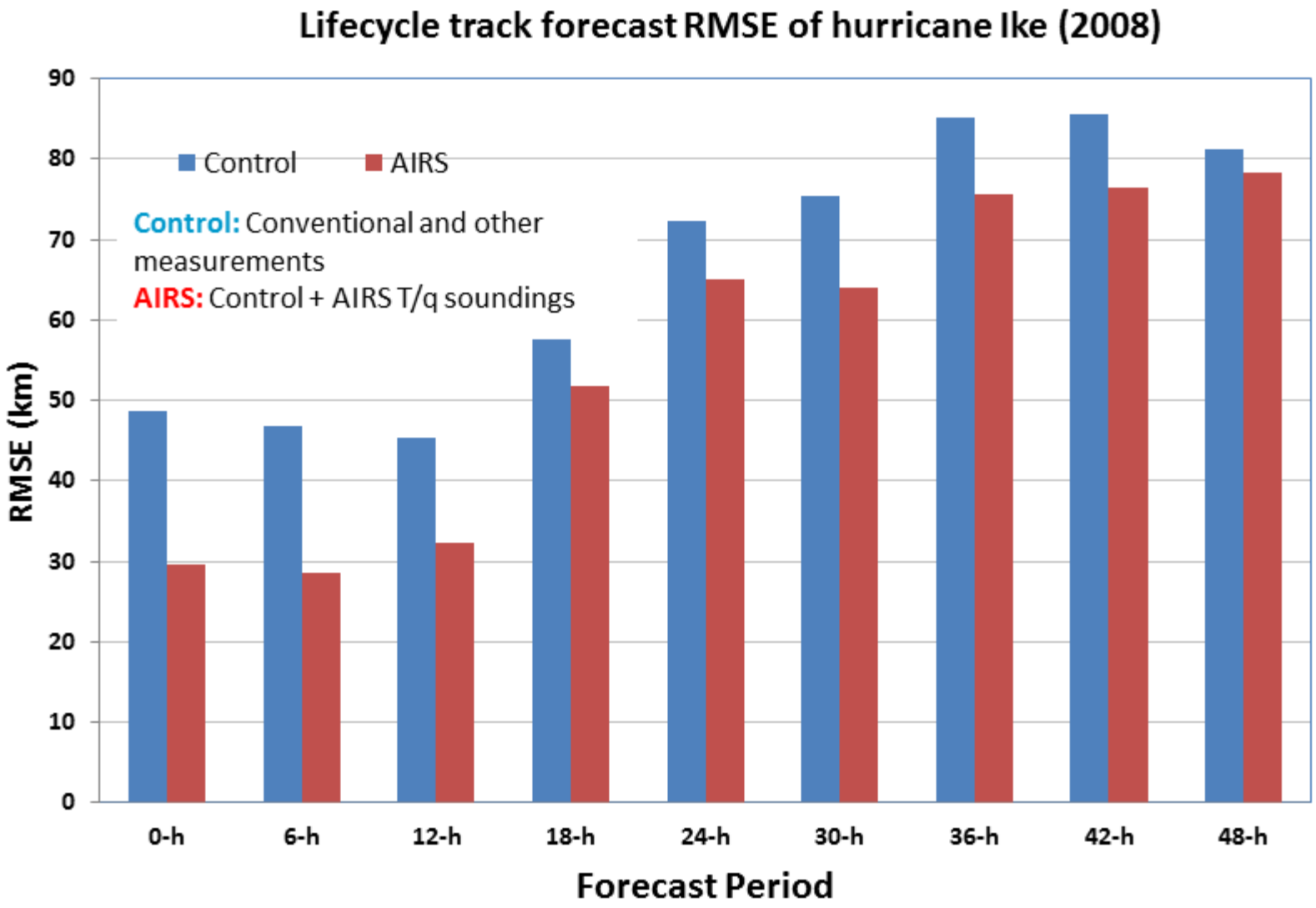
Compared to broadband sounders, observing absorption lines is mandatory to meeting requirements for temperature and moisture structure needed to improve weather forecasting

Many papers document science value of high spectral resolution sounder that support weather forecast needs.

Other Satellite-related DA work (Funded by GOES-RRR or other sources)

- High-Impact Weather
  - » Jun Li (etc), CIMSS
- Warn-on-Forecast
  - » Thomas Jones (CIMMS)
- AIRS in the Rapid Refresh
  - » Haidao Lin
  - » Steve Weygandt
  - » Ming Hu
- Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground
  - » Prof. Ming Xue, Center for Analysis and Prediction of Storms (CAPS)

Improving tropical cyclone forecasts with advanced IR soundings



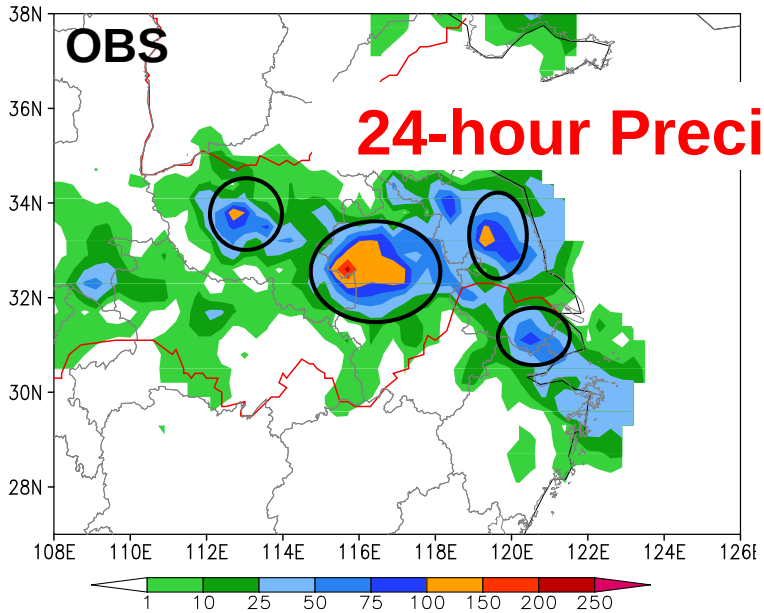
Jun Li, Jing Zheng, Tim Schmit, Jinlong Li

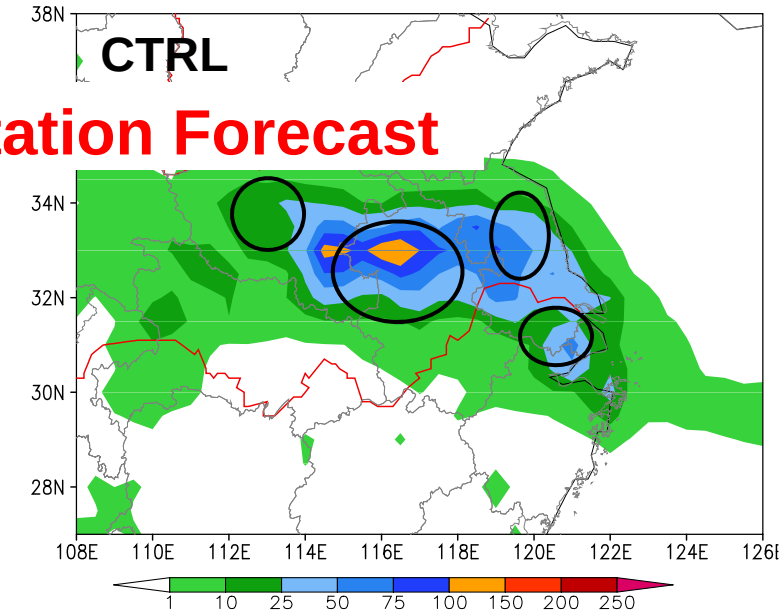
WRF/3DVAR forecasting and assimilation system is used.
Assimilation is done every 6 hours. 0-h is from analysis, others are forecasts.

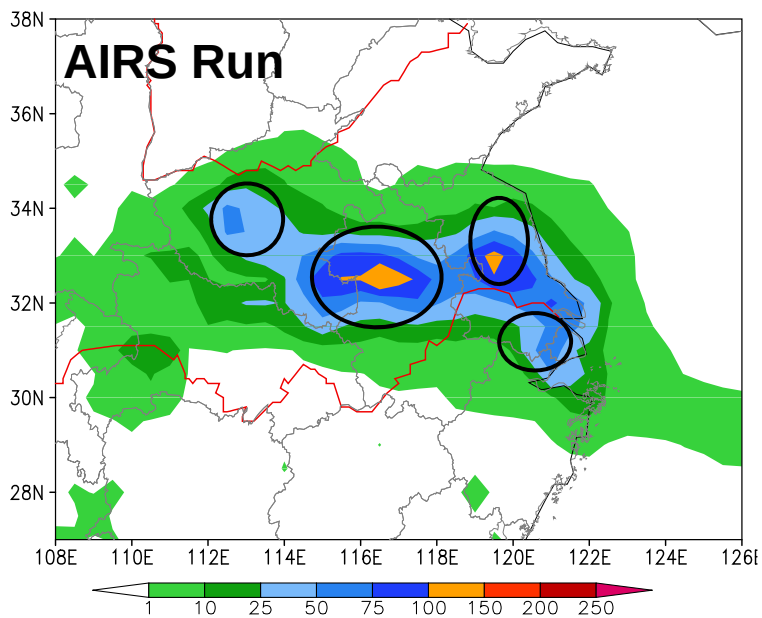
Improving precipitation forecasts with advanced IR soundings

Jun Li, Jinlong Li (CIMSS), Bin Wang, Bing Lu (IAP)

24-hour Precipitation Forecast







(1) 24-hour precipitation (00 UTC 22 – 00 UTC 23 July 2009) forecast.

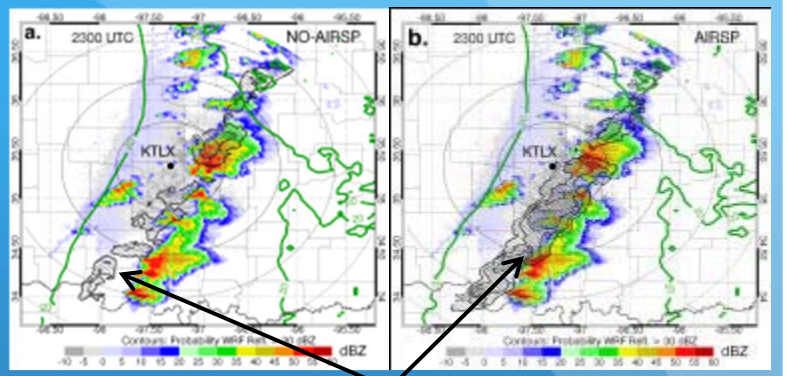
(2) Two AIRS overpass times: 06 UTC and 18 UTC 21 July 2009.

(3) CTRL run uses the NCEP analysis as initial, AIRS run uses soundings of both 06 UTC and 18 UTC.

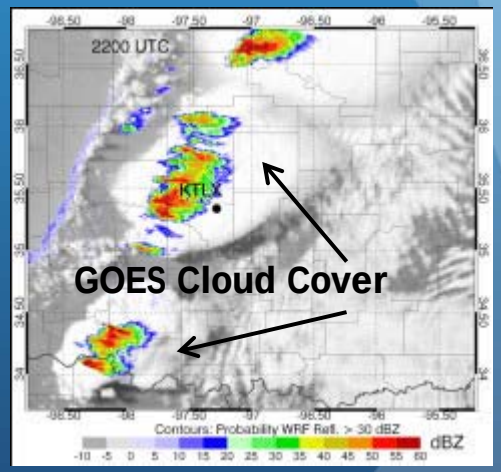
(4) The regional NWP model is Advanced Regional Eta-coordinate Model (AREM) with 37 km resolution. A collaborative work between CIMSS and Institute of Atmospheric Physics in Beijing.

Warn-on-Forecast

- **Current Projects:**
  - Use hyperspectral sounder data (AIRS) To improve 0-3 hour forecasts of a severe weather event (May 10, 2010).
  - Temperature and dewpoint profiles improve mid-tropospheric characterization of the atmosphere
  - Increases forecast convection compared to not assimilating these data.



Increases forecast convection
Better match to WSR-88D



- **Future Projects:**
  - Assimilate satellite derived cloud products
  - Examples include:
    - Cloud top pressure and temperature
    - Cloud coverage
    - Cloud liquid and ice water contents
  - All products to be retrieved from GOES-R ABI radiances
  - Testing of satellite-derived cloud products will utilize MODIS (and similar) data as will as OSSE experiments to prepare for GOES-R coming online in 2015-16.

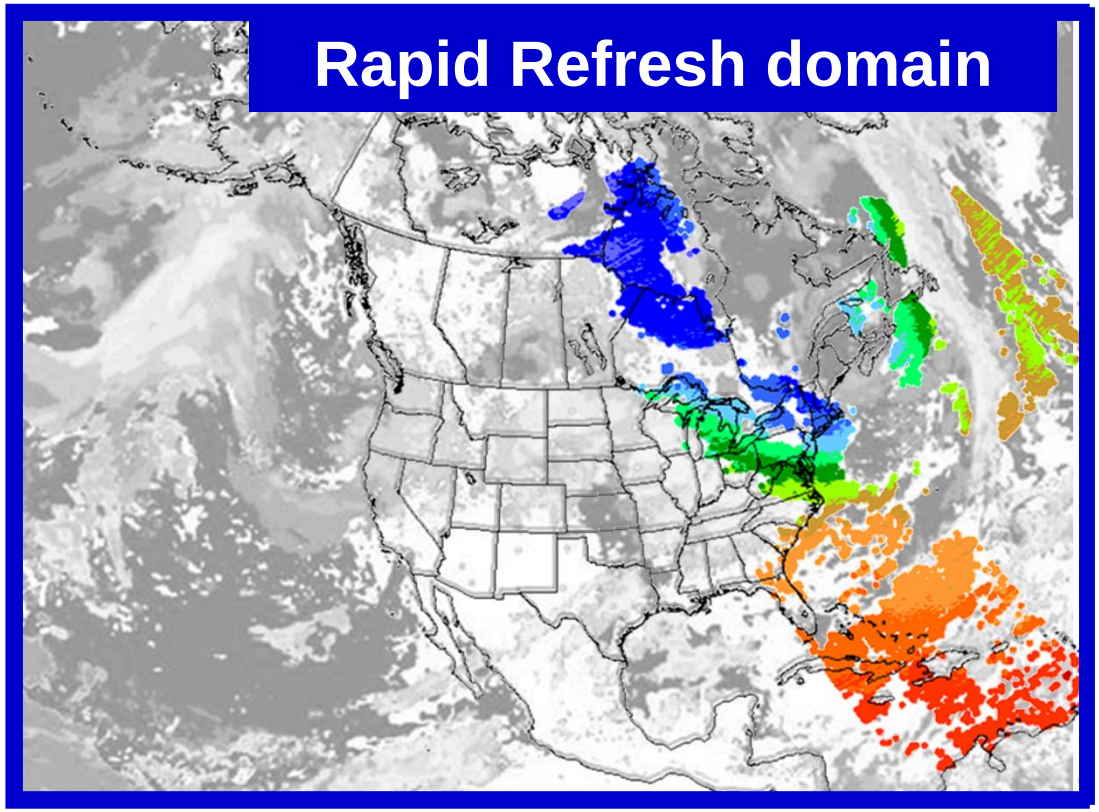
Thomas Jones

Assimilation of AIRS SFOV retrievals and radiance Data in the Rapid Refresh

Haidao Lin
Steve Weygandt
Ming Hu
Stan Benjamin

Assimilation and Modeling Branch
Global Systems Division
Cooperative Institute for Research in the Atmosphere
Colorado State Univerisity

Collaborators:
Tim Schmit – NOAA NESDIS
Jun Li, Jinlong Li – CIMSS, University of Wisconsin



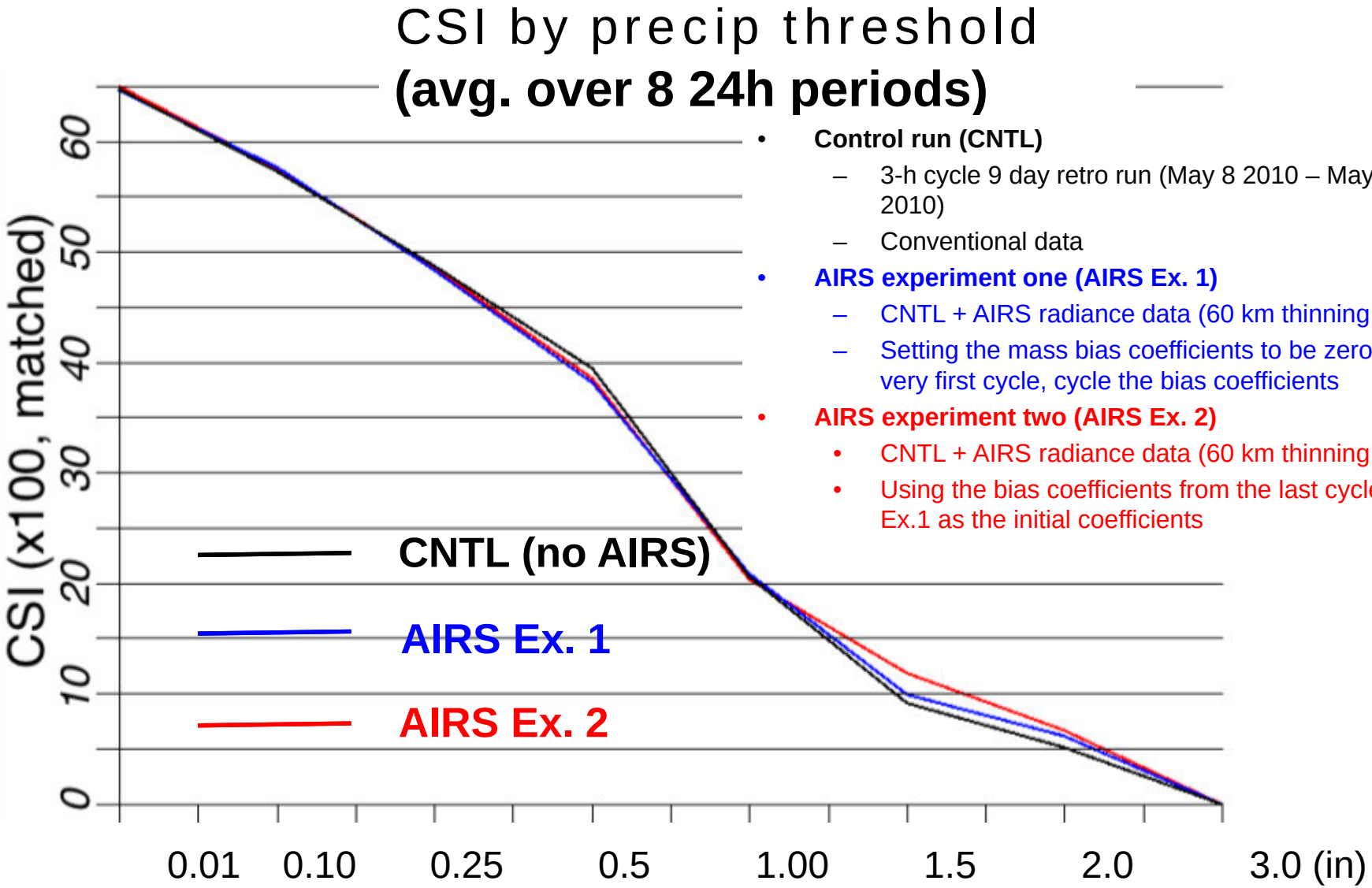
AIRS 500-mb retrieved temperature, grey-scaled RR cloud-top analysis

Supporting slides for oral summary presentation, GOES-R Science week, Huntsville, AL 22 Sept. 2011

Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

CIRA
Cooperative Institute for Research in the Atmosphere

24-h (2 X 12h) CPC Precipitation Verification



- **Control run (CNTL)**
  - 3-h cycle 9 day retro run (May 8 2010 – May 16 2010)
  - Conventional data
- **AIRS experiment one (AIRS Ex. 1)**
  - CNTL + AIRS radiance data (60 km thinning in GSI)
  - Setting the mass bias coefficients to be zero at the very first cycle, cycle the bias coefficients
- **AIRS experiment two (AIRS Ex. 2)**
  - CNTL + AIRS radiance data (60 km thinning in GSI)
  - Using the bias coefficients from the last cycle of Ex.1 as the initial coefficients

Slight improvement for heavy precipitation thresholds from AIRS radiance data

Summary and Future Work

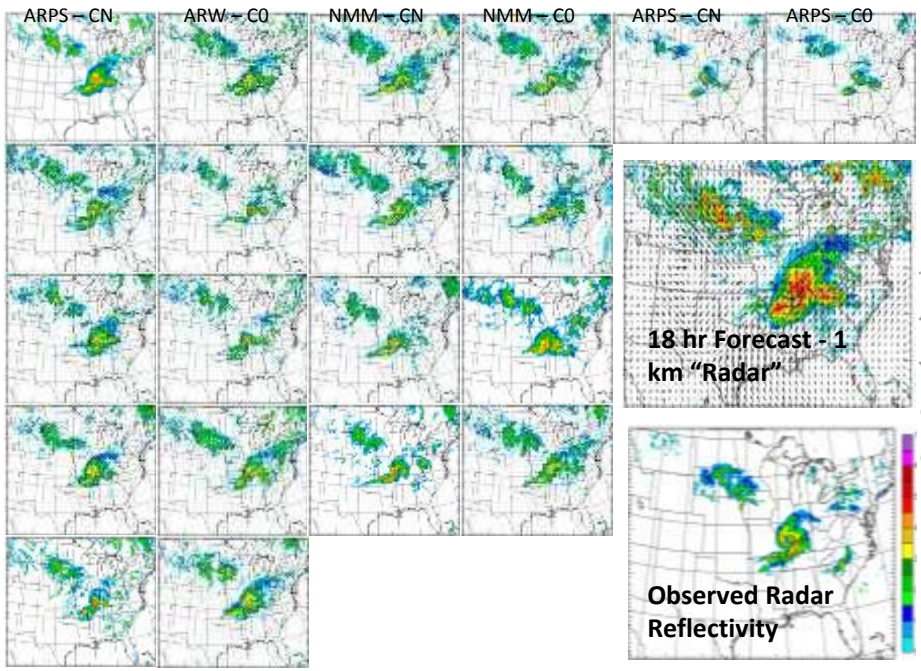
Progress in 2010-2011

- Set up RR retrospective systems for May 2010 period
- Processed SFOV data, append them to std. prepbufr files
- Evaluated the SFOV profiles with matched raob profiles
- Conducted / analyzed several RR AIRS SFOV retro expts.
- Produced AIRS radiance data files for 3-h cycle RR runs
- Conducted/ analyzed RR AIRS radiance retro experiments

Ongoing and future work for 2011-2012

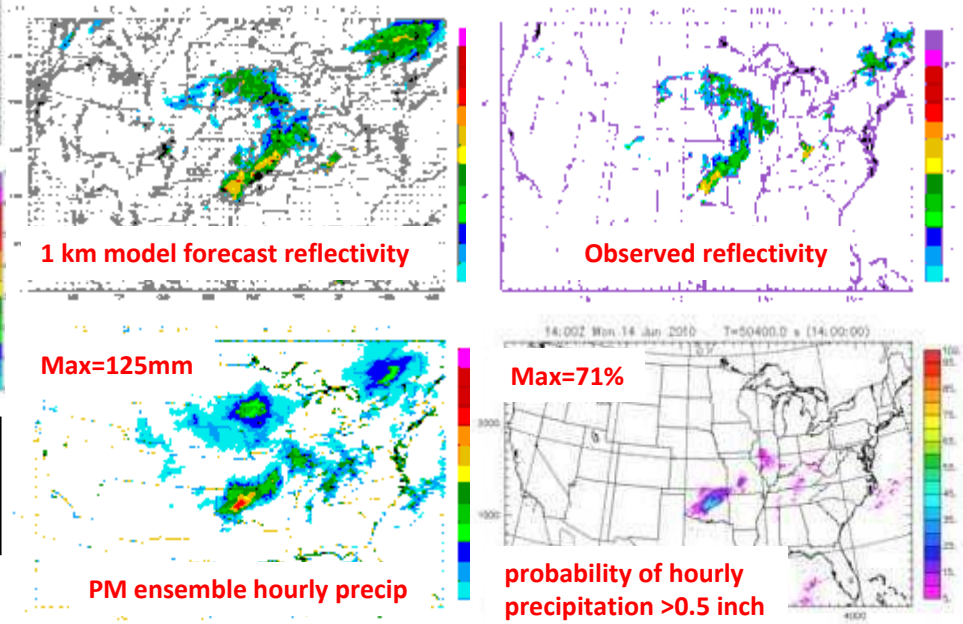
- Further evaluation of impact from SFOV moisture profiles
- More detailed analysis of SFOV assimilation results (O-B statistics, spatial distribution of analysis and forecast differences, possible HRRR runs from RR w/ and w/o SFOV)
- Test impact from additional SFOV QC procedures and bias correction schemes for temperature and moisture
- Jacobian and adjoint sensitivity study for AIRS channels
- AIRS radiance assimilation in RR with evaluation of channel selection strategies and cycled bias coefficients

Realtime Convection-Permitting Ensemble and Convection-Resolving Deterministic Forecasts of CAPS for the Hazardous Weather Testbed (HWT) Spring Experiments



CAPS 2011 SSEF:
51 4-km, one 1 km, 36h CONUS forecasts
8 microphysics, 4 PBL, 2 LSM schemes, assimilating WSR-88D data

June 14, 2010 – OKC Flooding Case, 14 h fcst



20 members from 2008
Support Probabilistic Forecasts

Principal Investigator: Prof. Ming Xue, Center for Analysis and Prediction of Storms (CAPS) and School of Meteorology, University of Oklahoma

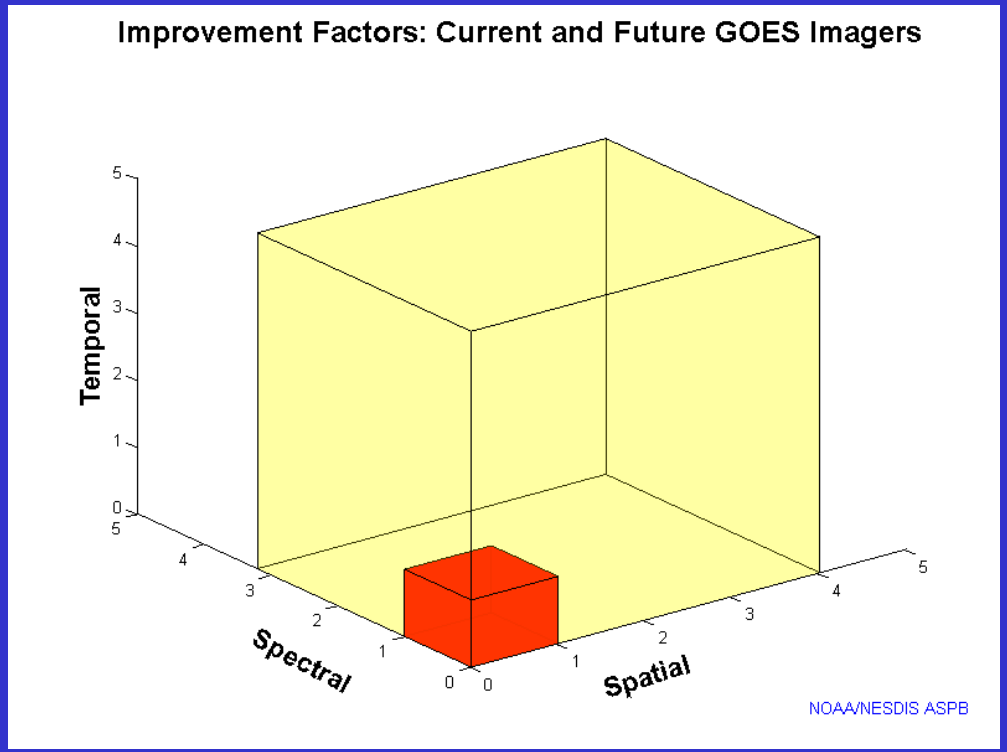
Proposed Work

Ensemble Simulation of GOES-R Proxy Radiance Data from CONUS Storm-Scale Ensemble Forecasts, Product Demonstration and Assessment at the Hazardous Weather Testbed GOES-R Proving Ground

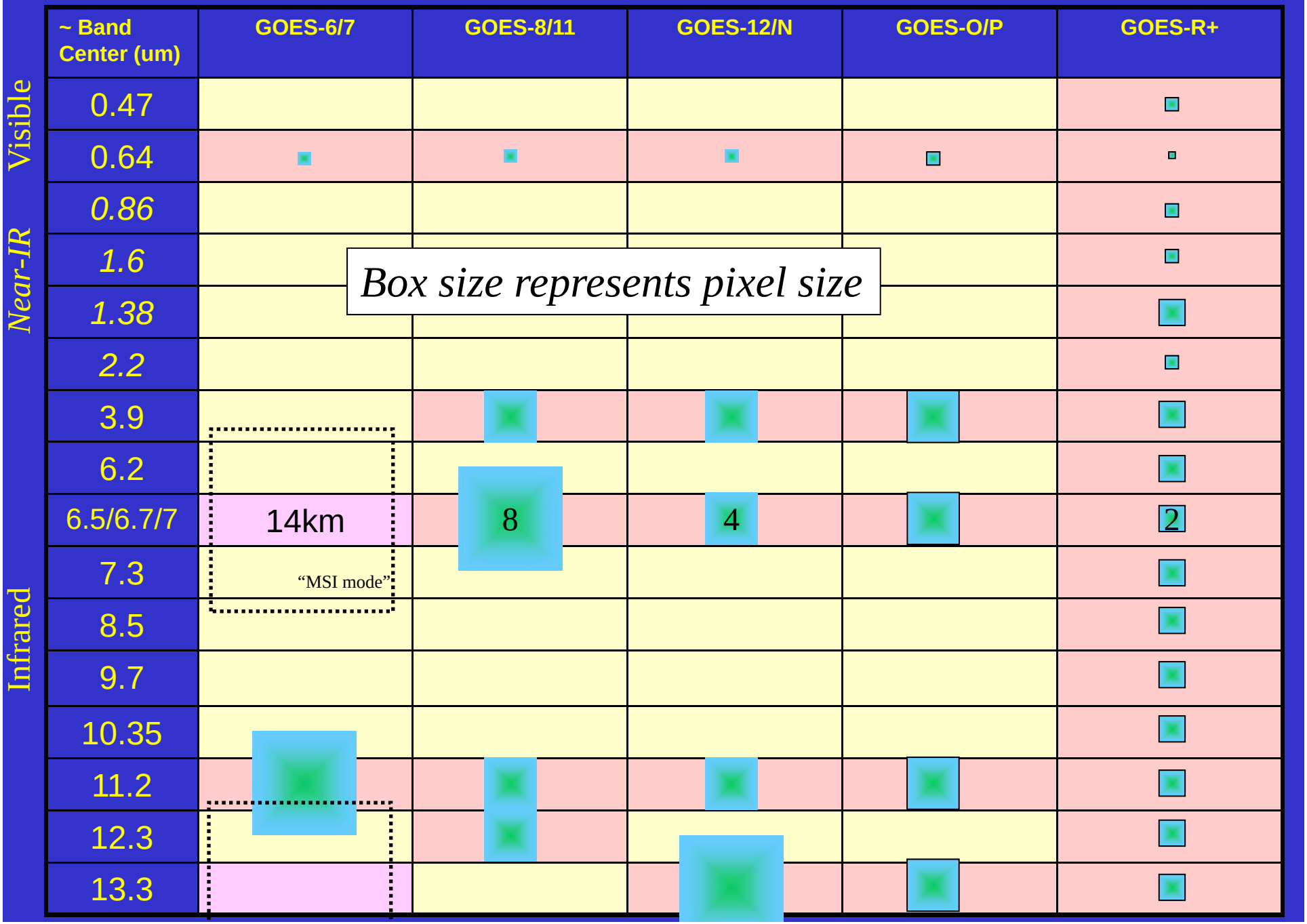
- Ensemble of ABI imagery using NESDIS CRTM, CIMSS and CIRA simulation packages, from CAPS's Storm-Scale ensemble in realtime.
- Probabilistic products in terms of satellite observables.
- Adapt the simulation packages to work with various microphysics schemes, including two-moment schemes
- Simulations for at least 5 bands (6.185, 7.35, 6.95, 10.35 and 12.3 mm), comparison with GOES observations
- Require ~3000-4000 CPU cores using three packages for ~ 30 members, need to run on NICS
- Send the products to HWT/GOES-R Proving Ground for realtime assessment during Spring Experiments

Outline

- History
- Current GOES Imager and Sounder
  - GOES-14/15
- ABI (Advanced Baseline Imager)
  - Temporal
  - Spatial
  - Spectral
- Select Products
- High Spectral res.
- Summary
  - More information
  - Questions



Approximate spectral and spatial resolutions of US GOES Imagers



Summary

- The ABI on GOES-R will improve over the current instrument, including improved image navigation and registration and radiometer performance (colder patch temperatures, etc).
- These improvements will greatly assist a host of data assimilation and NWP applications, especially on the regional and meso-scales via both direct assimilation and in-direct validations.
- Need to start with current geostationary data and products to best prepare for the ABI
- Still need the vertical resolution of high-spectral, high-temporal observations!

Summary

- There's so much more information from the GOES-R instruments (ABI, GLM, etc), that the best way for the forecaster and others to quickly gain benefit is if the information is assimilated into the appropriately-scaled numerical weather prediction models.
  - Need to use both clear and cloudy radiances
  - May need to continue to use select products
  - Upcoming Warn-on-Forecast/High Impact Weather Workshop. Feb. 8-9 in Norman, OK [POC: S. Goodman]
- That said, the direct use of imagery and products will continue, for model comparisons, rapidly changing phenomena, etc.

More information

GOES-R:

- http://www.goes-r.gov
- http://www.meted.ucar.edu/index.htm
- http://cimss.ssec.wisc.edu/goes_r/proving-ground.html

GOES and NASA:

- http://goespoes.gsfc.nasa.gov/goes/index.html
- http://goes.gsfc.nasa.gov/text/goes.databookn.html

UW/SSEC/CIMSS/ASPB:

- http://cimss.ssec.wisc.edu/goes_r/proving-ground/nssl_abi/nssl_abi_rt.html
- http://cimss.ssec.wisc.edu/goes_r/awg/proxy/nwp/
- http://cimss.ssec.wisc.edu/goes/abi/
- http://cimss.ssec.wisc.edu/goes/abi/wf
- http://cimss.ssec.wisc.edu/goes/blog/
- http://www.ssec.wisc.edu/data/geo/

AMS BAMS Article on the ABI (Aug. 2005)

Questions

- Ready for GOES-15 (e.g., December)?
- Ready for GOES-14?
- GOES-13 radiances operational? Hourly?
- Read netCDF for radiances and cloud mask (GOES-R ABI)
- Ready to exploit the high temporal data from the ABI? Current GOES radiances and products?
- Are the systems set-up for the in-direct validations?

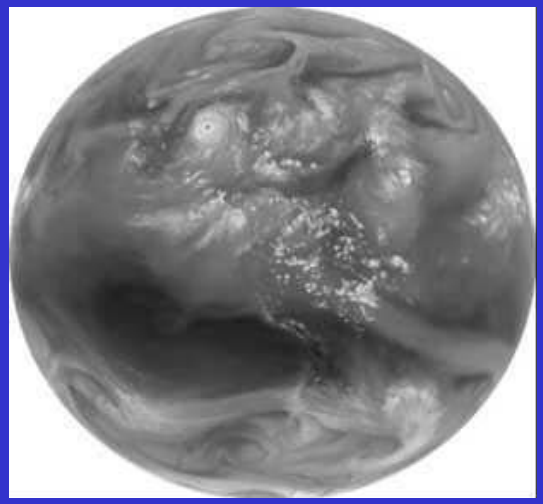
Questions

- Are there 'future capability' products that may be of use, either directly or in-directly?
  - Cloud Type
  - Turbulence
  - Overshooting Top
  - Visibility
  - Total Ozone
  - Surface Emissivity/Albedo
  - Convective Initiation
  - Low Cloud and Fog
  - SO_2 Detections
  - Upward LW Radiation
  - Aerosol Particle Size
  - Vegetation Index
- Using current GOES to better tune?
- Interested in any of the GOES-R training material?
- Ready for assimilating GLM information?

Acknowledgements

- The authors would like to thank the entire GOES-R team (especially the GOES-R Program Office); within the government, industry and academia.

- The views, opinions, and findings contained in this presentation are those of the author and should not be construed as an official National Oceanic and Atmospheric Administration or U.S. Government position, policy, or decision.



Progress!

Back-up

- More high-resolution IR spectra
- AOD assimilations
- ABI Weighting Functions
- Select Products
- Possible GOES-R at 137W scan strategy

Select High-Spectral References

Schmit, T. J., J. Li, S. A. Ackerman, and J. J. Gurka, 2009: **High spectral and temporal resolution infrared measurements from geostationary orbit**, Journal of Atmospheric and Oceanic Technology, 26, 2273 - 2292.

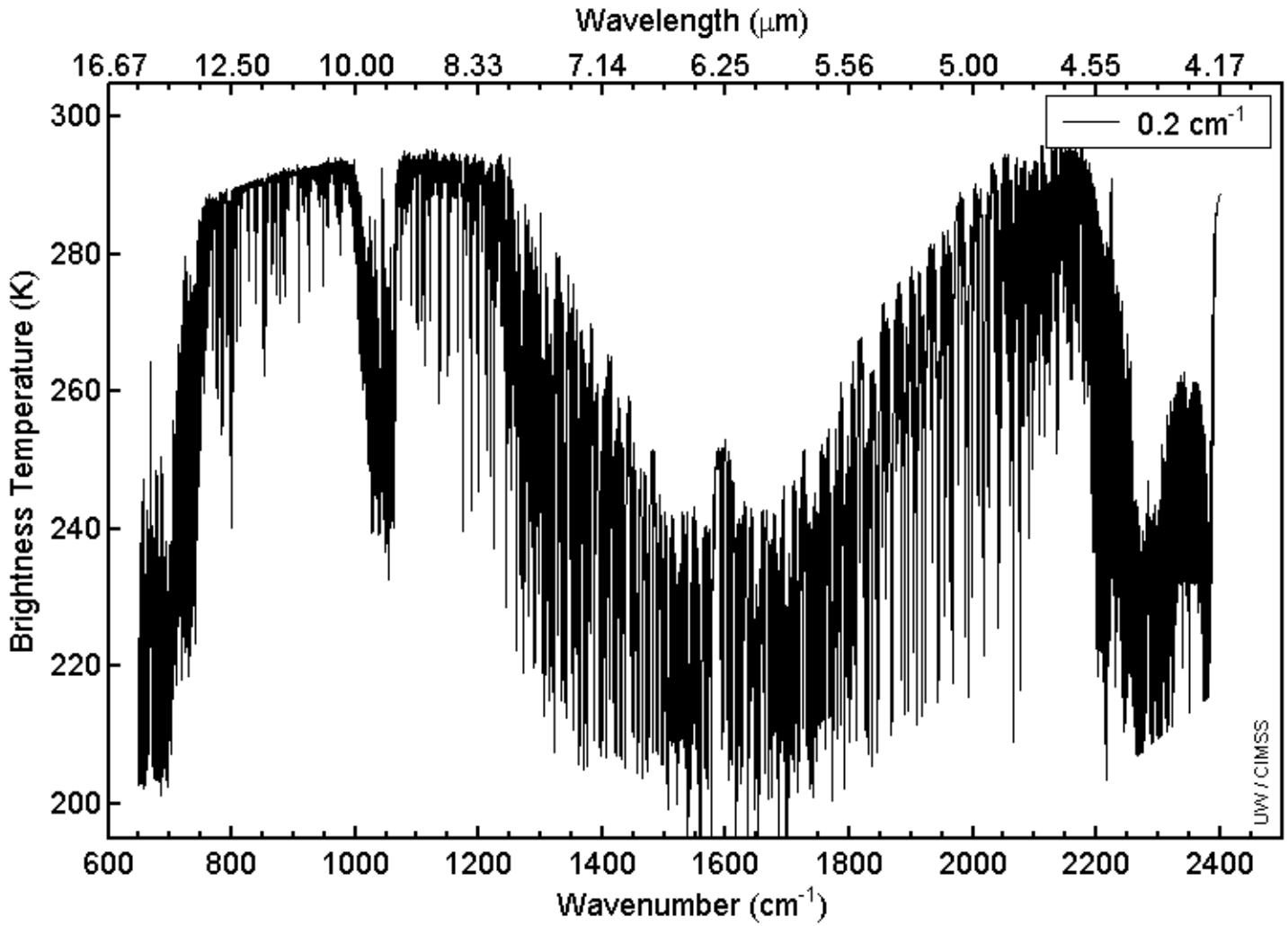
(a.k.a., *why we need an advanced sounder*)

Sieglaff, J., M., T. J. Schmit, W. P. Menzel, S. A. Ackerman, 2009: **Inferring Convective Weather Characteristics with Geostationary High Spectral Resolution IR Window Measurements: A Look into the Future.** J. Atmos. Oceanic Technol., 26, 1527–1541.

(a.k.a., *potential now-casting applications*)

Schmit, T. J., J. Li, J. J. Gurka, M. D. Goldberg, K. Schrab, J. Li, W. Feltz, 2008: **The GOES-R ABI (Advanced Baseline Imager) and the continuation of current sounder products.** J. of Appl. Meteor., 47, 2696–2711.

(a.k.a., *the ABI isn't an advanced sounder*)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8.33
7.14
6.25
5.56
5.00
4.55
4.17
0.2 cm-1
Brightness Temperature (K)
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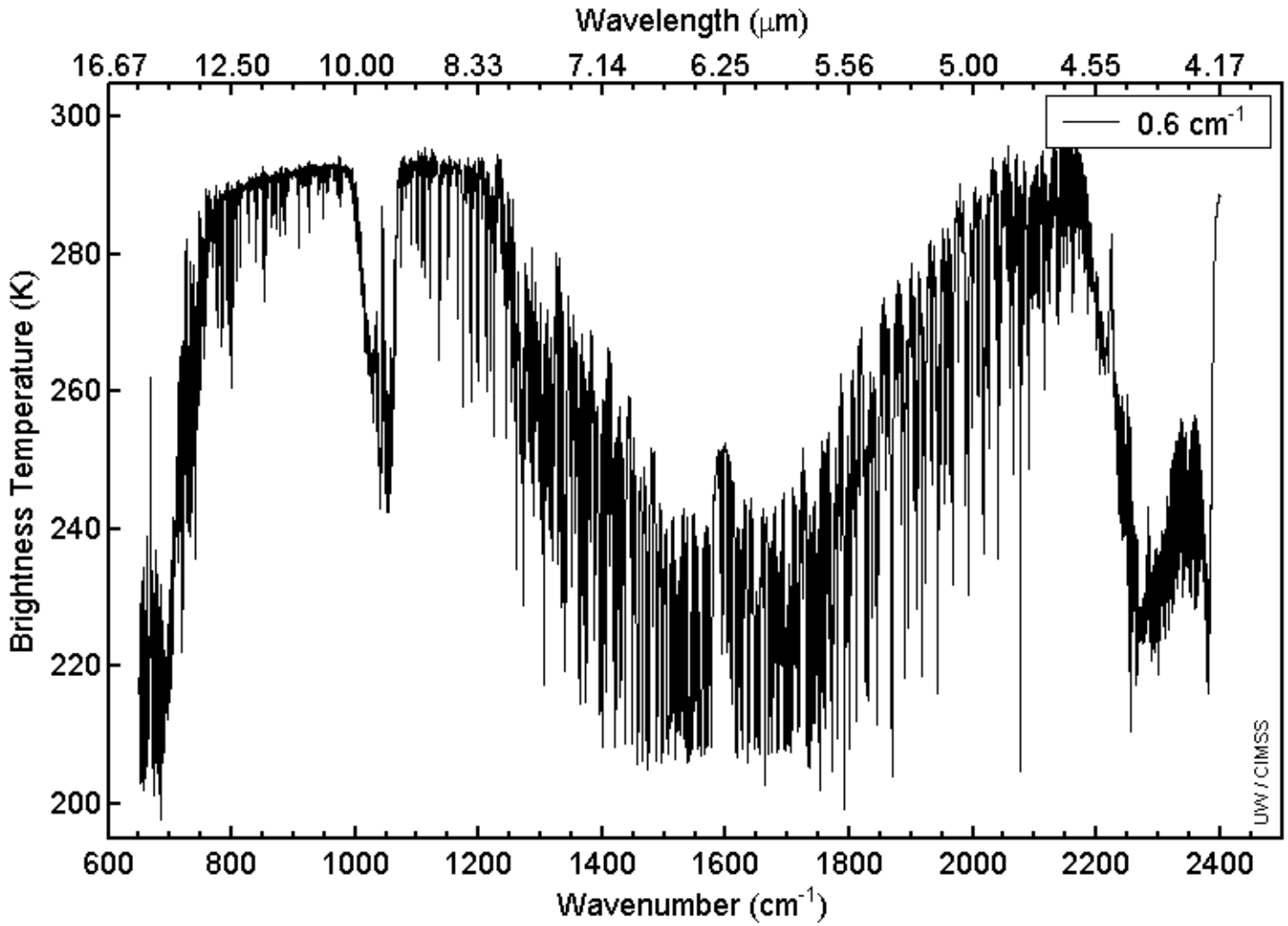
Wavenumber (cm-1)
UW / CIMSS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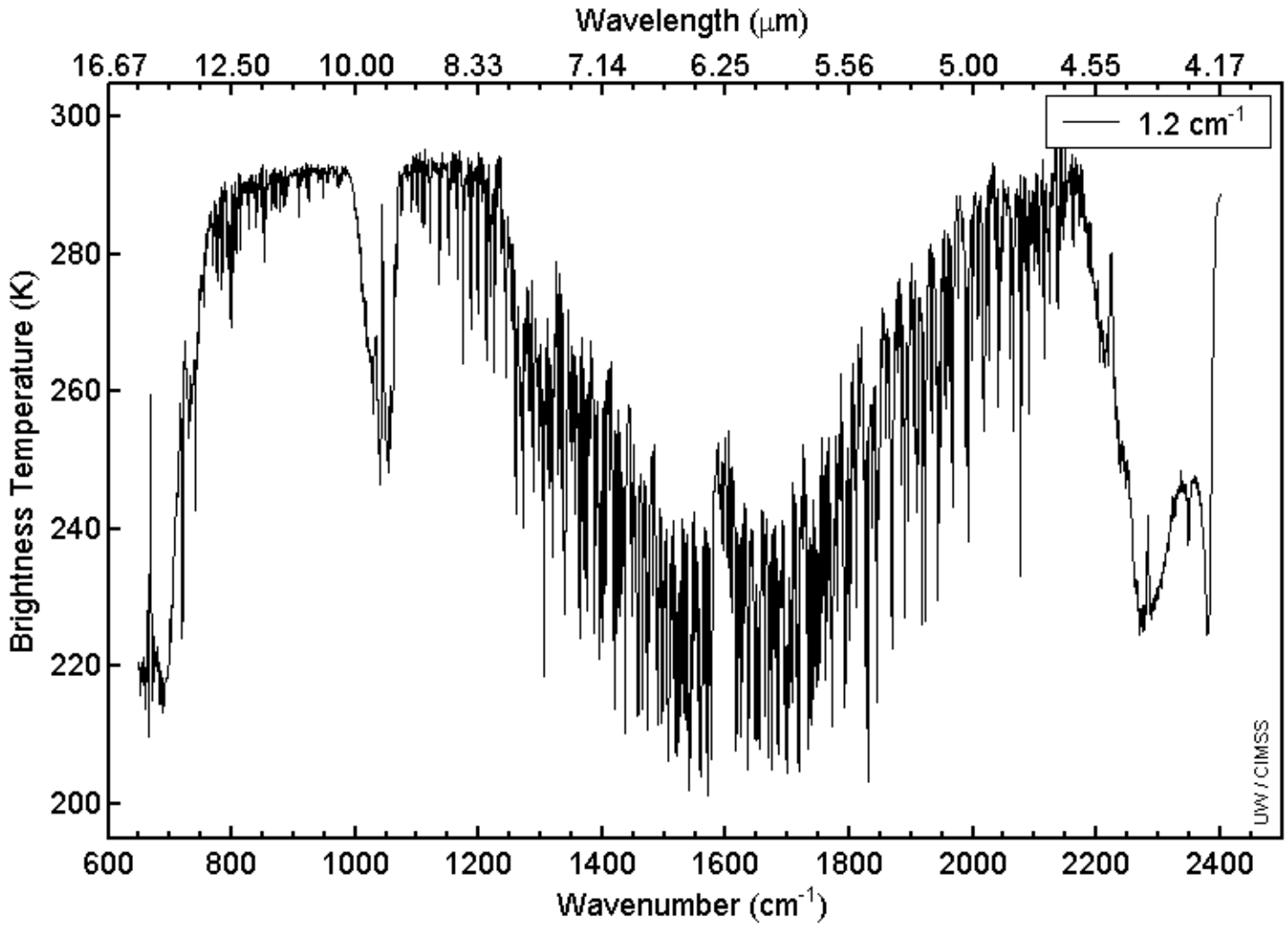
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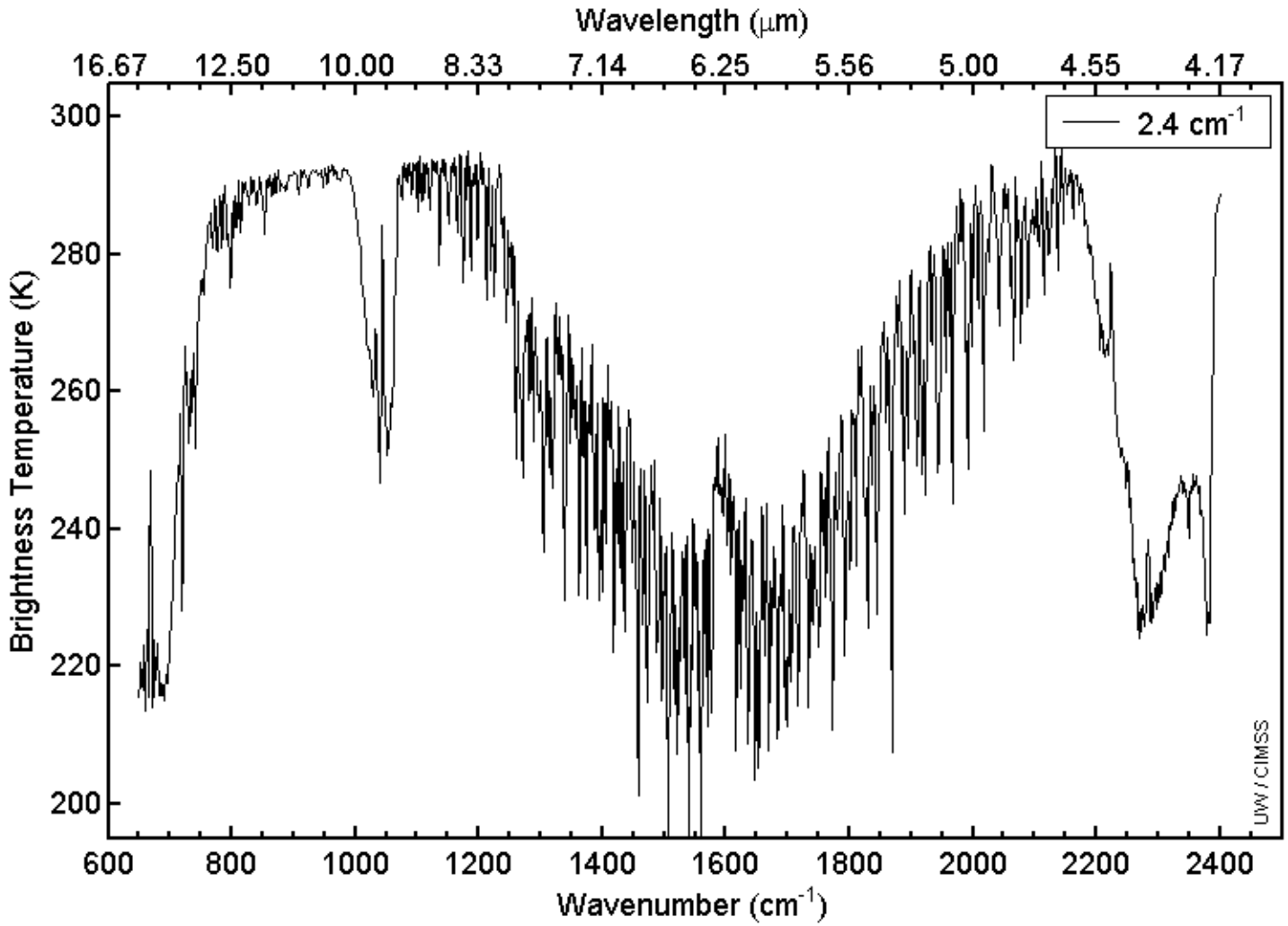
UW / CIMSS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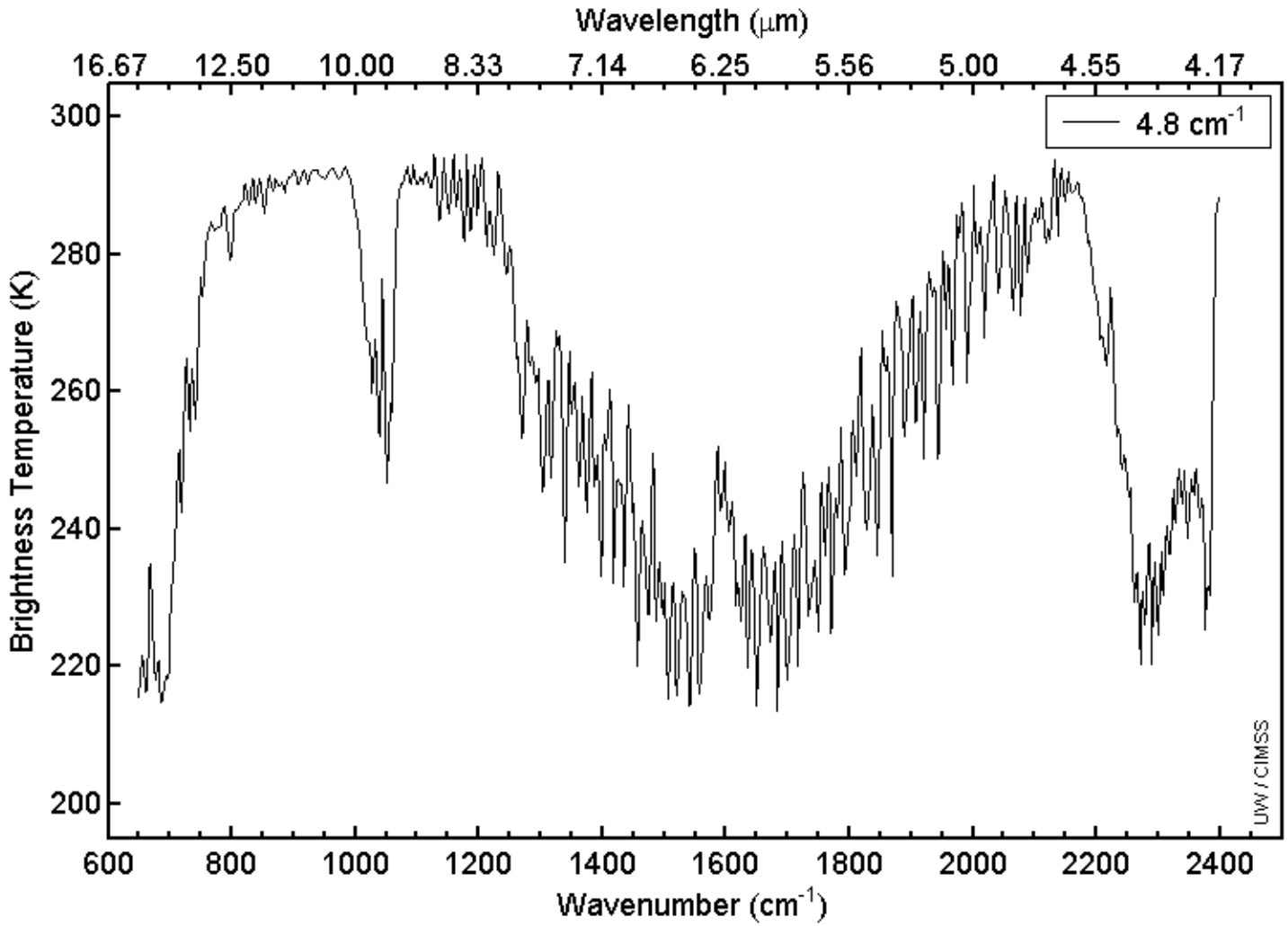
Wavenumber (cm-1)
UW / CIMSS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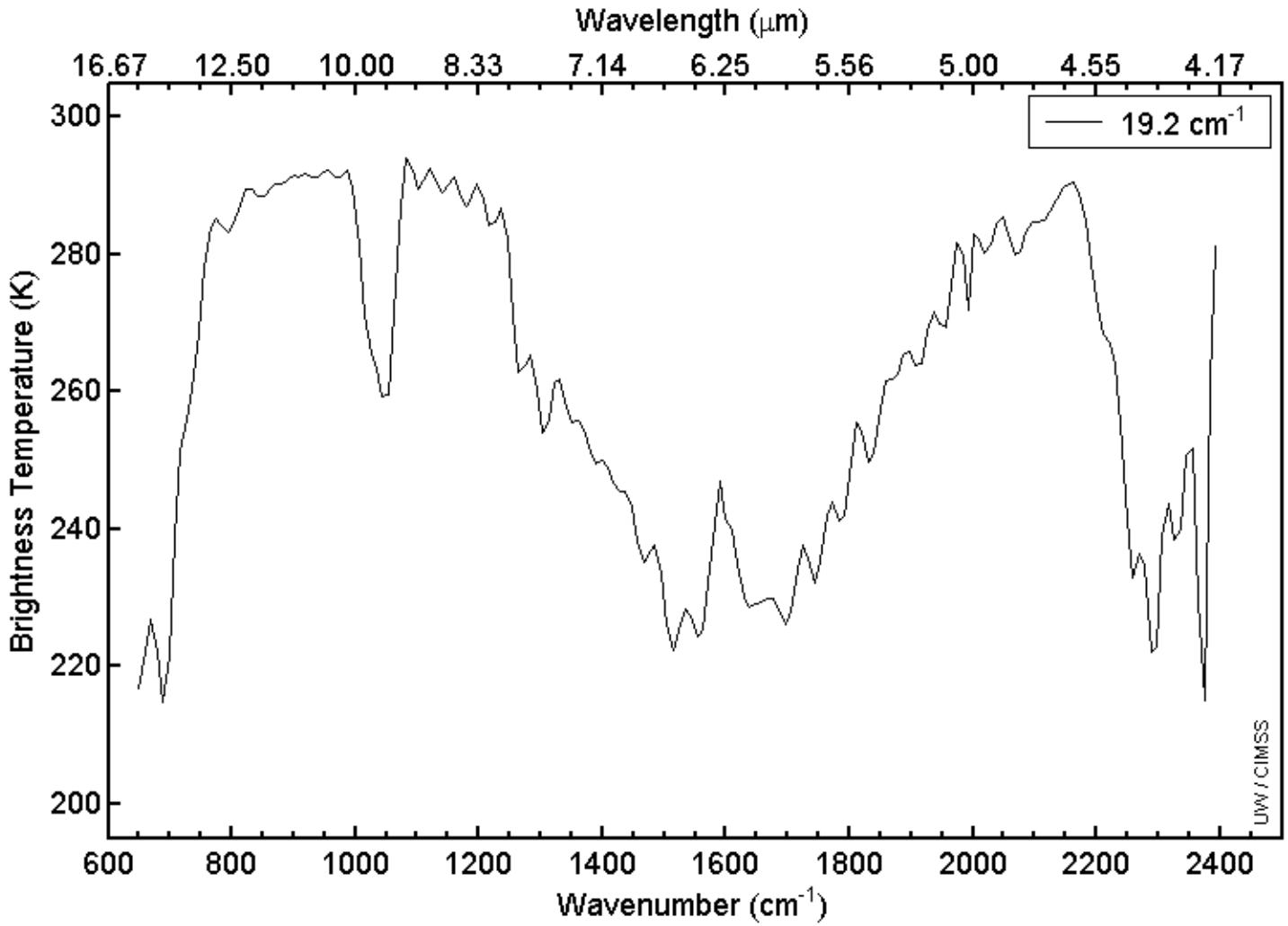
UW / CIMSS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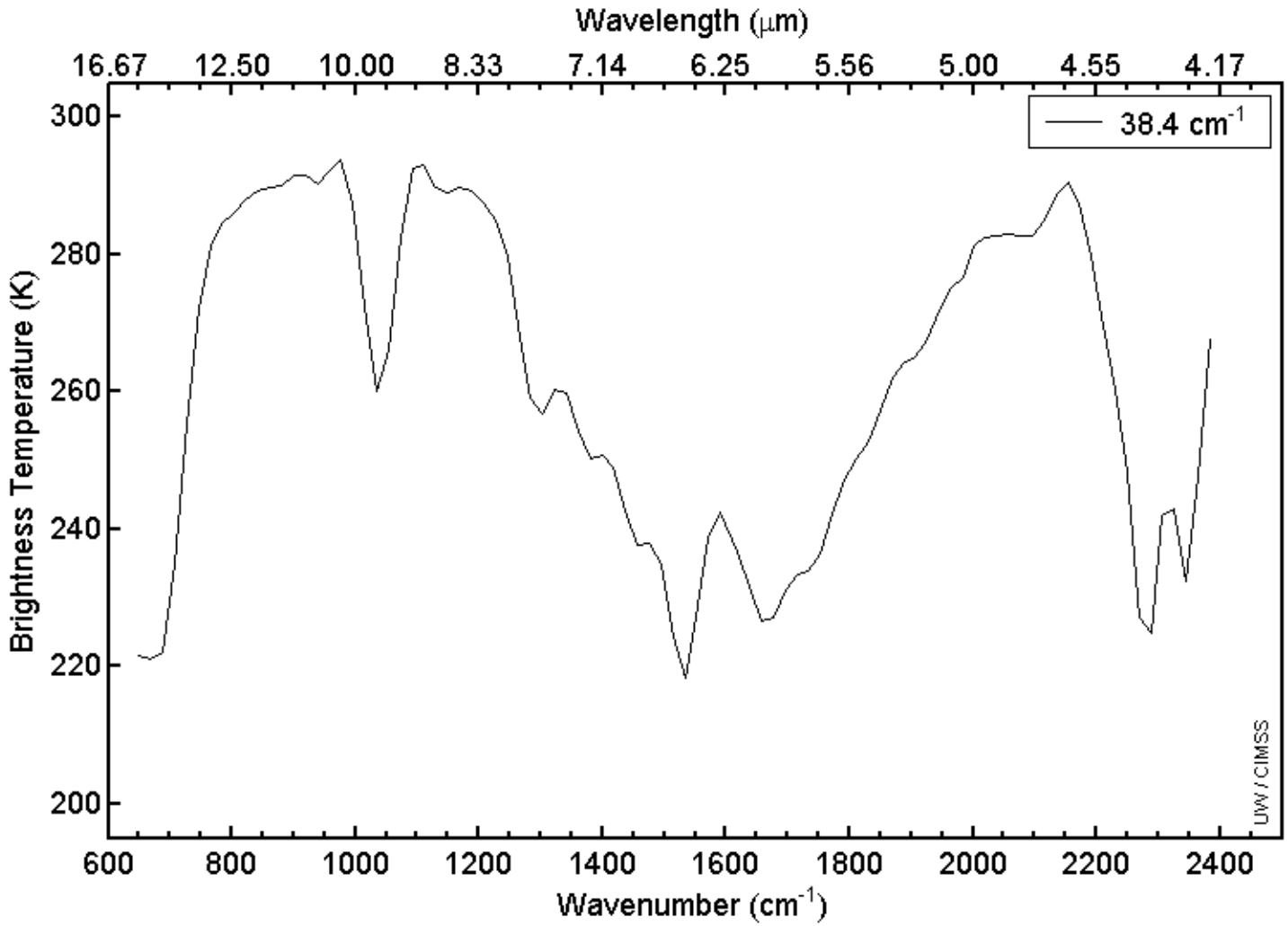
Wavenumber (cm-1)
UW / CIMSS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Brightness Temperature (K)
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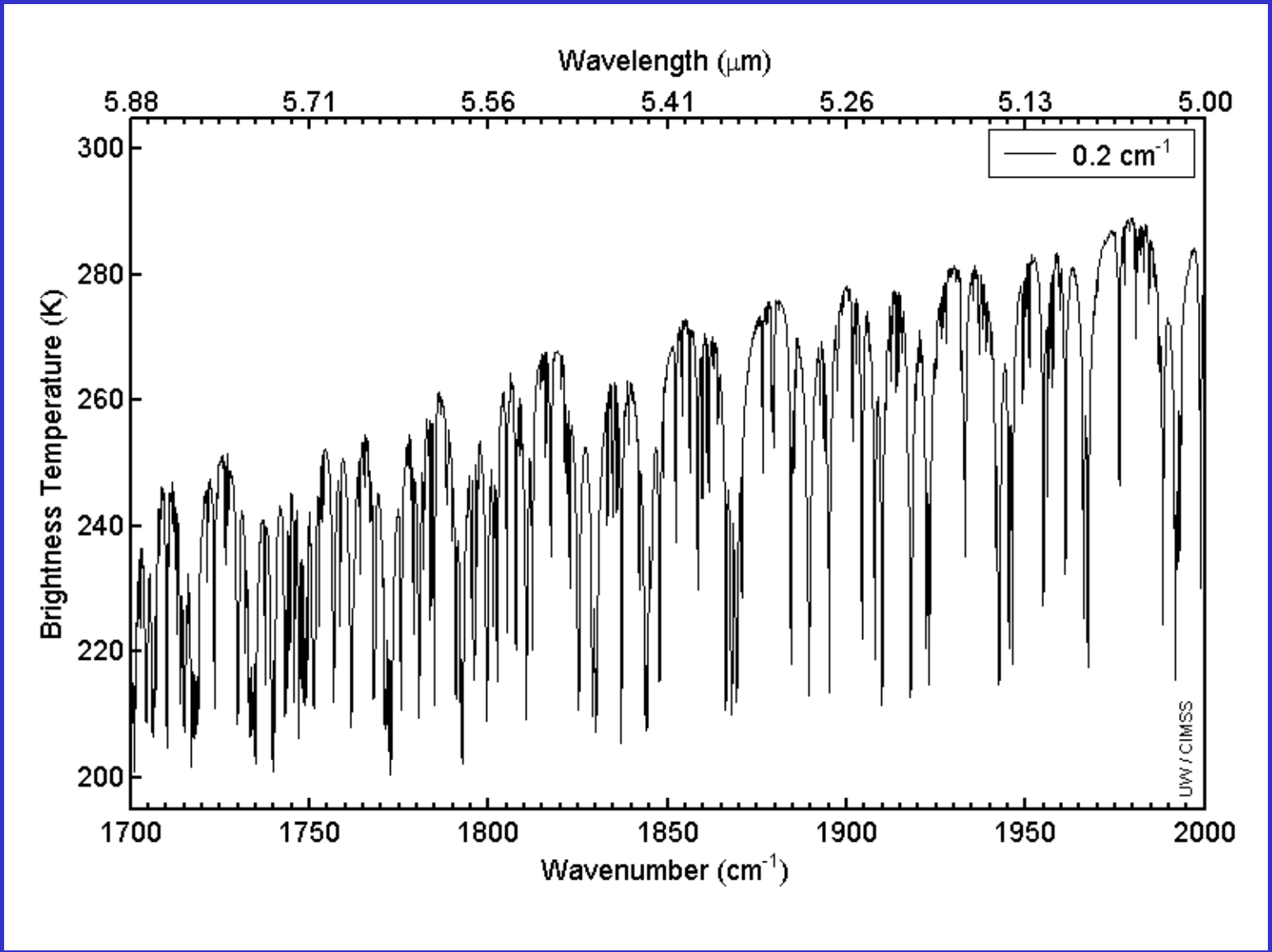
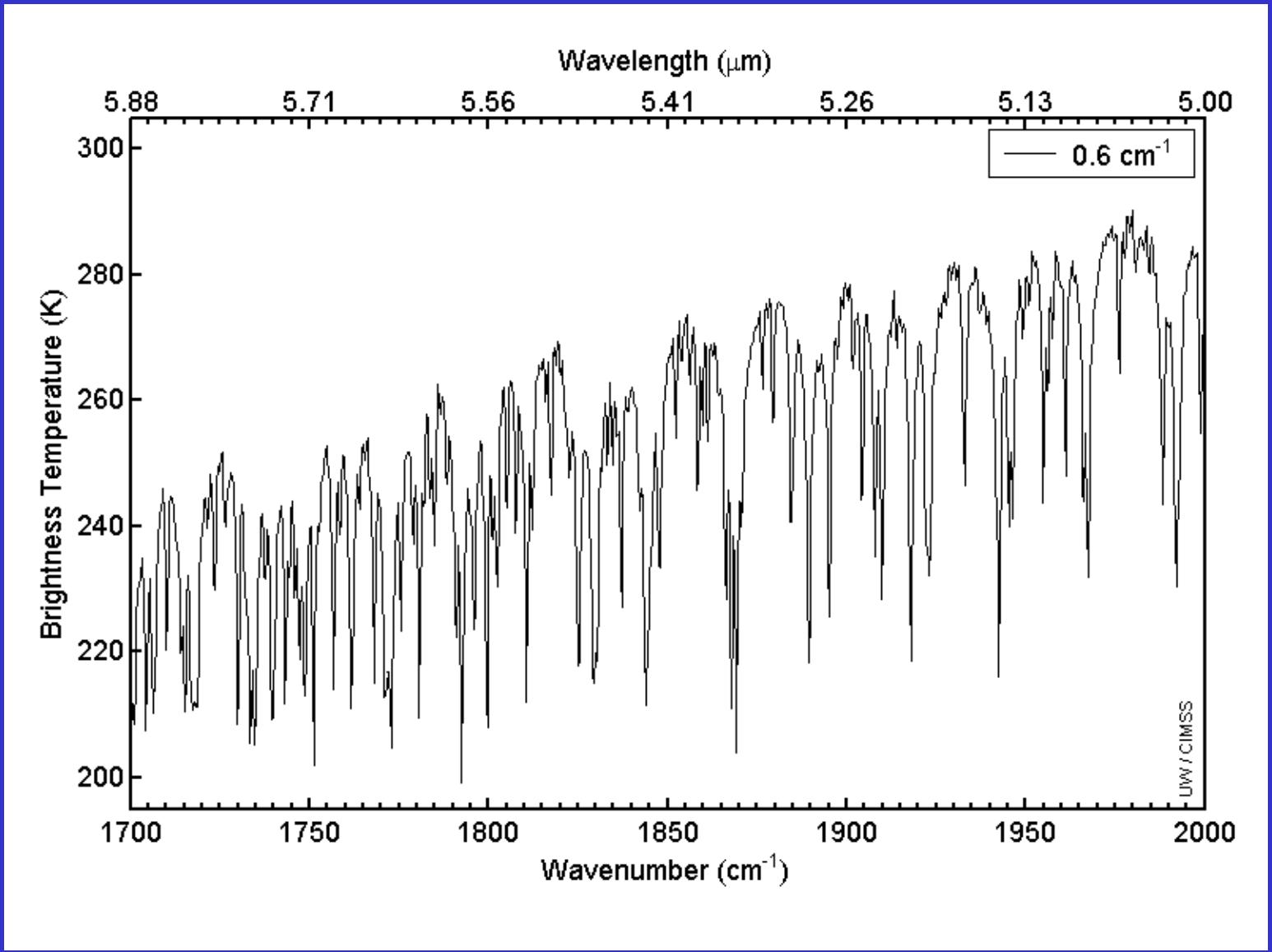
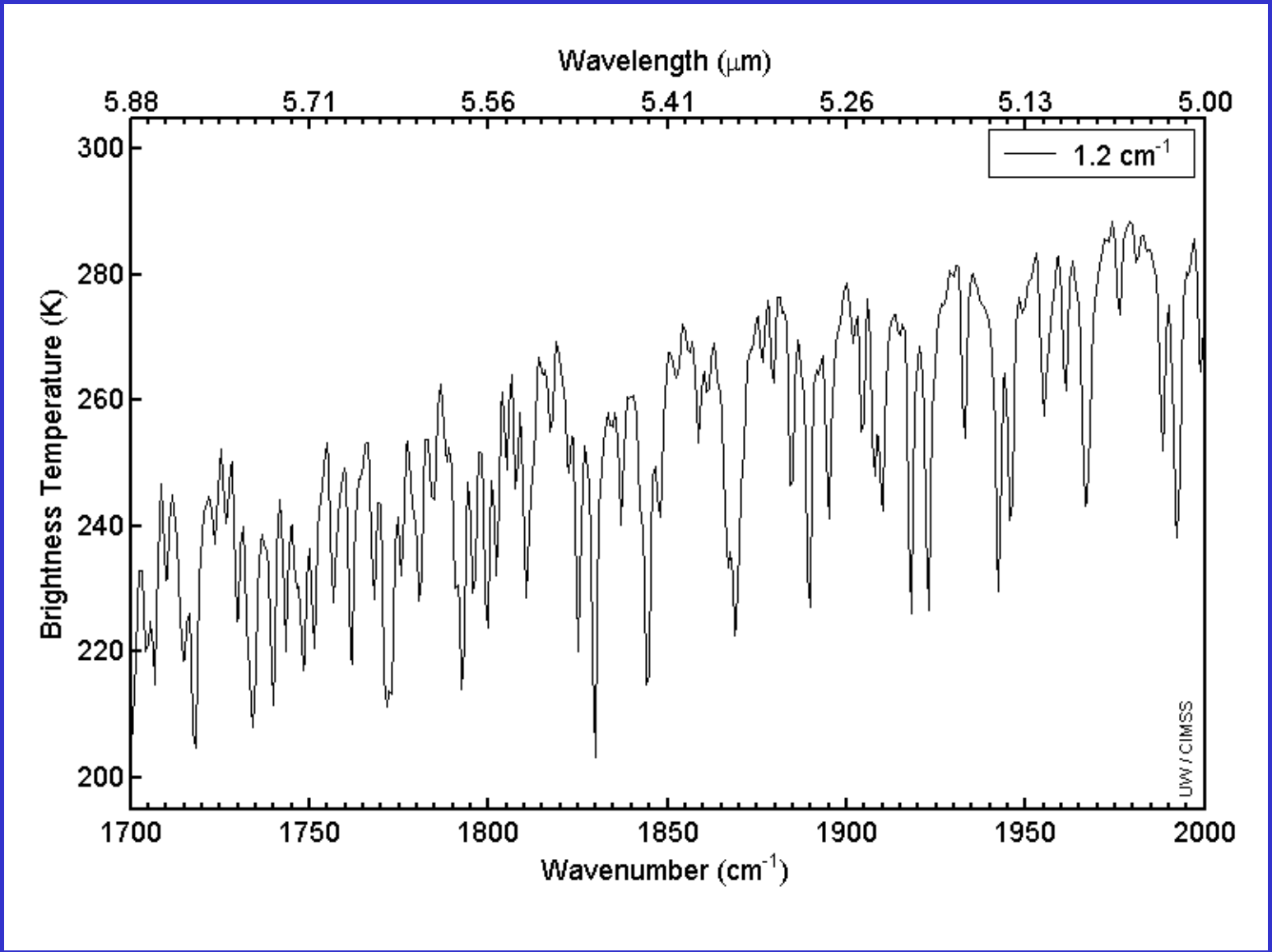
Wavenumber (cm-1)
UW / CIMSS



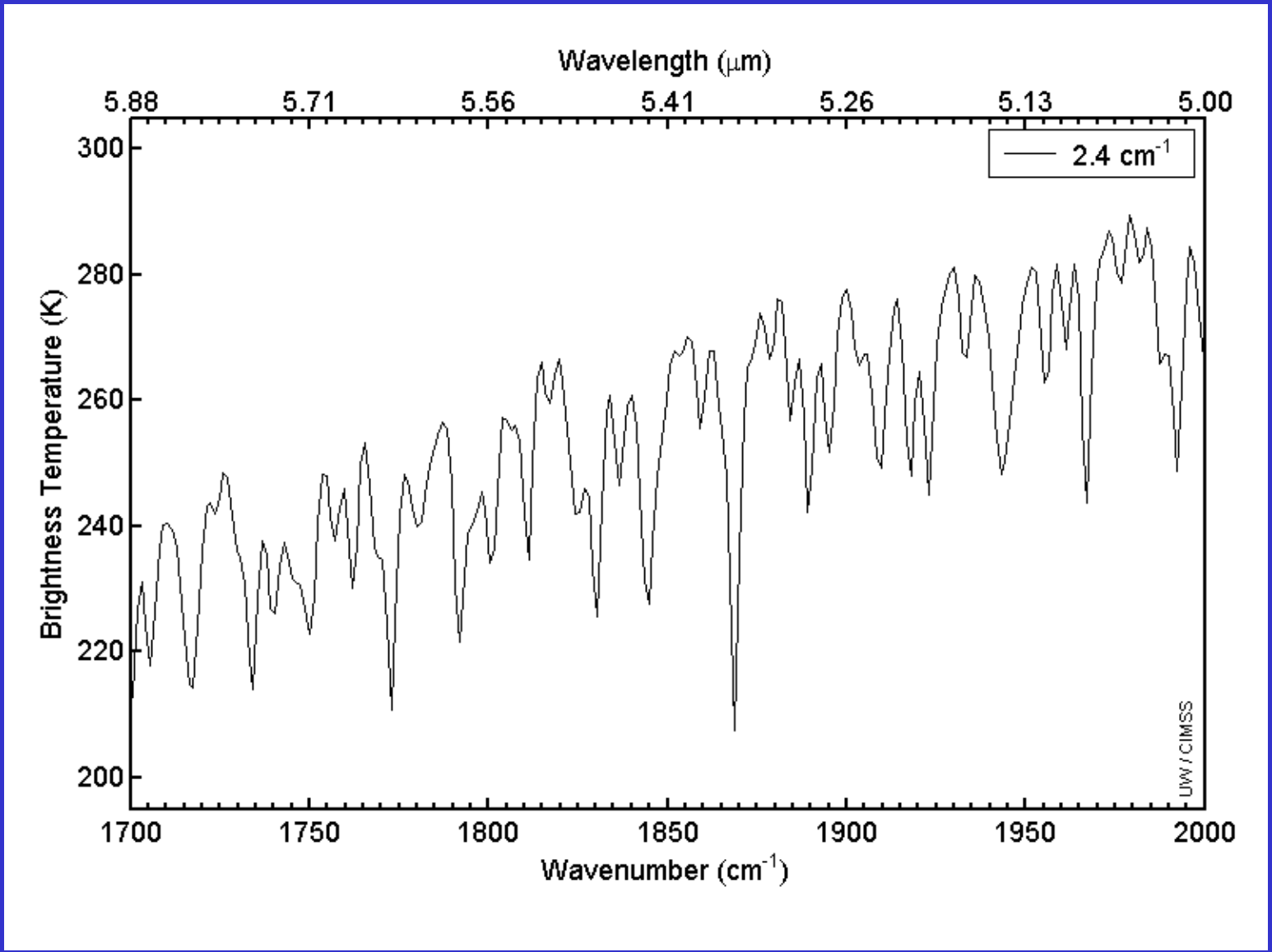
Water vapor region



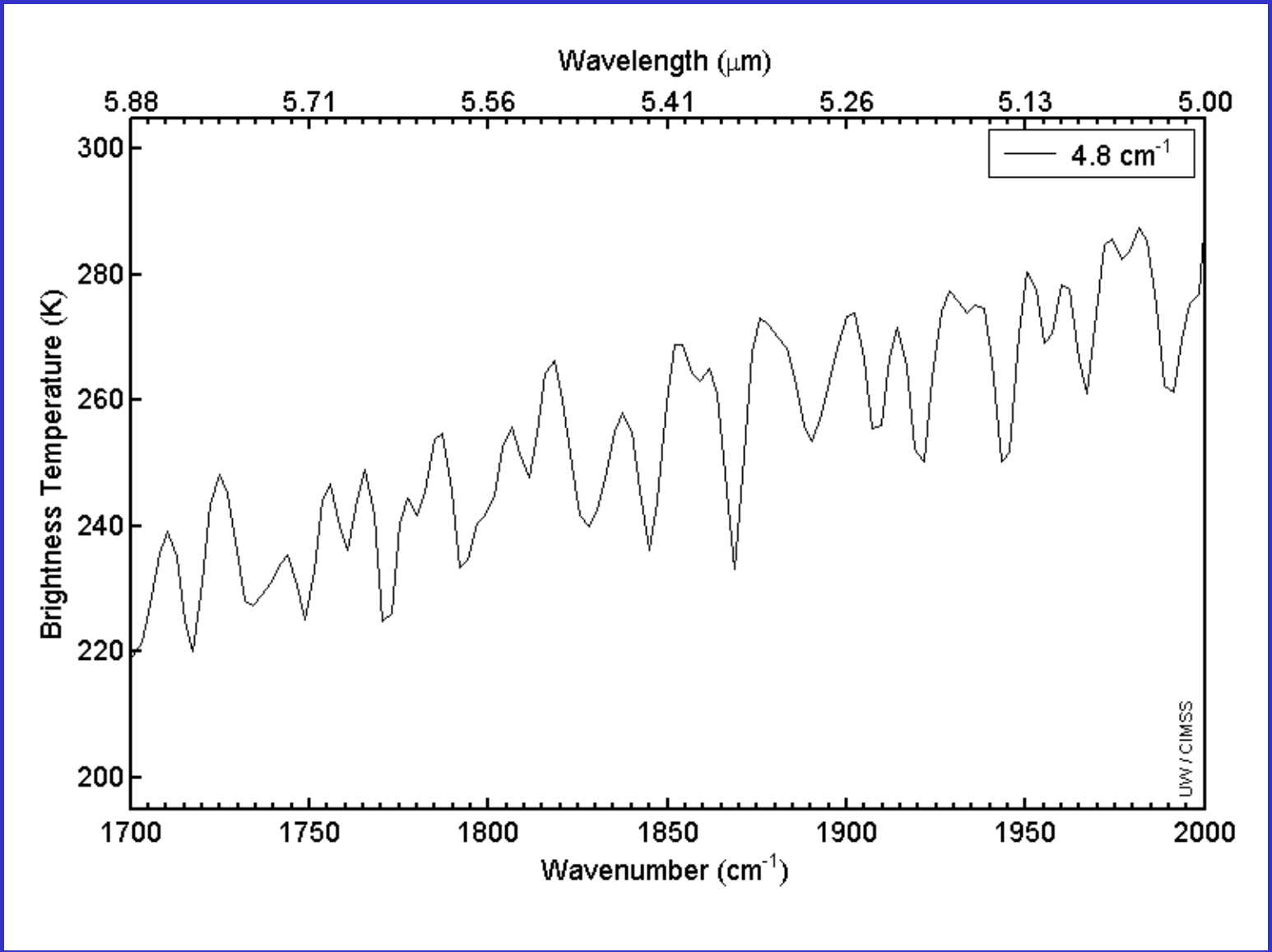
Water vapor region



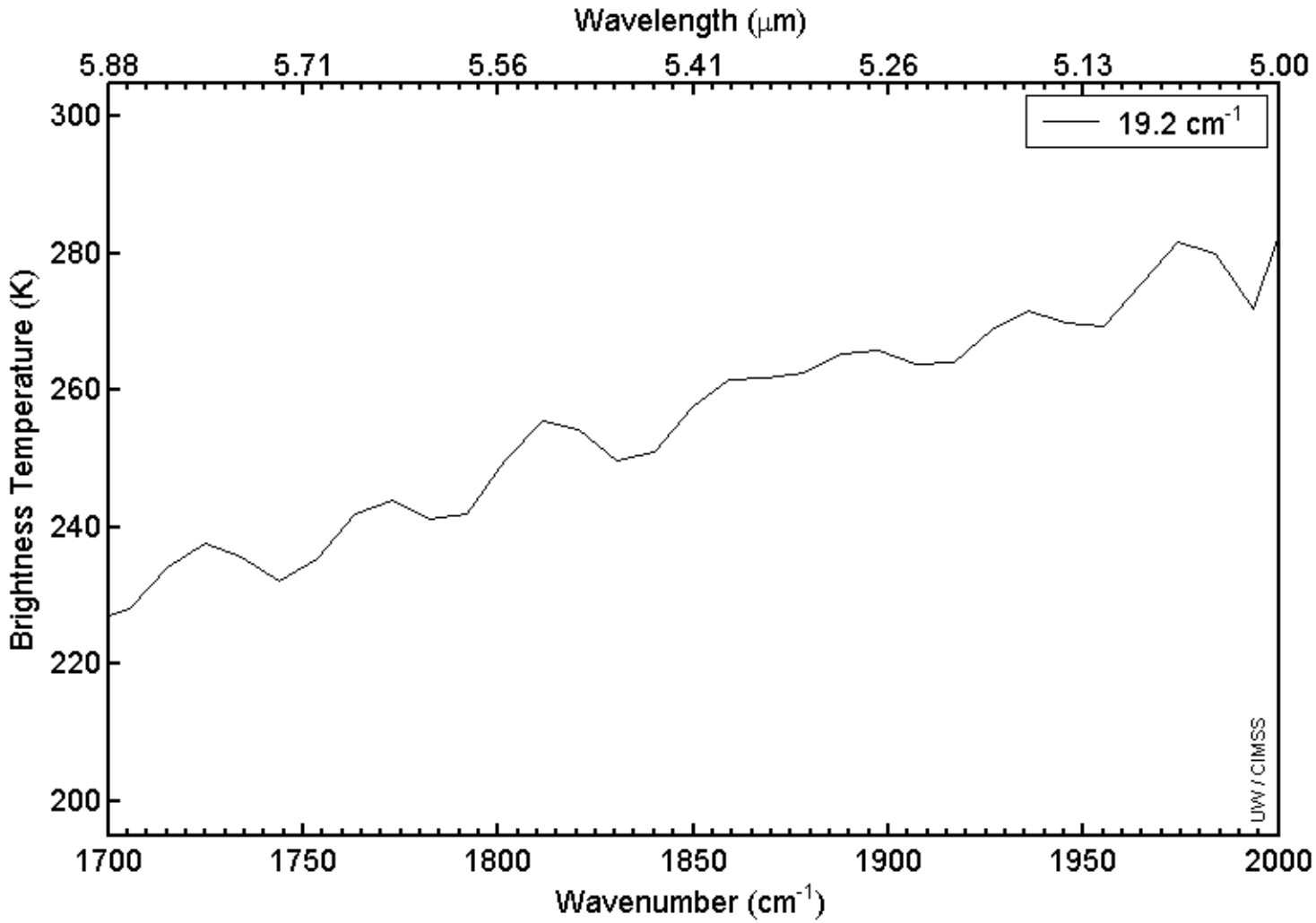
Water vapor region



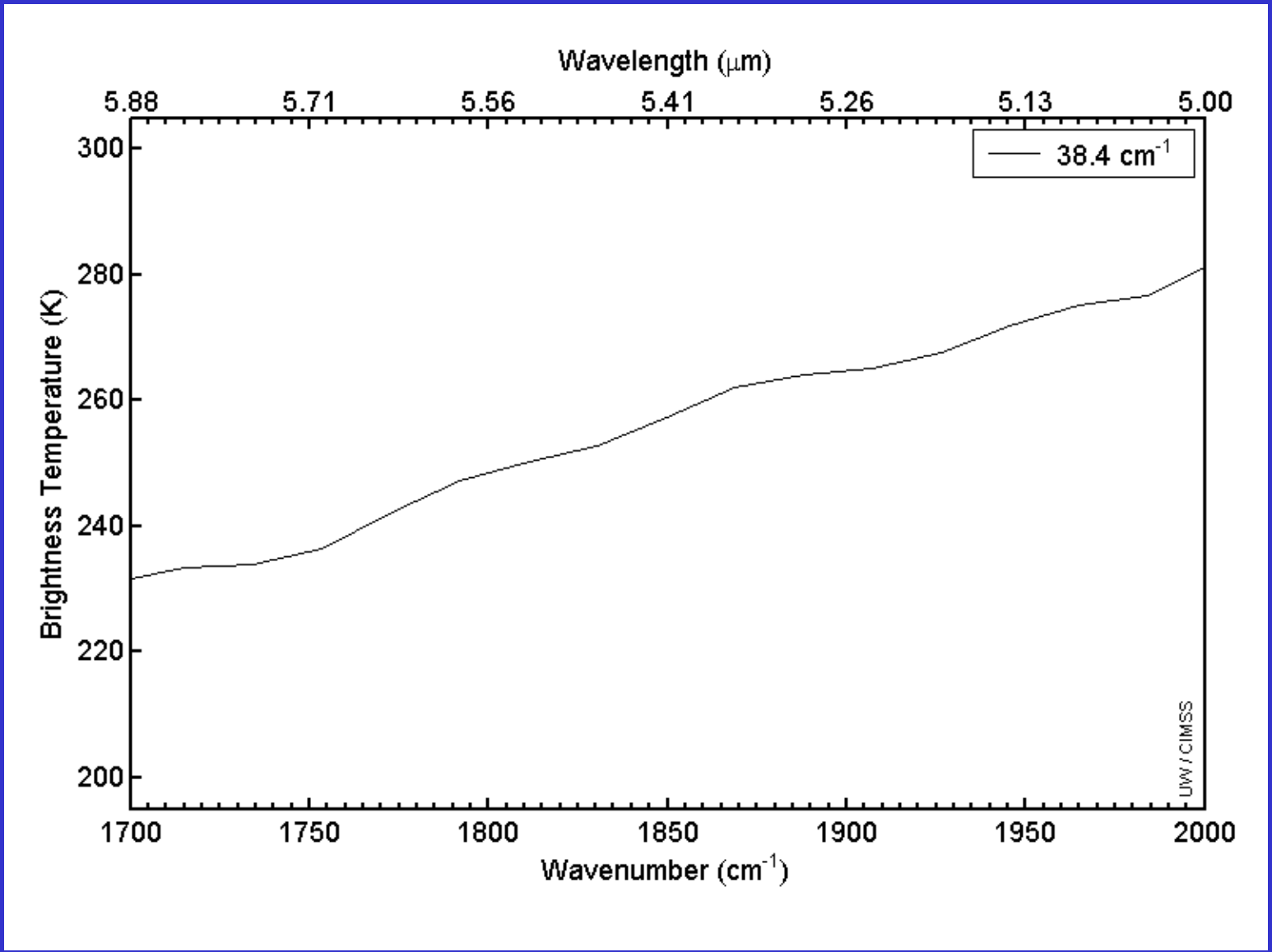
Water vapor region



Water vapor region

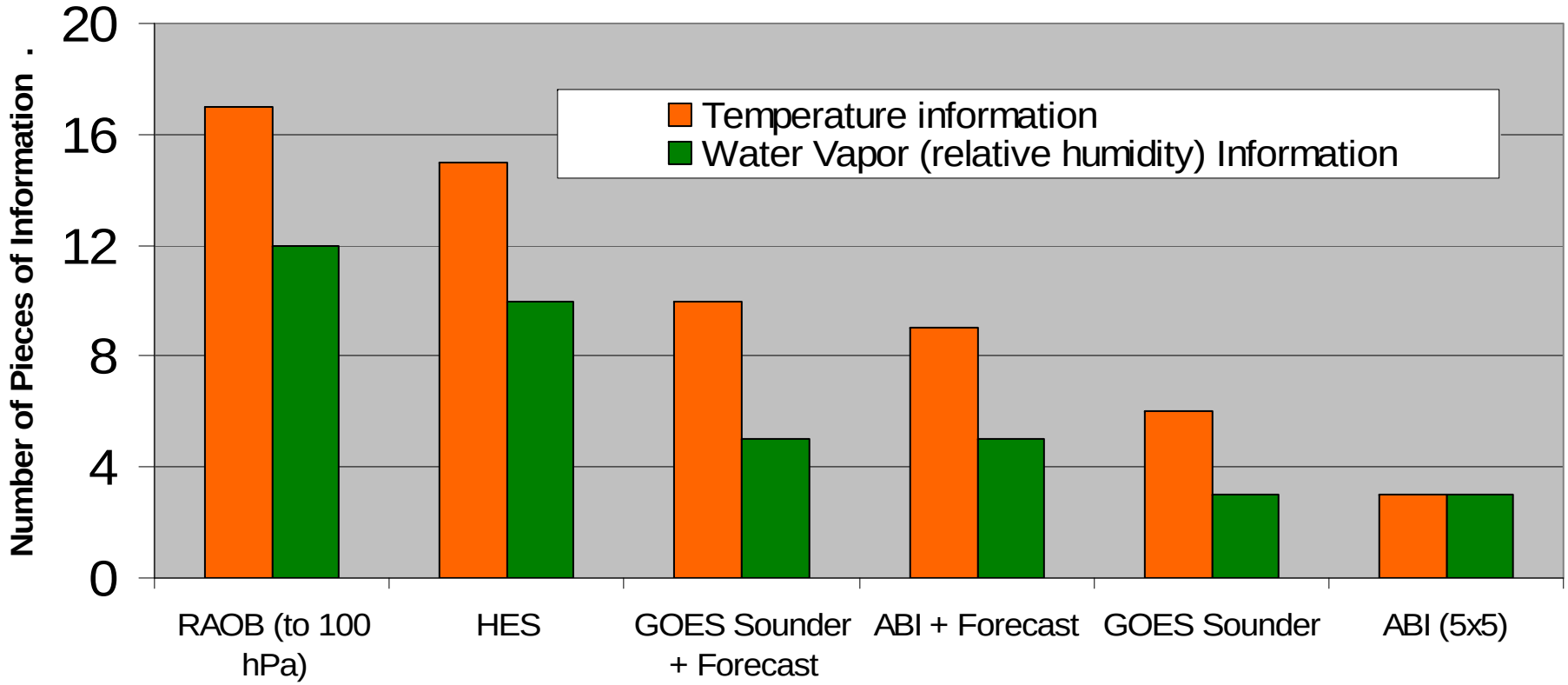


Water vapor region



Water vapor region

Profile Information Content

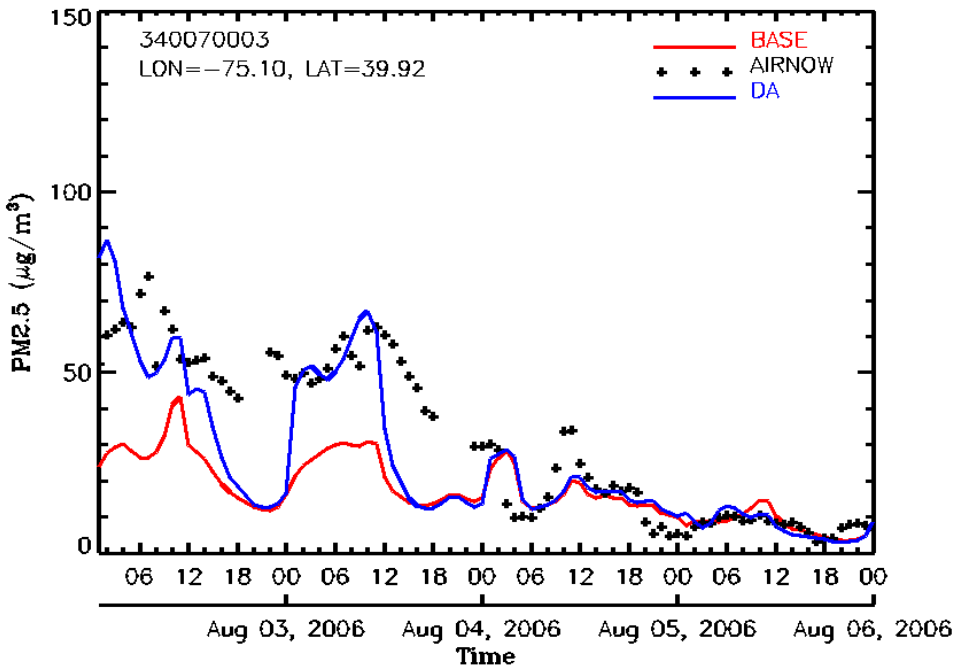


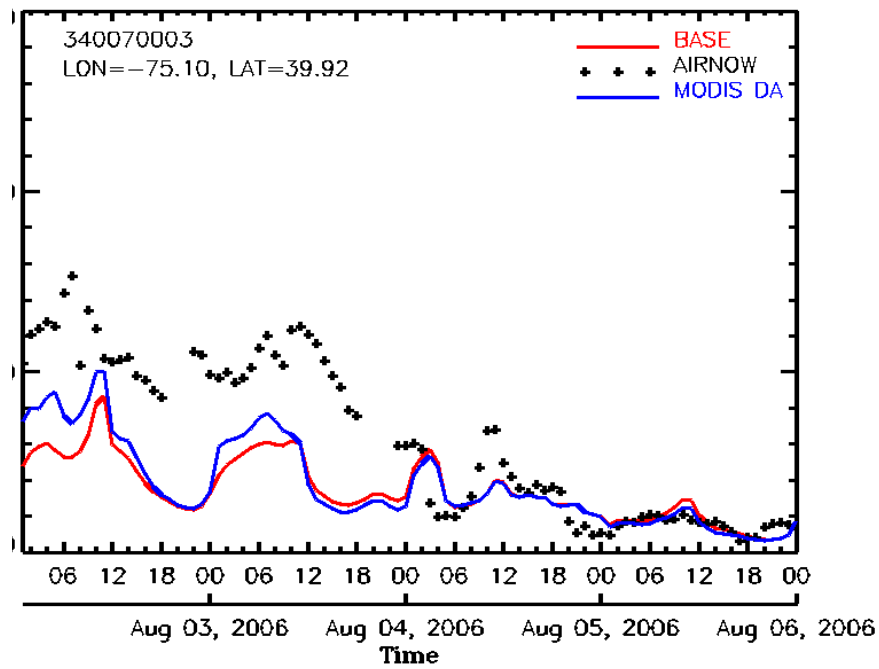
The relative vertical number of independent pieces of information is shown. Note that the moisture content is similar between the ABI and the current GOES Sounder. The Sounder does show more temperature information than the ABI. Caveat: Even if two systems have the same number of pieces of information, they may represent different vertical levels. This information content analysis does not account for any spatial or temporal differences.

Time Series of PM2.5 concentrations

GOES AOD Assimilation

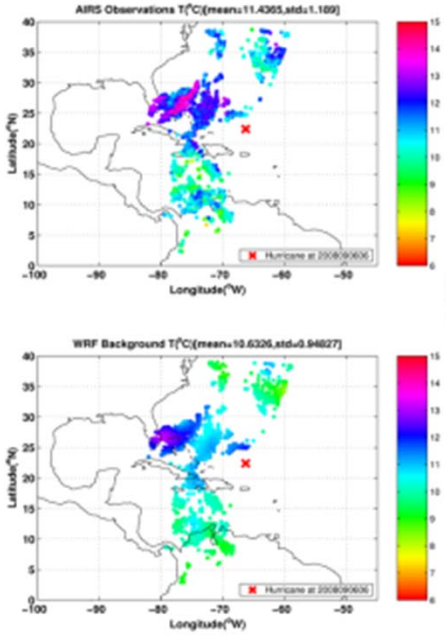
MODIS AOD Assimilation



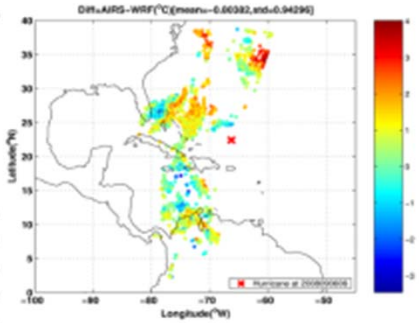


- WRF-CMAQ assimilation runs are reinitialized every 24 hours with satellite AOD observations. GOES has a 10-hr observational window during which hourly mini-cycling is used.
- Both GOES and MODIS assimilation improve surface PM2.5 predictions. GOES has a bigger impact than MODIS due to hourly cycling.
- Loss of information around 18 UTC in base case as well as assimilation run was determined to be due to boundary layer dynamics

Shobha Kondragunta, STAR



AIRS 700 hPa T (upper left);
WRF 700 hPa T (lower left);
Difference between AIRS and WRF

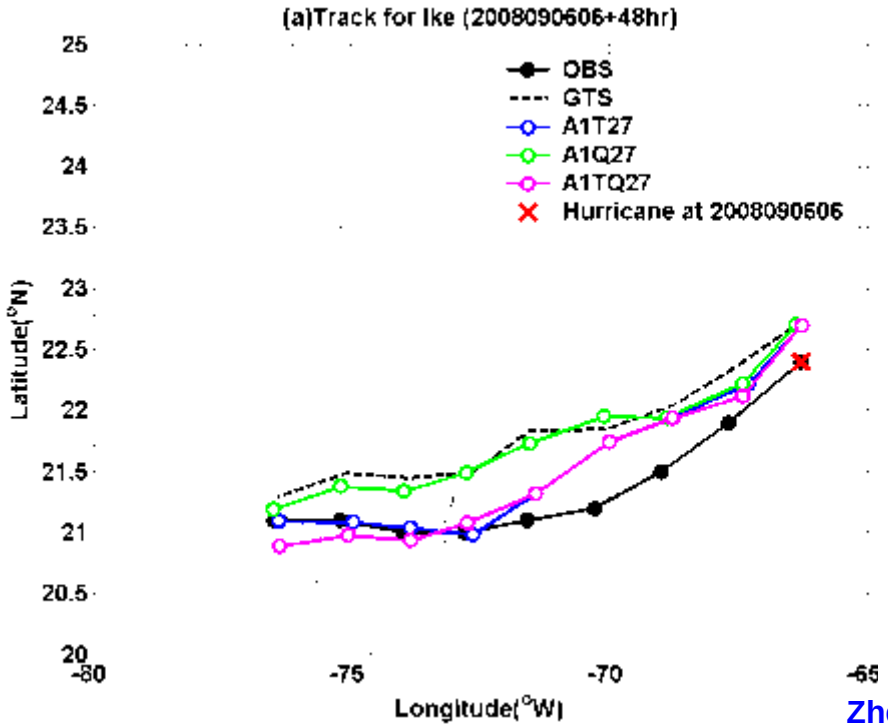


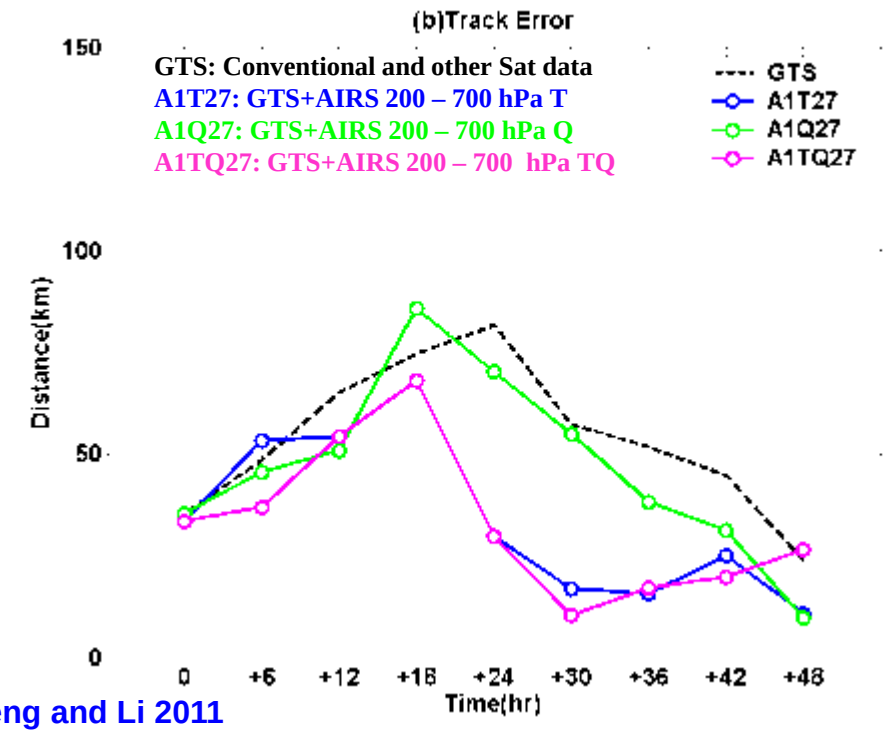
AIRS run with WRF/3DVAR uses clear-skies from 3 granules g066/067/068, assimilate T/q profiles between 200 - 700hPa in the experiments for next 48 hour Hurricane Ike (2008) track forecast

Future work:

(1) Assimilate the GOES Sounder high temporal resolution precipitable water (PW) between 300 and 700 hPa;

(2) Combined AIRS and MODIS/GOES Sounder for hurricane forecast in order to prepare the application of combined GOES-R/JPSS atmospheric profiles in high impact weather applications;

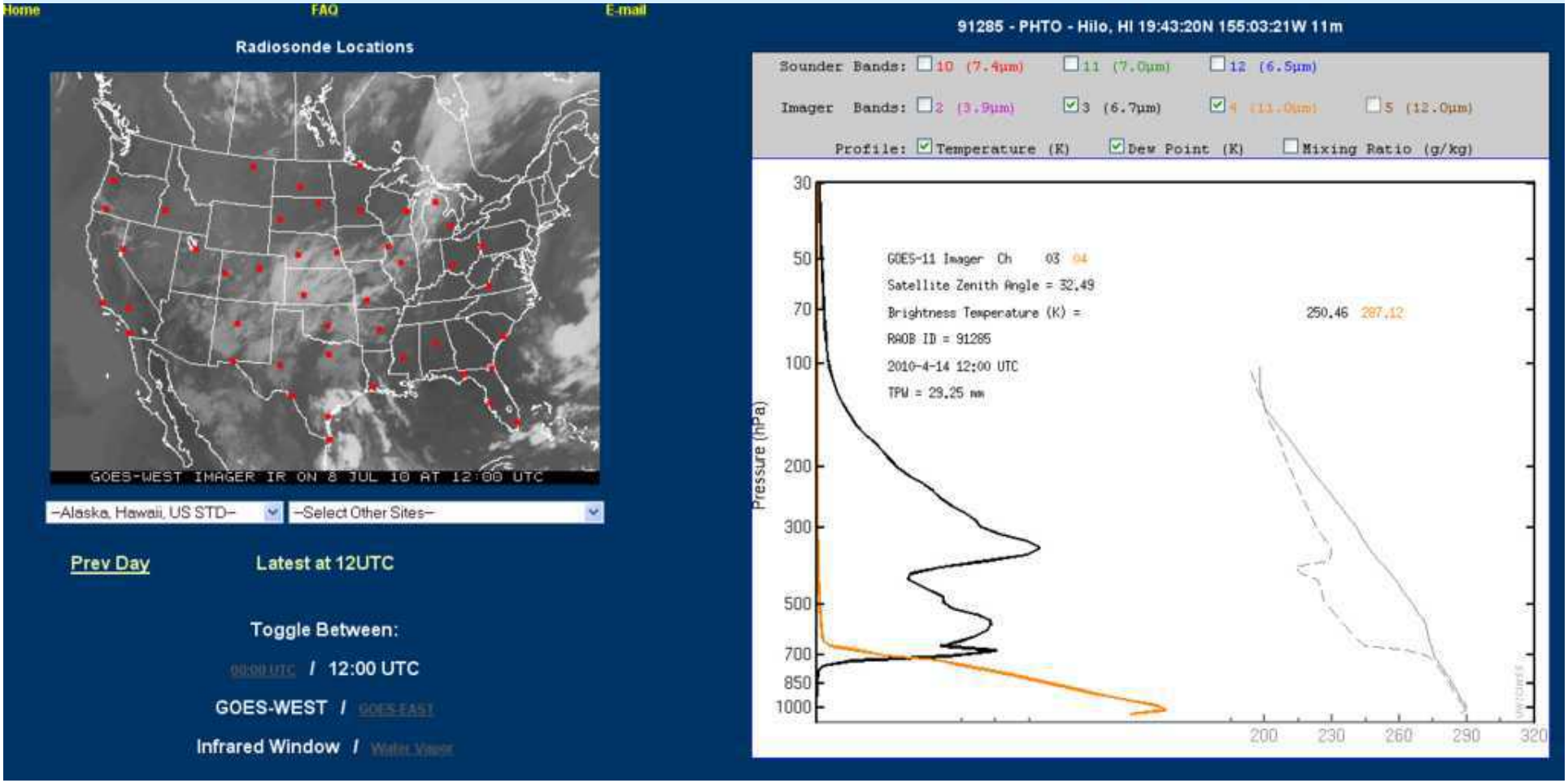




Zheng and Li 2011

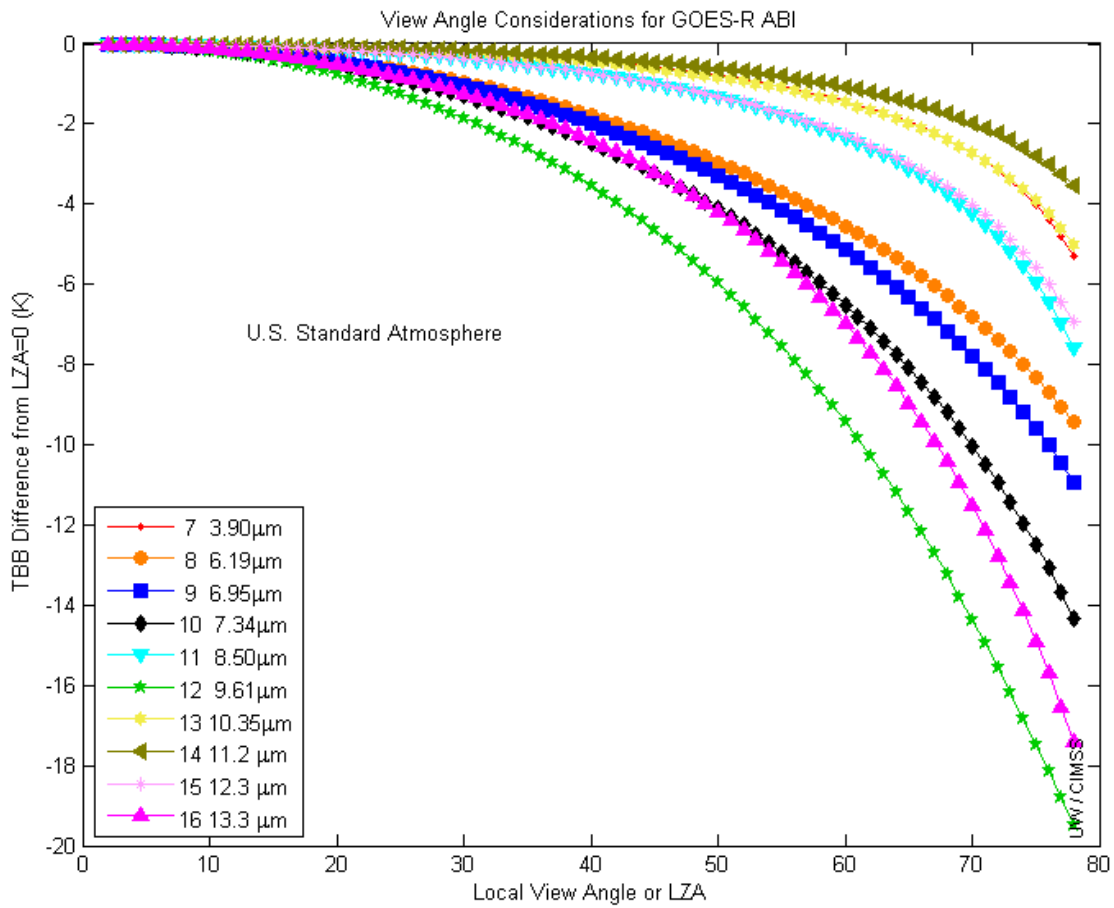
CIMSS Real-time WF and ABI web page

- http://cimss.ssec.wisc.edu/goes/wf/
- http://cimss.ssec.wisc.edu/goes/wf/ABI/



ABI Weighting Functions

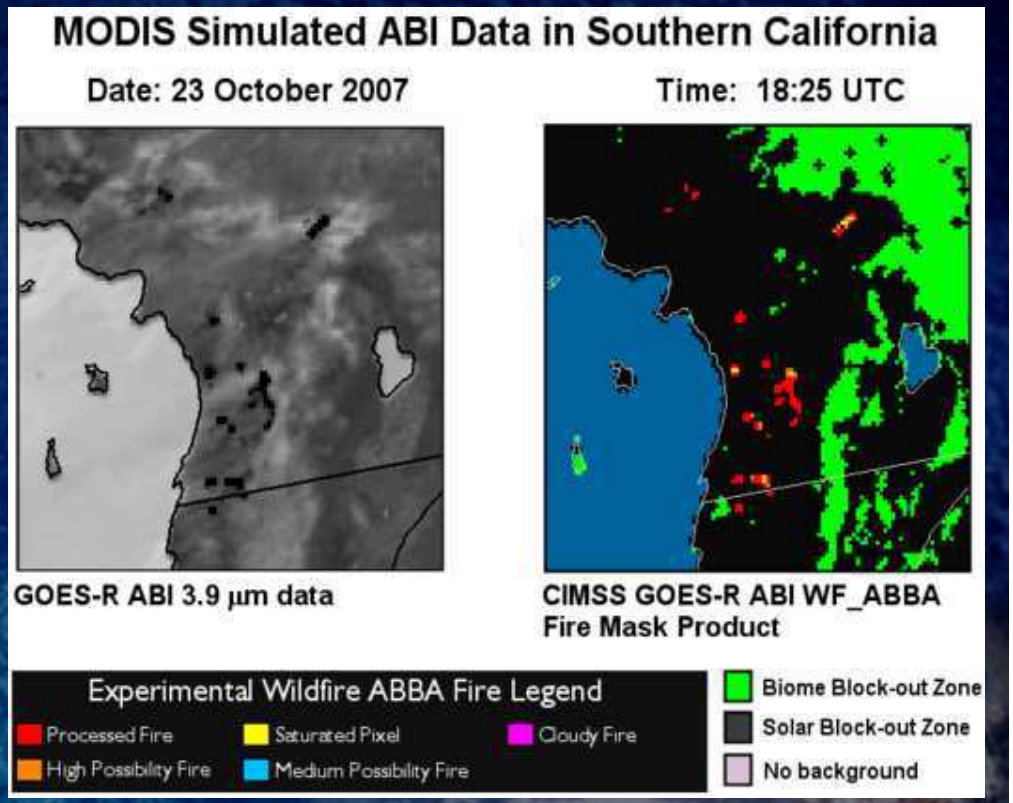
- As a function of….
  - » View angle



Fire/Hot Spot Characterization

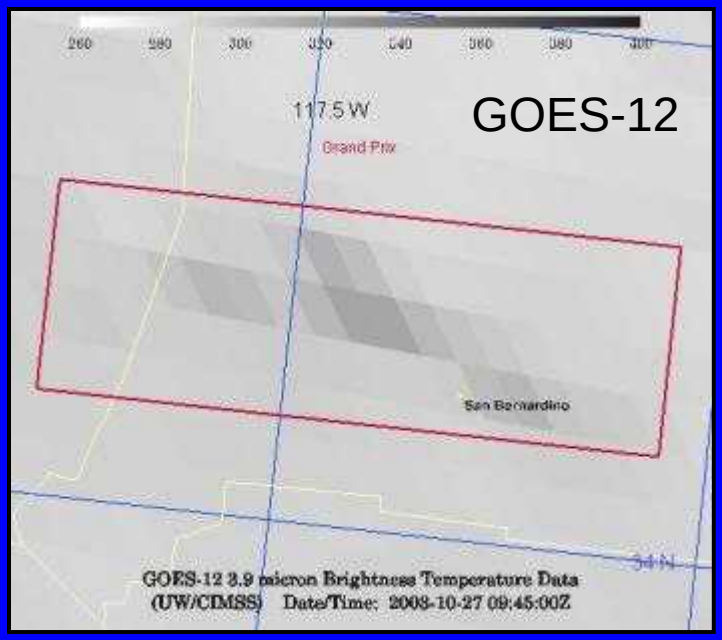
- **Algorithm Highlights**
  - Heritage lies with the GOES operational Wildfire Automated Biomass Burning Algorithm (WF_ABBA)
  - Dynamic, multi-spectral, thresholding contextual algorithm
  - Utilizes the 0.64, 3.9, 11.2 and 12.3 μm channels
  - Leverages ABI's higher spatial and temporal resolution data

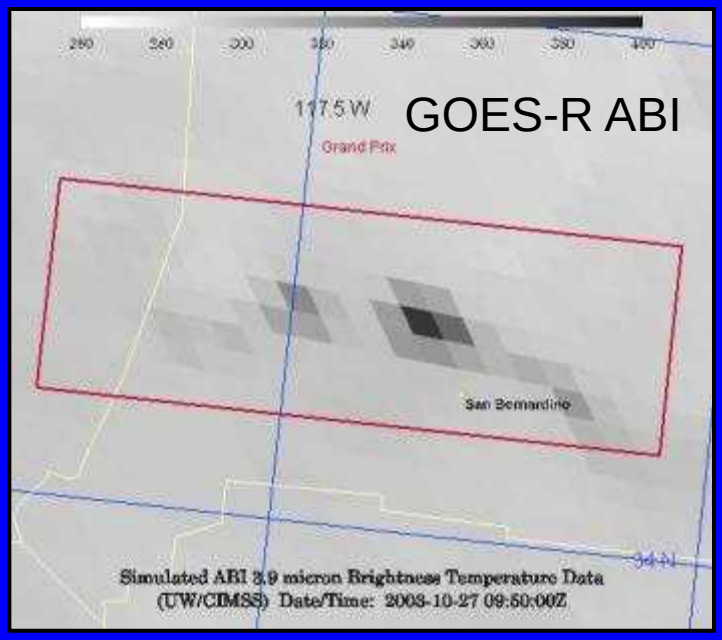
- **Operational Applications**
  - Fire weather forecasting
  - Air quality forecasting

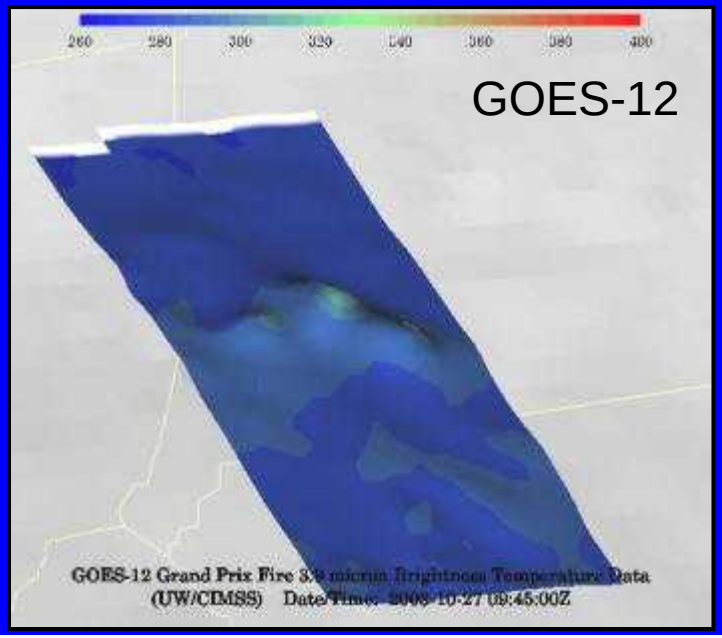


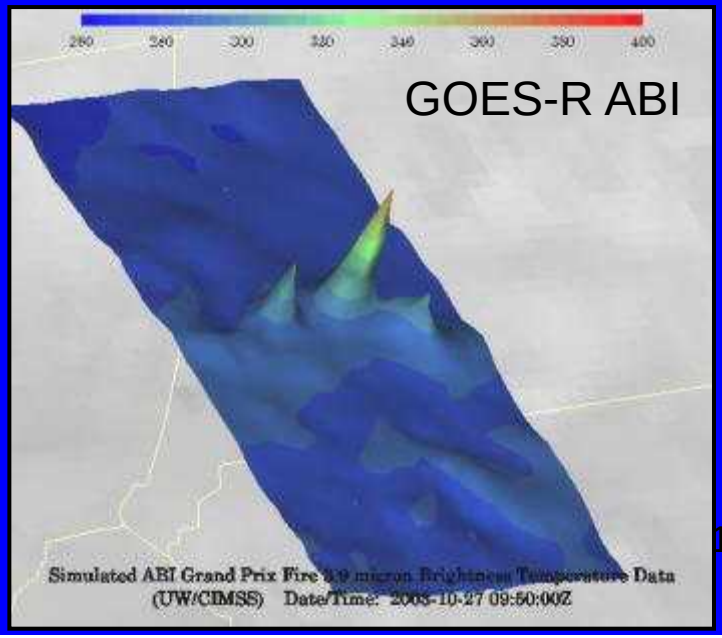
Courtesy C. Schmidt: CIMSS

GOES-12 and GOES-R ABI
Simulation of Grand Prix Fire/Southern California

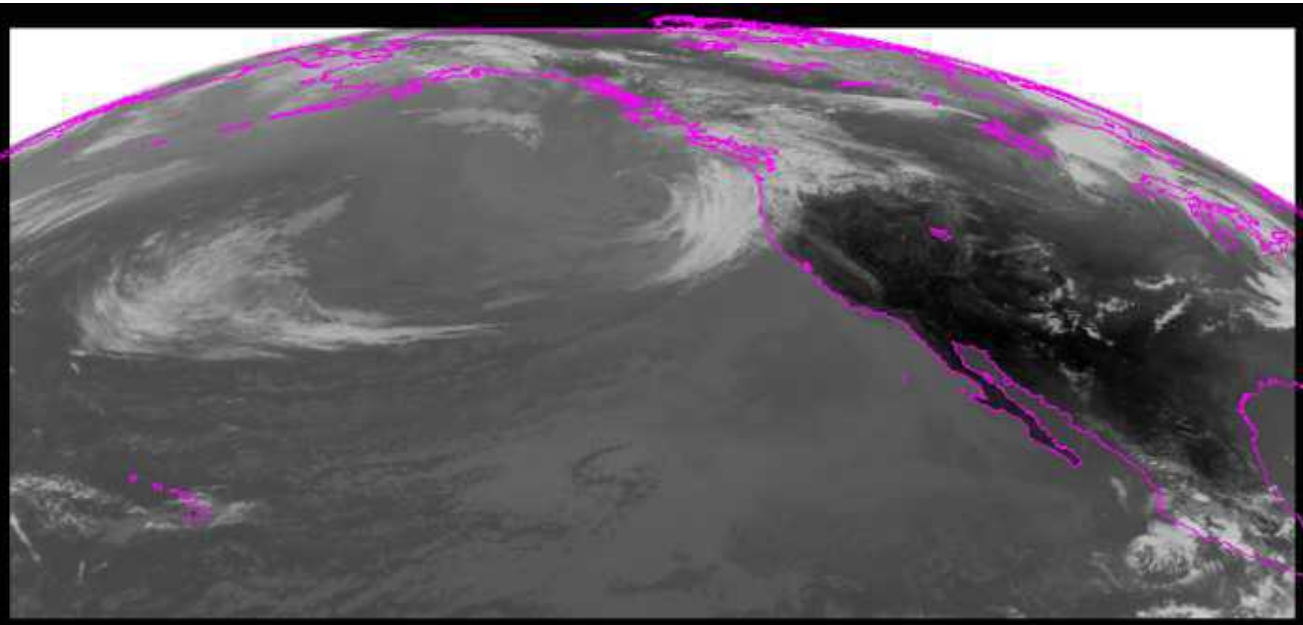


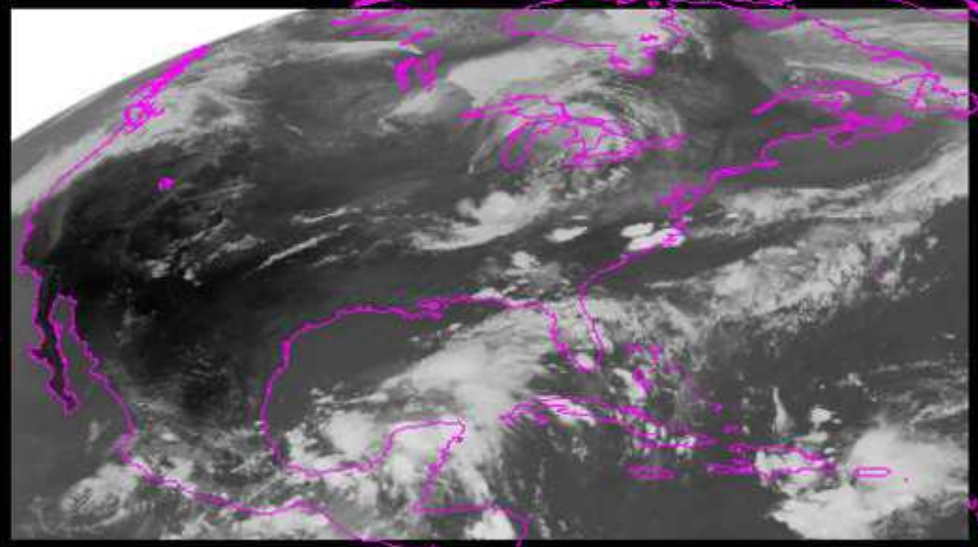






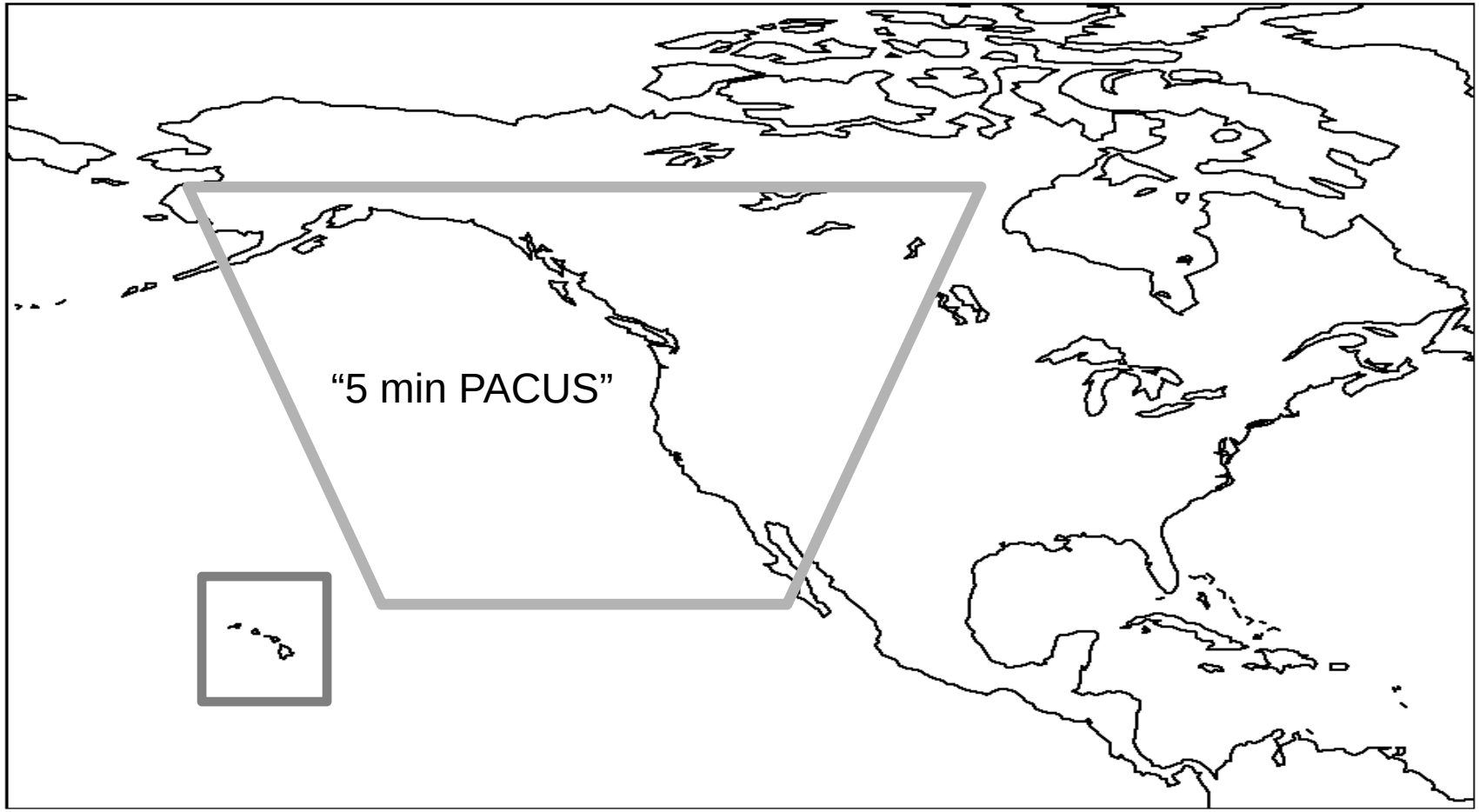
J. Feltz





Current GOES Imager scans: PACUS and CONUS (note that PACUS is one-third larger). These regions are sub-selected for AWIPS.

Proposed –Shifted "5 min PACUS"



Proposed "shifted" "PACUS" would give a 5 min scan of southern AK and western CONUS. This would mean that Hawaii could be covered with one of the meso-scales (and 15 min FD); if in 'flex mode (3)'. Note that the positions are approximate.

Visualization ("decision aid")

- "RGB Color" (VIS 0.6, VIS 0.8, and NearIR 1.6 um) with ABI simulated data (from CIMSS); image from William Straka, CIMSS and using the EUMETSAT enhancement.

Algorithm Working Group (AWG)

Develop algorithms for the Level 2 products (Both 'Baseline' and 'Future Capability' products)

Advanced Baseline Imager (ABI)

- **Clouds and Moisture Imagery (KPP)**
- Clear Sky Mask
- Cloud Top Pressure and Height
- Cloud Top Phase
- Cloud Top Temperature
- Cloud Particle Size Distribution
- Cloud Optical Path
- Temperature and Moisture Profiles
- Total Precipitable Water
- Stability Parameters (Lifted Index, etc.)
- Aerosol Detection
- Aerosols Optical Depth
- Derived Motion Winds
- Hurricane Intensity
- Fire/Hot Spot Characterization
- Land and Sea Surface Temperature
- Volcanic Ash
- Rainfall Rate
- Snow Cover
- Downward Solar Insolation: Surface
- Reflected Solar Insolation: TOA

GLM

- Lightning Detection

- Cloud Layer/Heights
- Cloud Ice Water Path
- Cloud Liquid Water
- Cloud Type
- Convective Initiation
- Turbulence
- Low Cloud and Fog
- Enhanced "V"/Overshooting Top
- Aircraft Icing Threat
- SO_2 Detections (Volcanoes)
- Visibility
- Upward Longwave Radiation (TOA)
- Downward Longwave Radiation (SFC)
- Upward Longwave Radiation (SFC)
- Total Ozone
- Aerosol Particle Size
- Surface Emissivity
- Surface Albedo
- Vegetation Index
- Vegetation Fraction
- Flood Standing Water
- Rainfall probability and potential
- Snow Depth
- Ice Cover
- Sea & Lake Ice Concentration, Age, Extent, Motion
- Ocean Currents, Currents: Offshore

ABI "Baseline" Products

Wavelength Micrometers	0.47	0.64	0.865	1.378	1.61	2.25	3.90	6.185	6.95	7.34	8.5	9.61	10.35	11.2	12.3	13.3
Channel ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Baseline Products																
Aerosol Detection	X	X	X	X	X	X	X							X	X	
Suspended Matter/OD	X	X	X		X	X										
Clear Sky Masks		X		X	X		X		X	X	X			X	X	
Cloud & Moisture Imagery	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cloud Optical Depth		X				X	X							X	X	
Cloud Particle Size		X				X	X							X	X	
Cloud Top Phase										X	X			X	X	
Cloud Top Height														X	X	X
Cloud Top Pressure														X	X	X
Cloud Top Temperature														X	X	X
Hurricane Intensity													X			
Rainfall Rate/QPE								X		X	X			X	X	
Legacy Vertical Moisture Profile								X	X	X	X	X	X	X	X	X
Legacy Vertical Temp Profile								X	X	X	X	X	X	X	X	X
Derived Stability Indices								X	X	X	X	X	X	X	X	X
Total Precipitable Water								X	X	X	X	X	X	X	X	X
Downward Solar Insolation Surf	X	X	X		X	X										
Reflected Solar Insolation TOA	X	X	X		X	X										
Derived Motion Winds		X					X	X	X	X				X		
Fire Hot Spot Characterization		X					X							X	X	
Land Surface Temperature														X	X	
Snow Cover	X	X	X		X	X	X						X			
Sea Surface Temps							X				X		X	X	X	

Bands may also be used by needed "upstream" products, such as the cloud mask.

ABI "Option 2" Products

Wavelength Micrometers	0.47	0.64	0.865	1.378	1.61	2.25	3.90	6.185	6.95	7.34	8.5	9.61	10.35	11.2	12.3	13.3
Channel ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Option 2 Products																
Cloud Layer/Heights														X	X	X
Cloud Ice Water Path							X							X	X	
Cloud Liquid Water		X				X					X					
Cloud Type										X	X			X	X	
Convective Initiation								X	X	X	X	X		X	X	X
Turbulence								X								
Low Cloud and Fog		X					X									
Enhanced-V/Overshooting Top														X		
Aircraft Icing Threat		X				X	X			X	X			X	X	X
SO_2 Detection								X		X	X			X	X	
Visibility (no direct use of ABI bands)																
Upward Longwave Radiation (TOA)								X		X	X		X			X
Downward Longwave Radiation (SFC)									X	X	X	X	X	X	X	X
Upward Longwave Radiation (SFC)											X		X	X	X	
Total Ozone								X	X	X		X	X	X	X	X
Aerosol Particle Size	X	X	X		X	X										
Surface Emissivity								X	X	X	X	X	X	X	X	X
Surface Albedo	X	X	X		X	X										
Vegetation Index		X	X													
Vegetation Green Fraction		X	X													
Flood/Standing Water		X	X		X									X	X	
Rainfall Potential (no direct use of ABI bands)								X		X	X			X	X	
Rainfall Probability (no direct use of ABI bands)								X		X	X			X	X	
Snow Depth (no direct use of ABI bands)	X	X	X		X	X	X						X			
Sea & Lake Ice: Age (no direct use of ABI bands)		X	X		X									X	X	
Sea & Lake Ice: Concentration		X	X		X									X	X	
Sea & Lake Ice: Motion														X		
Ocean Currents														X		
Ocean Currents: Offshore														X		