GOES-R overview -- The future of U.S. GOES measurements

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and many, many others

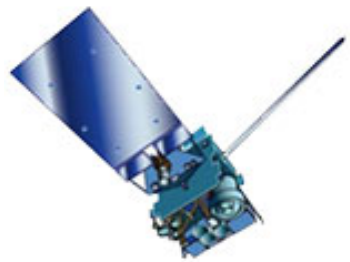
AOS-907 Seminar

September 14, 2005

UW-Madison

Overview

- GOES-N update
- GOES-R Baseline Instruments
- GOES-R simulations
- Possible scan scenarios
- More information



Overview

- GOES-N update
- **GOES-R Baseline Instruments**
- GOES-R simulations
- Possible scan scenarios
- More information

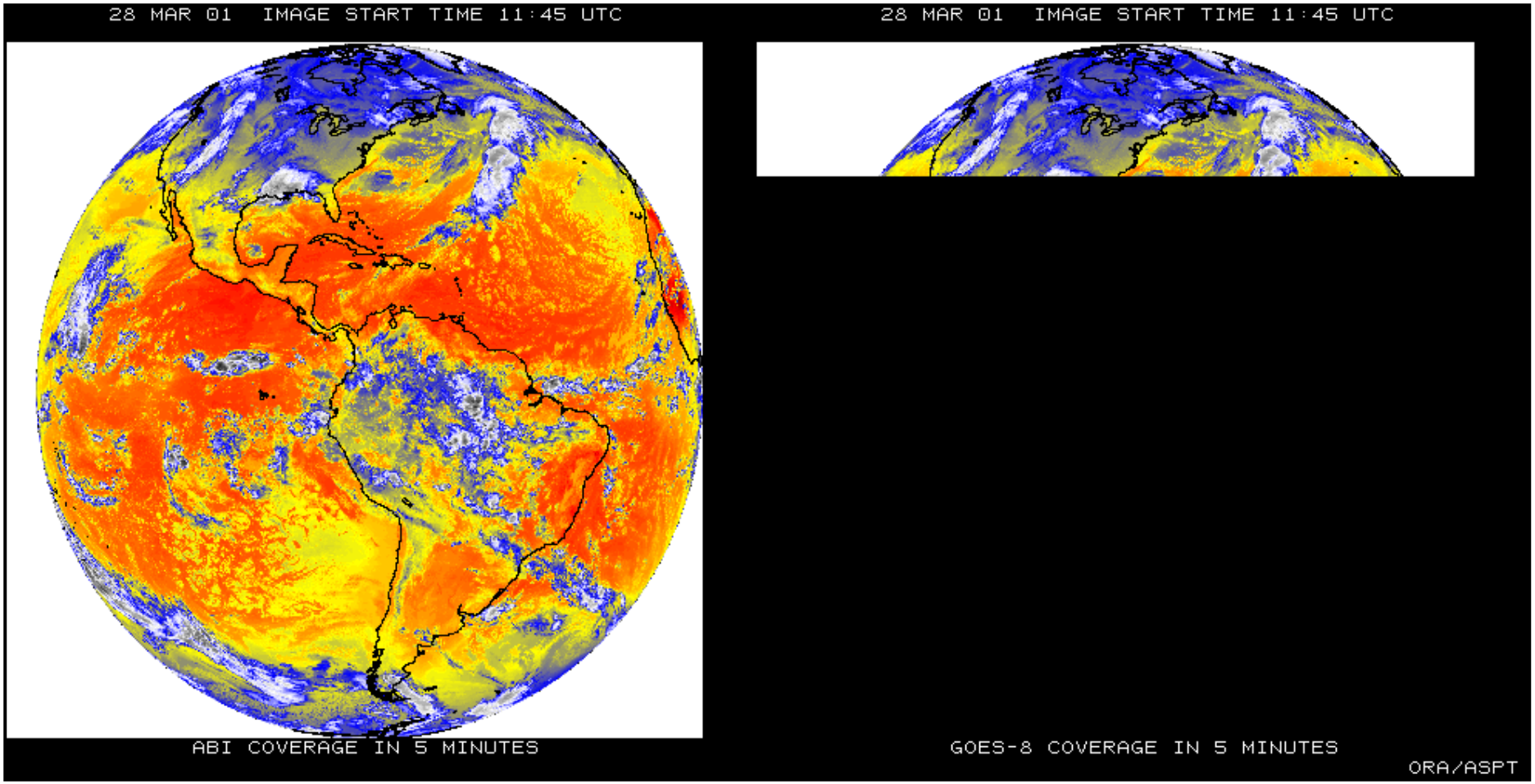
GOES R Baseline Instruments

- **Advanced Baseline Imager (ABI)**
- **Hyperspectral Environmental Suite (HES)**
  - **Disk Sounding**
  - **Severe Weather Mesoscale**
  - **Coastal Waters**
- **Geostationary Lightning Mapper (GLM)**
- Solar Instrument Suite (SIS)
- Space Environment In Situ Suite (SEISS)
- Auxiliary Services

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/nearIR	1.0 km	n/a
Bands (>2 μm)	2 km	Approx. 4 km
Spatial coverage		
Full disk	4 per hour	Every 3 hours
CONUS	12 per hour	~4 per hour
Mesoscale	Every 30 sec	-
Visible		
On-orbit calibration	Yes	No

ABI spatial coverage rate versus the current GOES Imager

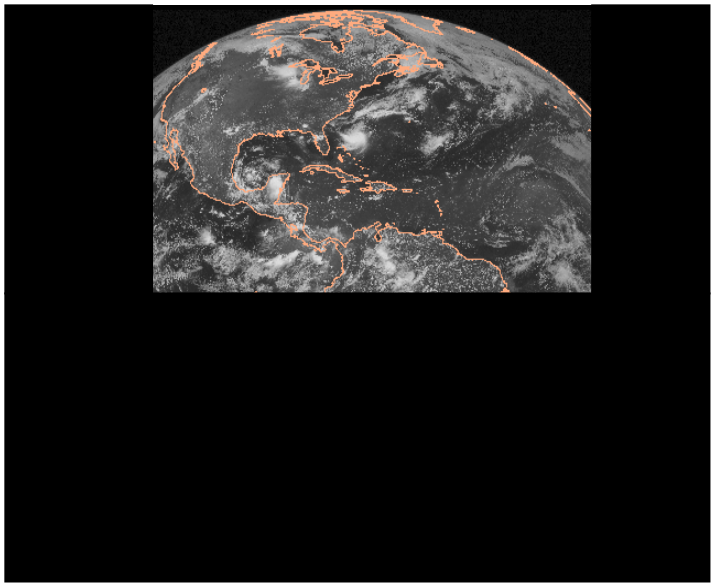


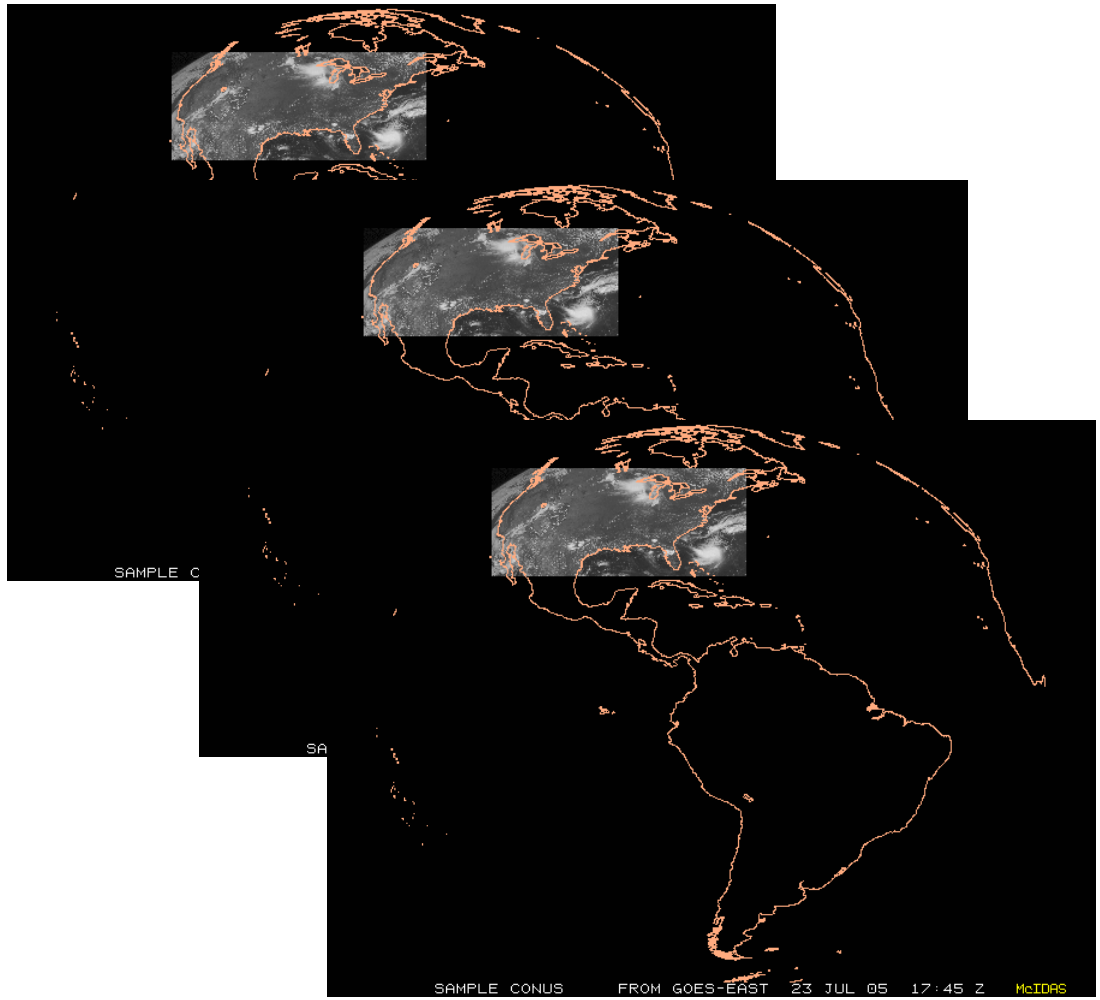
ABI coverage in ~5 minutes Current GOES coverage in 5 minutes

There are two anticipated scan modes for the ABI:

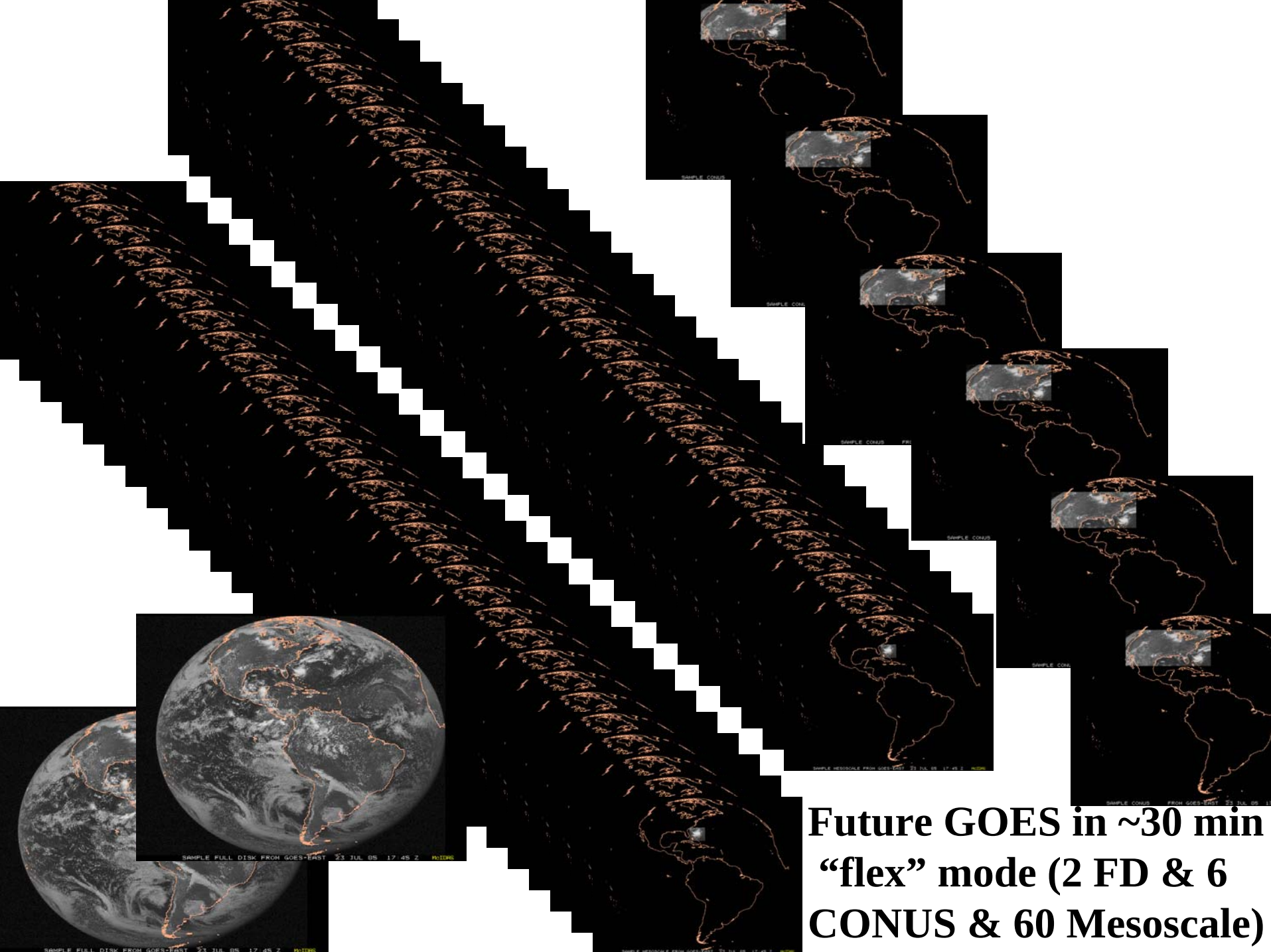
1) full disk images every 15 minutes + CONUS images every 5 minutes + mesoscale.
2) Full disk every 5 minutes.

Current GOES in ~30 minutes (Rapid Scan Operations)



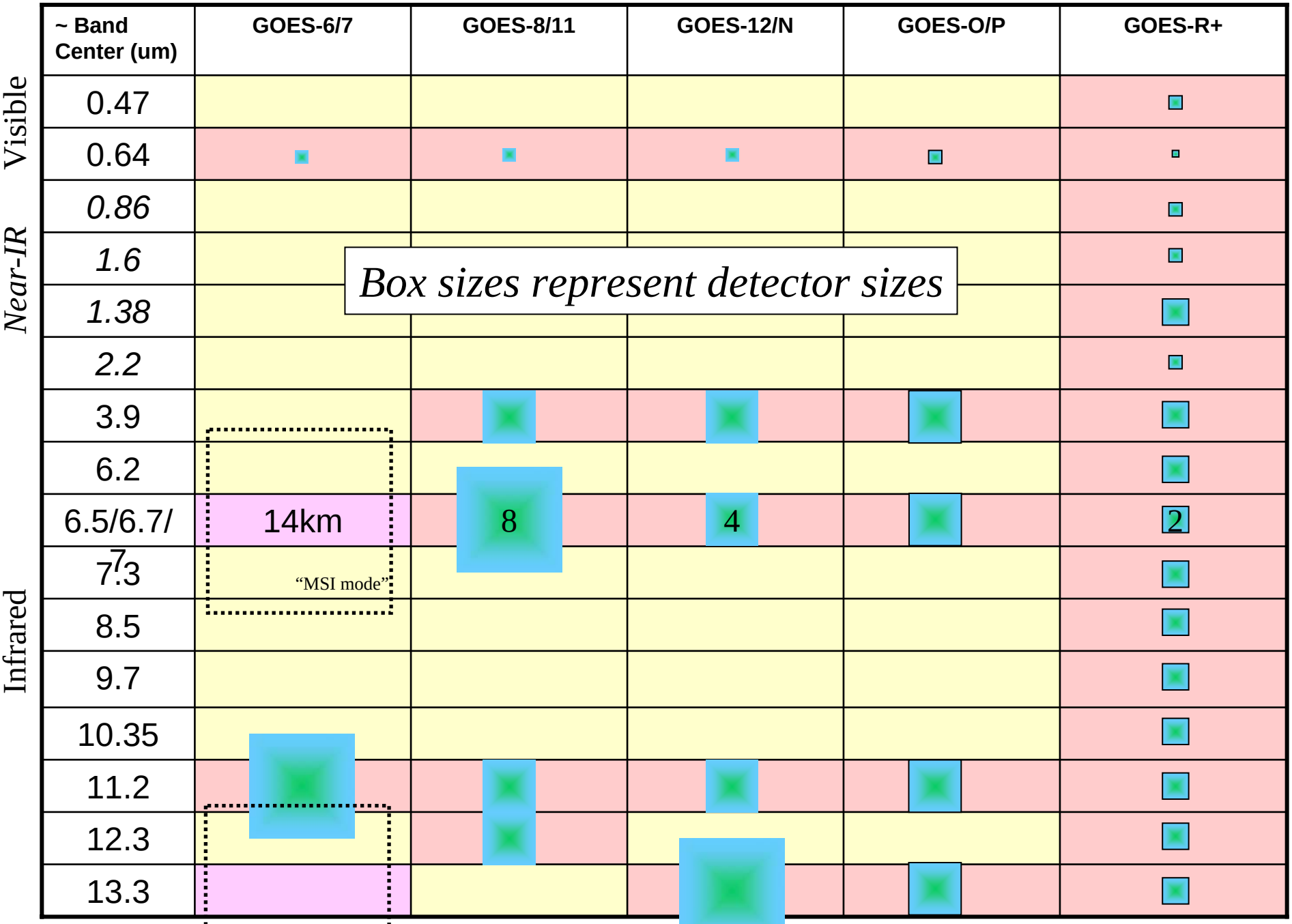


hh:45:00 NORTHERN HEMISPHERE	9:44 min
hh:55:00 CONTINENTAL US (CONUS)	4:43 min
hh:02:11 CONTINENTAL US (CONUS)	4:43 min
hh:10:00 CONTINENTAL US (CONUS)	4:43 min



Future GOES in ~30 min “flex” mode (2 FD & 6 CONUS & 60 Mesoscale)

Approximate spectral and spatial resolutions of US GOES Imagers

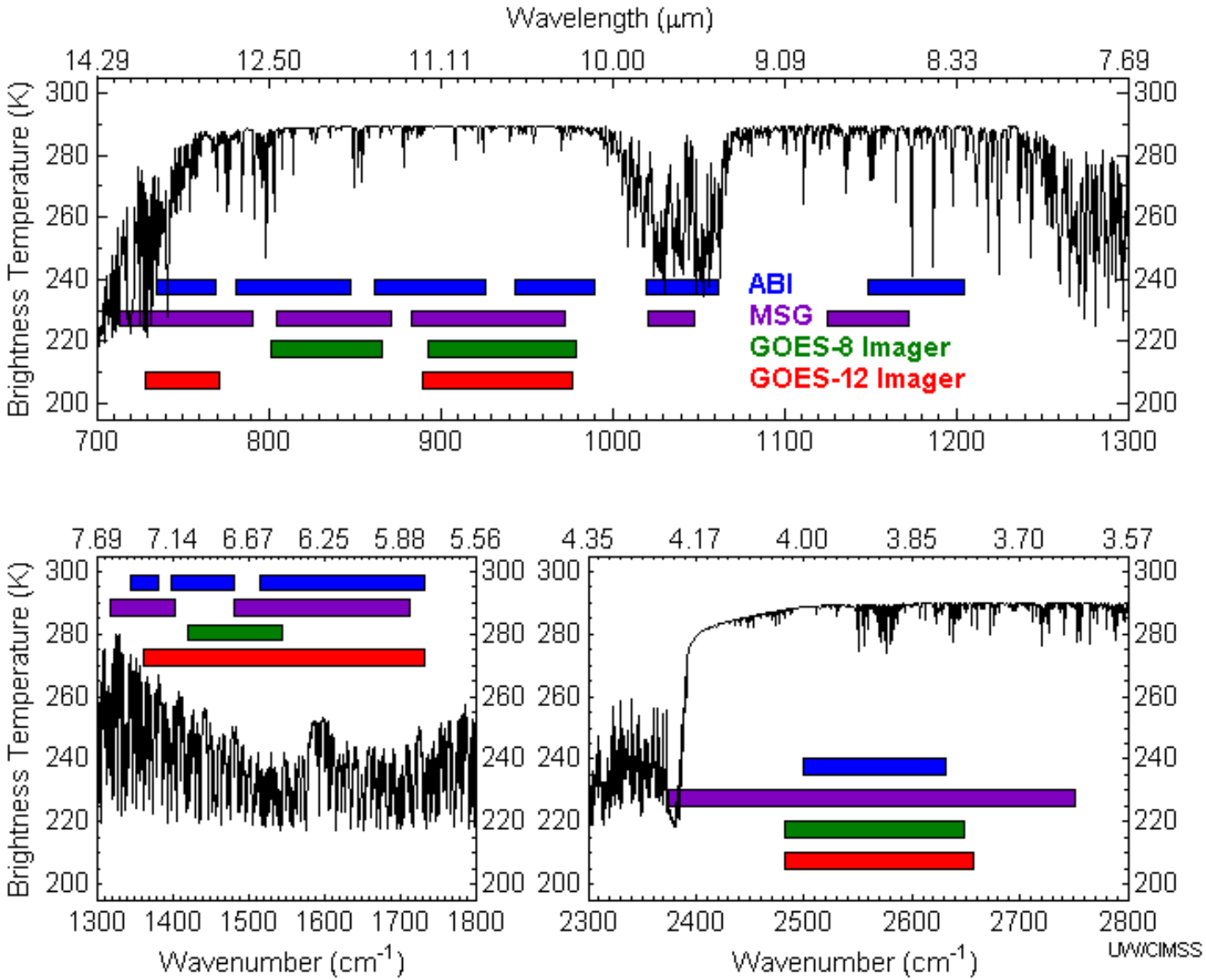


ABI Visible/Near-IR Bands

Future GOES Imager (ABI) Band	Wavelength Range (µm)	Central Wavelength (µm)	Sample Objective(s)
1	0.45-0.49	**0.47**	Daytime aerosol-over-land, Color imagery, etc.
2	0.59-0.69	**0.64**	Daytime clouds fog, insolation, winds, etc.
3	0.846-0.885	**0.865**	Daytime vegetation & aerosol-over-water, winds, etc.
4	1.371-1.386	**1.378**	Daytime cirrus cloud, etc.
5	1.58-1.64	**1.61**	Daytime cloud water, snow, etc.
6	2.225 - 2.275	**2.25**	Day land/cloud properties, particle size, vegetation, etc.

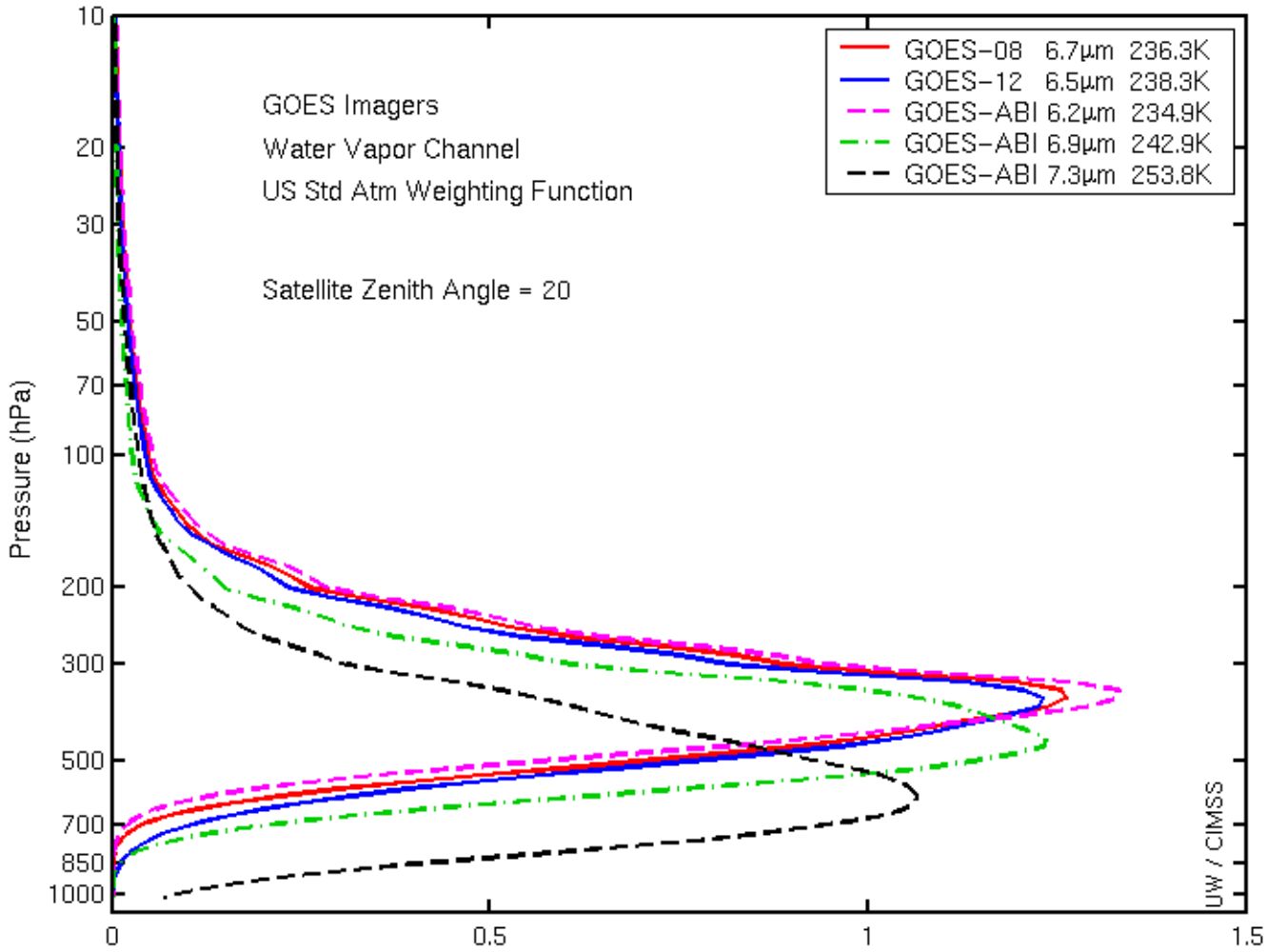
ABI IR Bands

Future GOES Imager (ABI) Band	Wavelength Range (μm)	Central Wavelength (μm)	Sample Objective(s)
7	3.80-4.00	**3.90**	Sfc. & cloud/fog at night, fire, etc.
8	5.77-6.6	**6.19**	High-level atmospheric water vapor, winds, rainfall, etc.
9	6.75-7.15	**6.95**	Mid-level atmospheric water vapor, winds, rainfall, etc.
10	7.24-7.44	**7.34**	Lower-level water vapor, winds & SO_2, etc.
11	8.3-8.7	**8.5**	Total water for stability, cloud phase, dust, SO_2, etc.
12	9.42-9.8	**9.61**	Total ozone, turbulence, winds
13	10.1-10.6	**10.35**	Surface properties, low-level moisture & cloud, etc.
14	10.8-11.6	**11.2**	Total water for SST, clouds, rainfall, etc.
15	11.8-12.8	**12.3**	Total water & ash, SST, etc.
16	13.0-13.6	**13.3**	Air temp & cloud heights and amounts, etc.

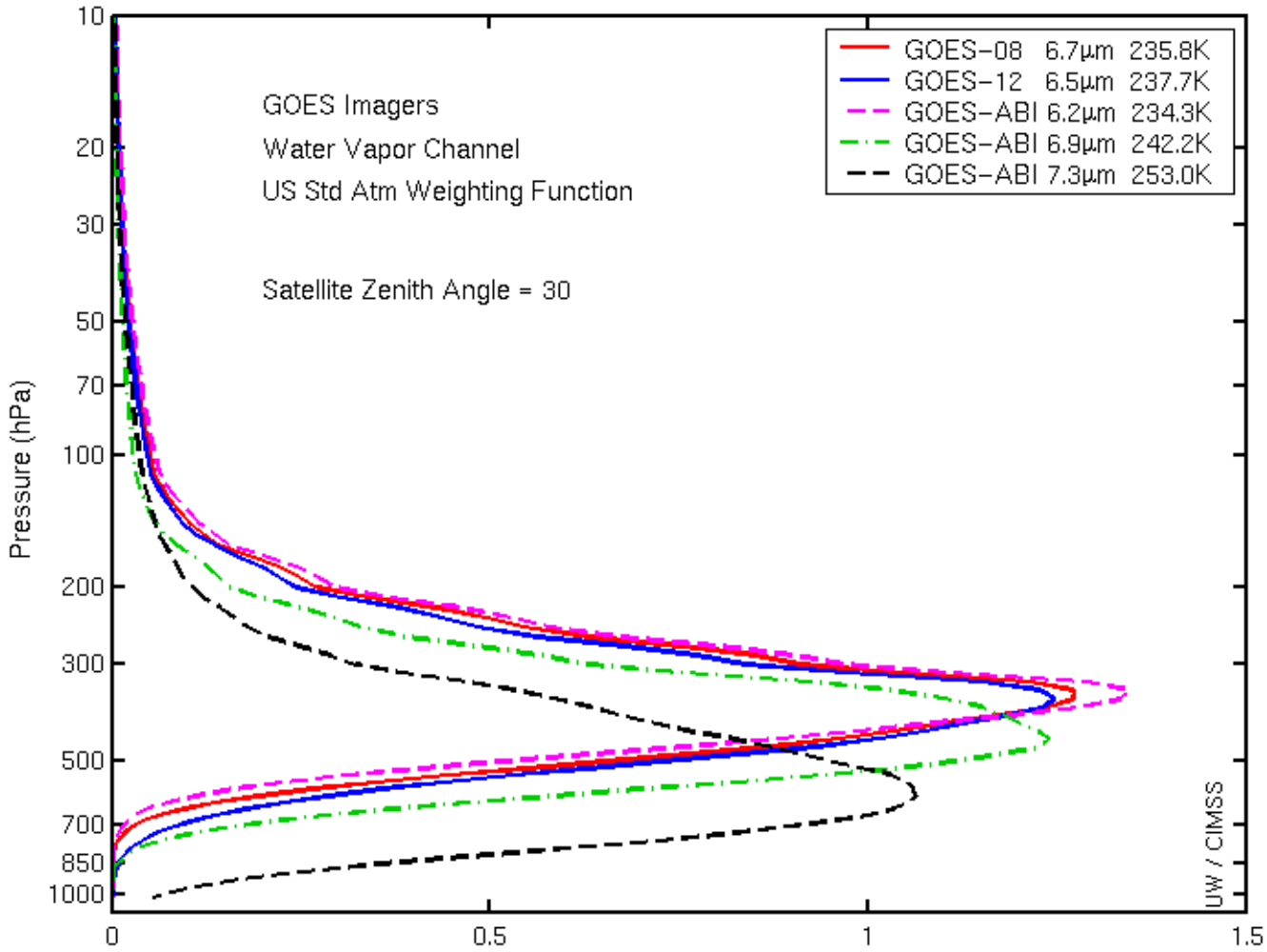


While there are differences, there are also many similarities for the spectral bands on MET-8 and the Advanced Baseline Imager (ABI). Both the MET-8 and ABI have many more bands than the current operational imagers.

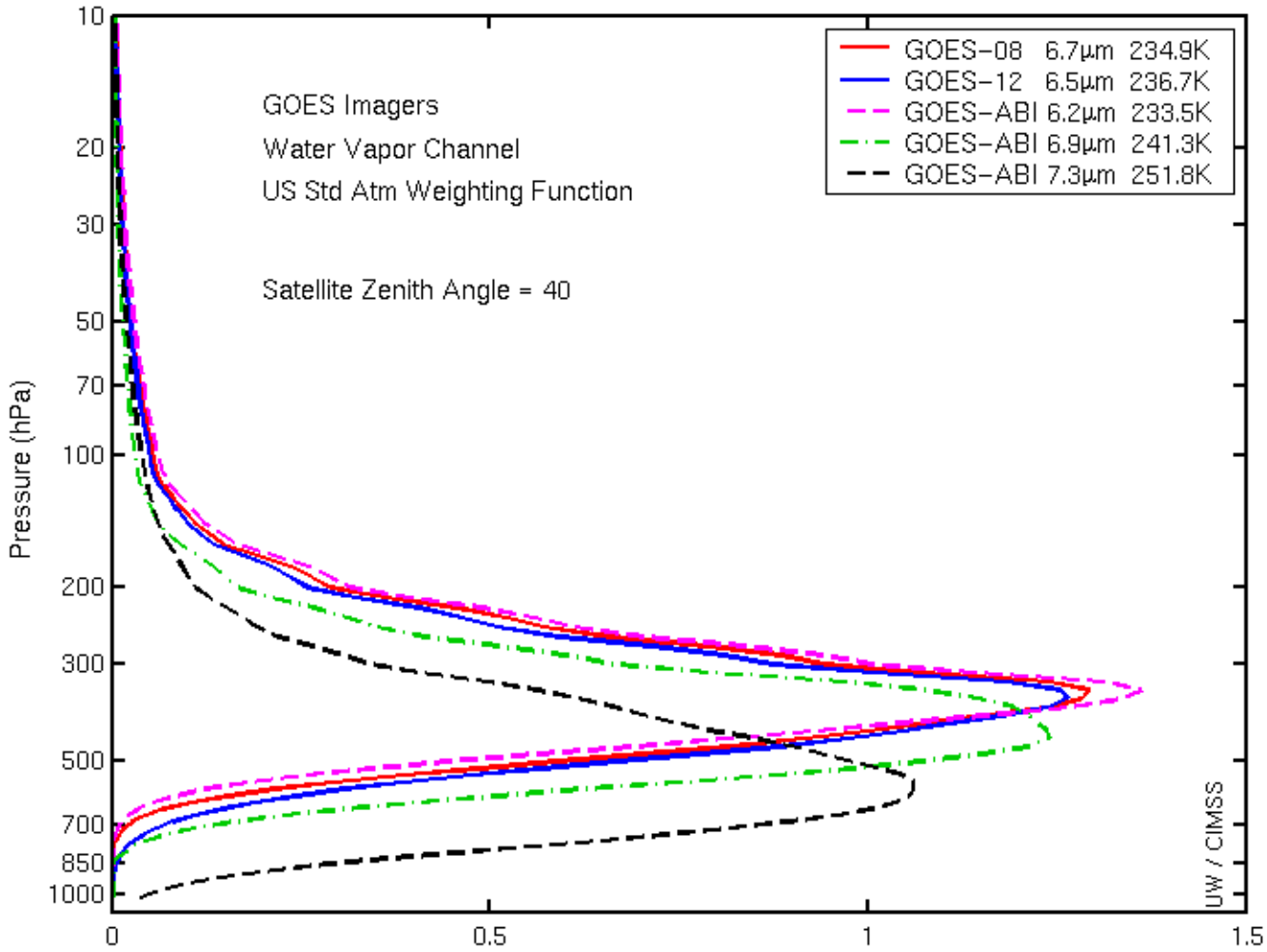
ABI and GOES Imager WF by Zenith Angle (20 deg.)



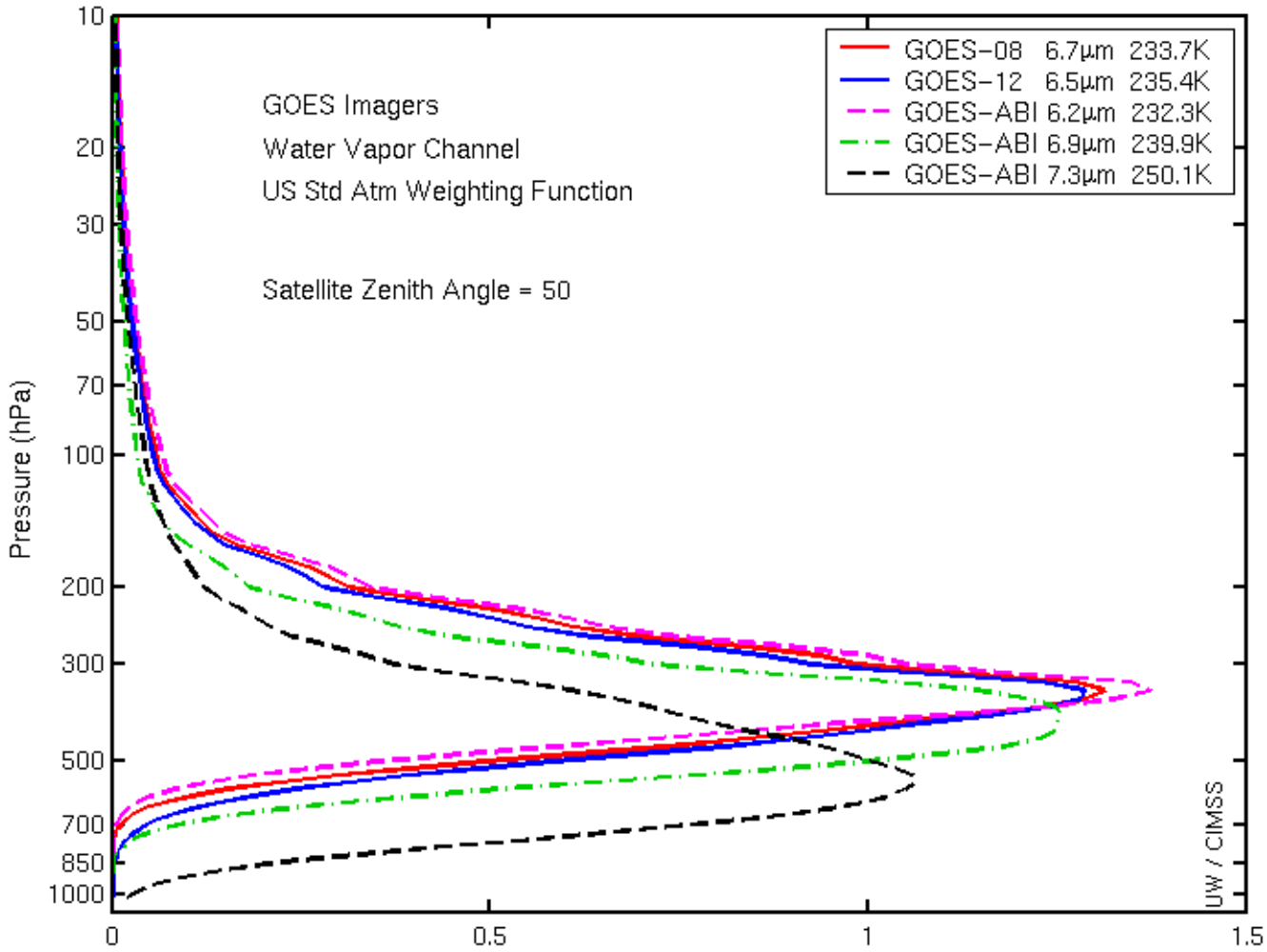
ABI and GOES Imager WF by Zenith Angle (30 deg.)



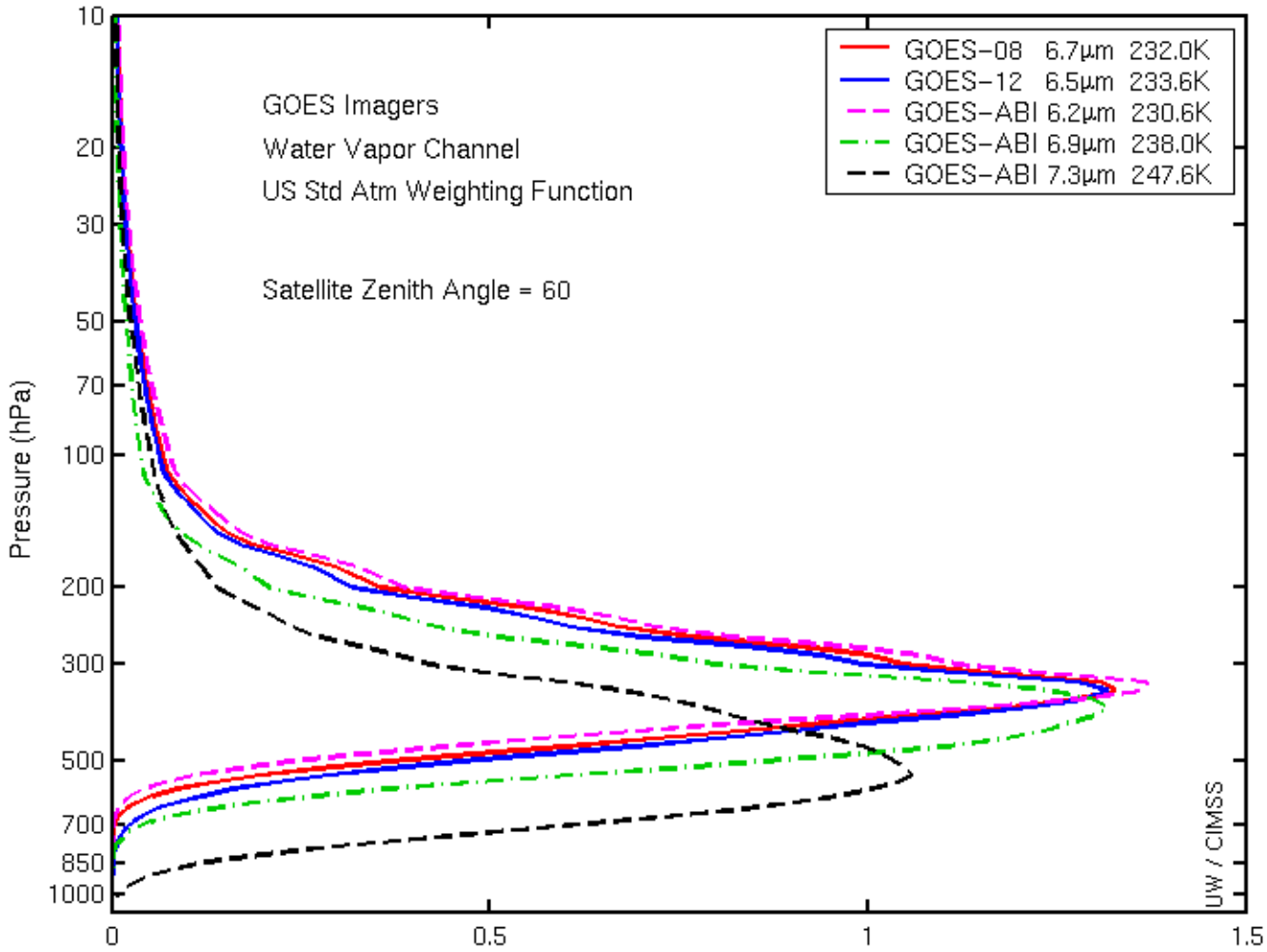
ABI and GOES Imager WF by Zenith Angle (40 deg.)



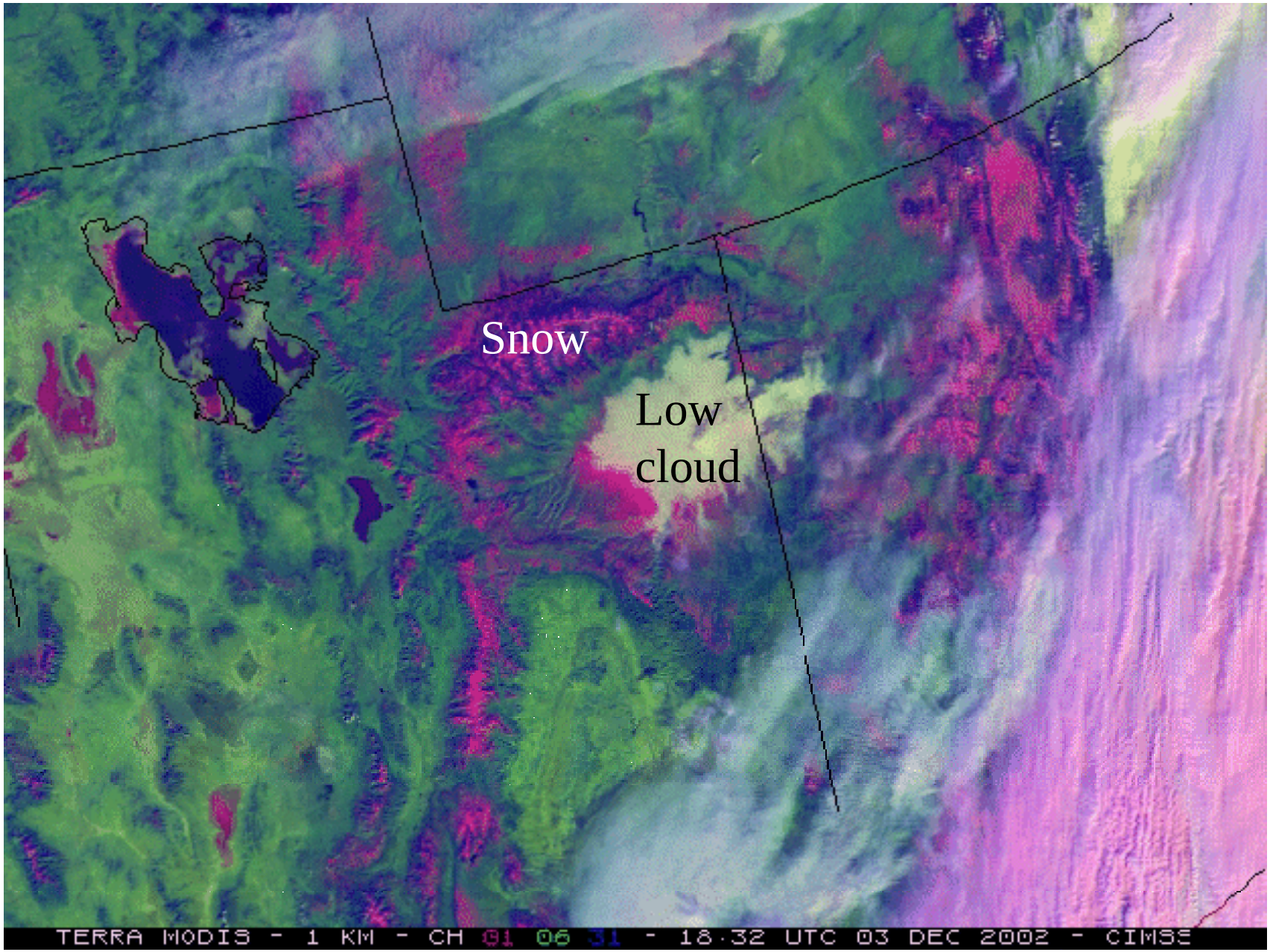
ABI and GOES Imager WF by Zenith Angle (50 deg.)



ABI and GOES Imager WF by Zenith Angle (60 deg.)

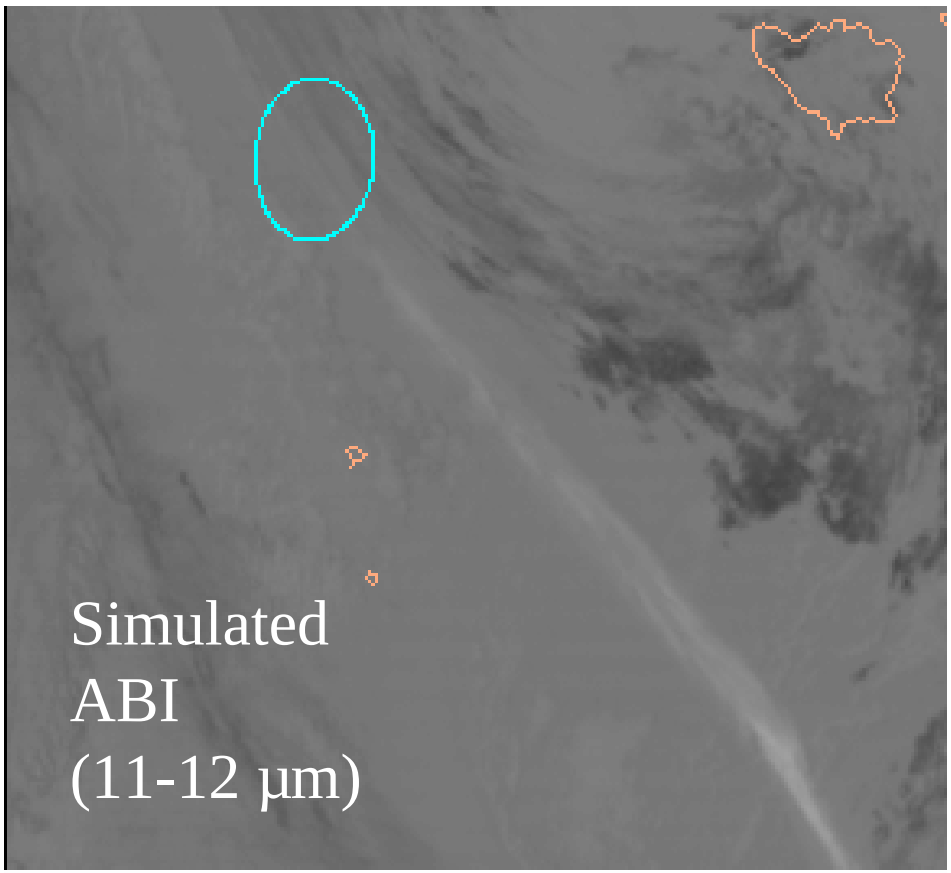


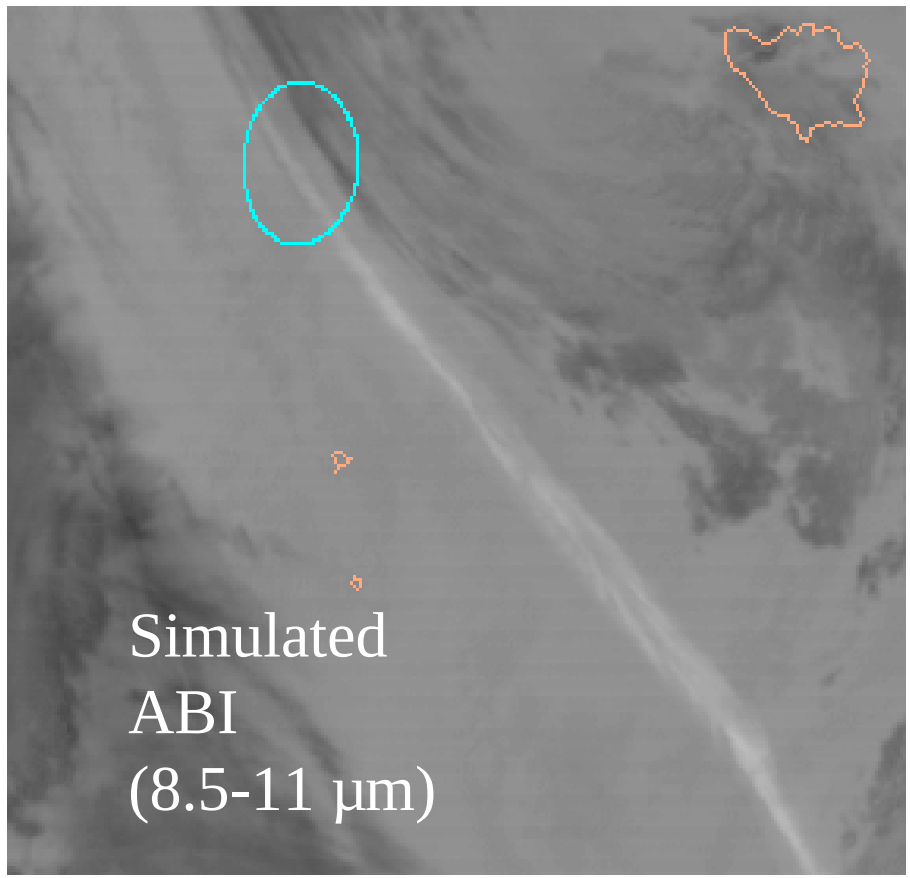
Three-color composite (0.64, 1.6 and 11 μm) shows the low cloud over the snow and the water versus ice clouds.



Volcanic Ash Plume: 11-12 and 8.5-11 µm images

One day after the Mt. Cleveland eruption
20 February 2001, 0845 UTC



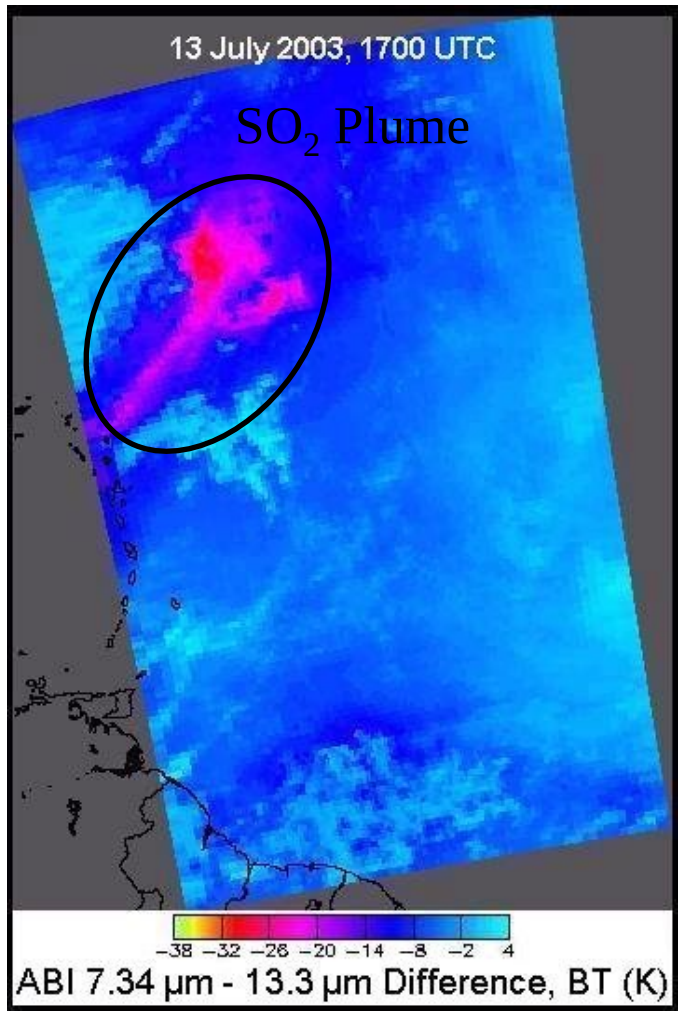


GOES-R ABI detects SO2 plumes

Water Vapor Band Difference convolved from AIRS data sees SO_2 plume from Montserrat Island, West Indies

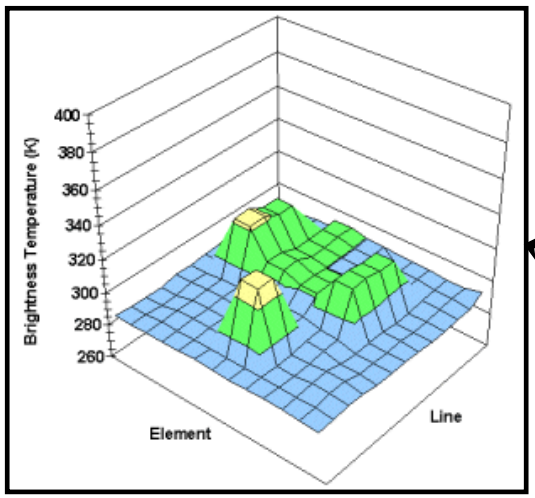
Current GOES Imager
No skill in monitoring

Current GOES Imager can not detect SO_2

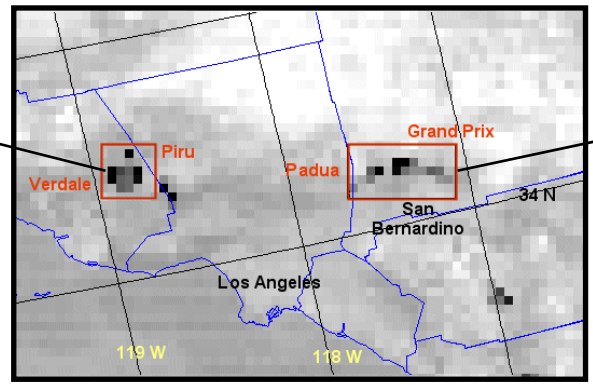


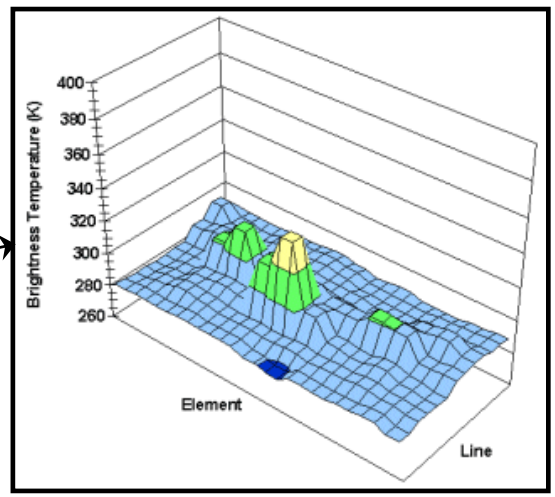
ABI 7.34 µm – 13.3 µm

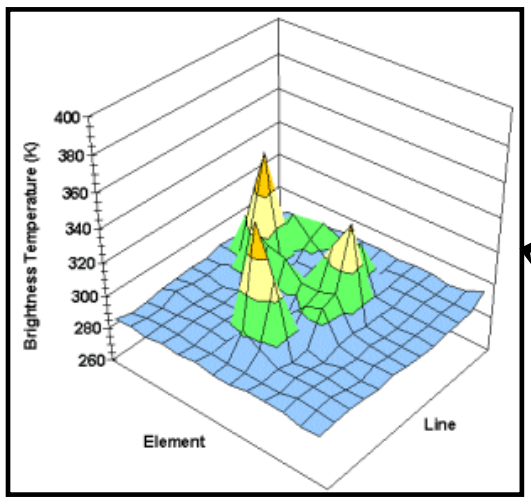
GOES-R and GOES-I/M Simulations of Southern California Fires



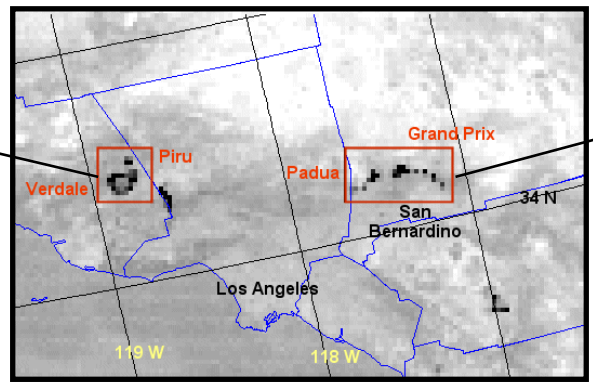
GOES-12 Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03 Time: 09:50 UTC

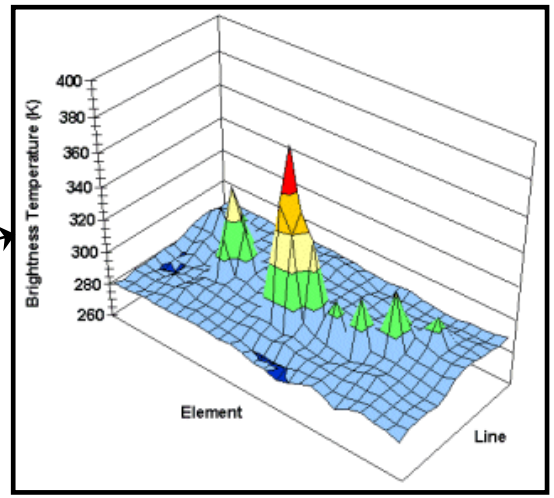






GOES-R Simulated 3.9 micron Data
Padua/Grand Prix Fires
Date: 27-Oct-03 Time: 09:50 UTC





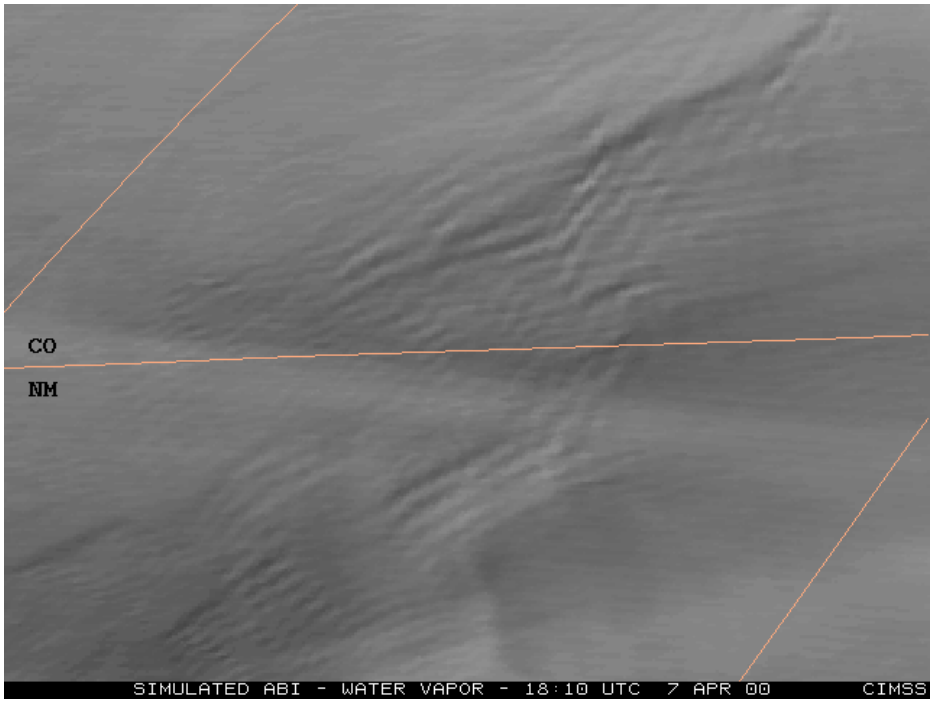
Brightness Temperature (K)

260-280 | 280-300 | 300-320 | 320-340 | 340-360 | 360-380 | 380-400

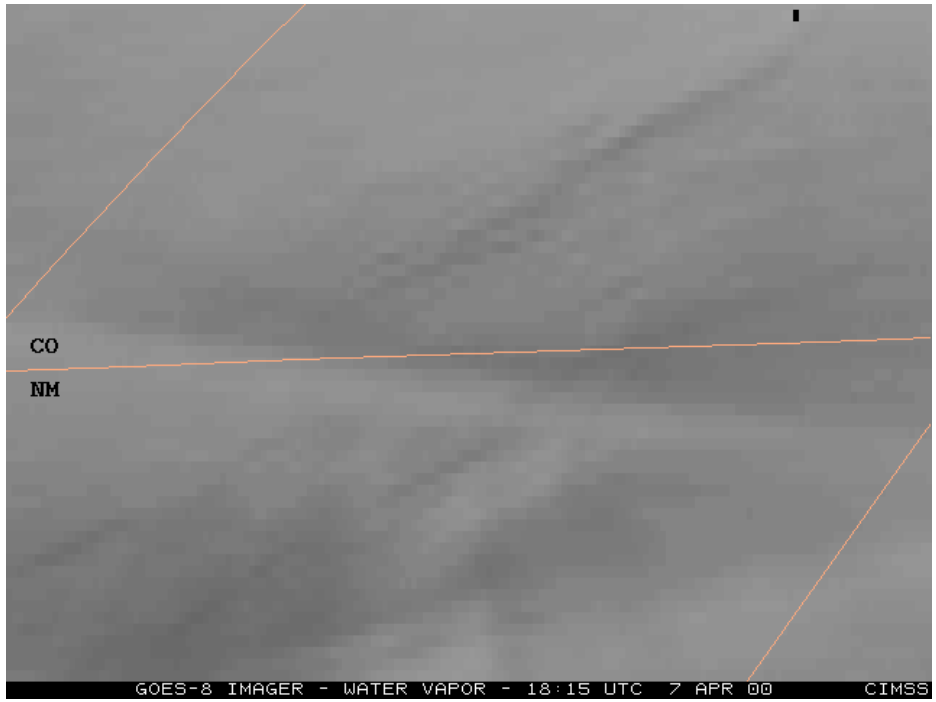
Mountain Waves in WV channel (6.7 µm)

7 April 2000, 1815 UTC

Simulated ABI



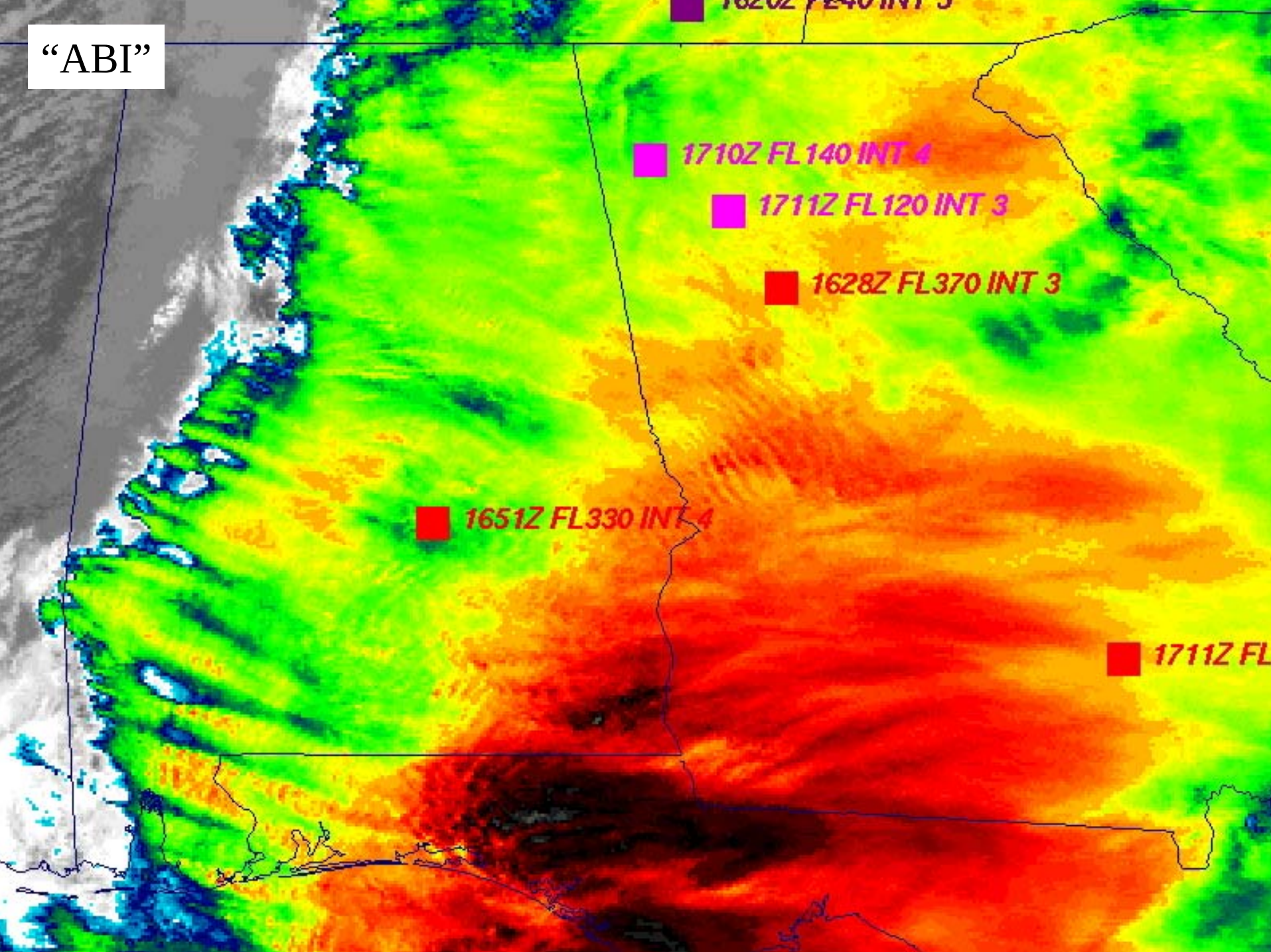
Actual GOES-8

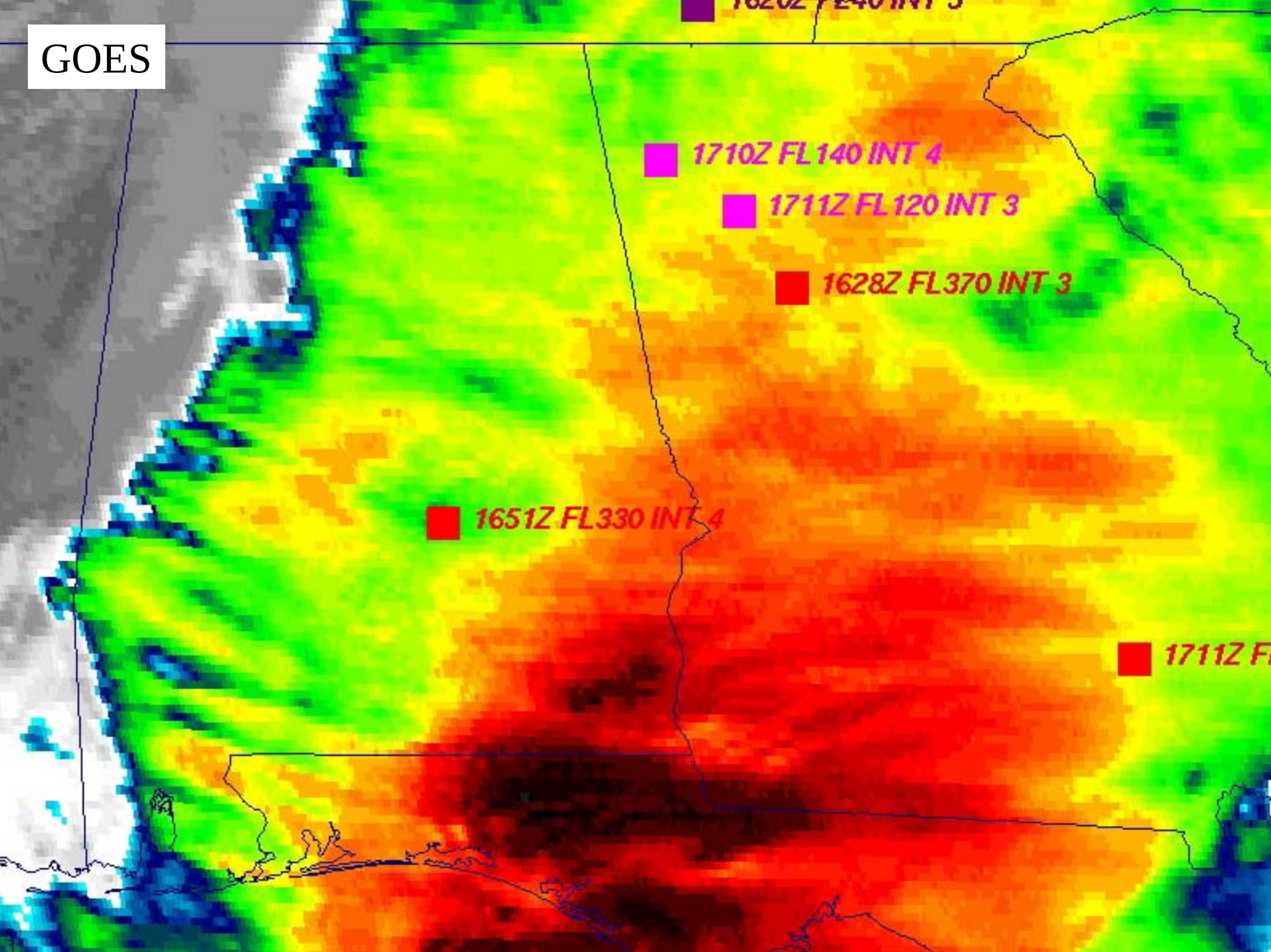


Mountain waves over Colorado and New Mexico were induced by strong northwesterly flow associated with a pair of upper-tropospheric jet streaks moving across the elevated terrain of the southern and central Rocky Mountains. The mountain waves appear more well-defined over Colorado; in fact, several aircraft reported moderate to severe turbulence over that region.

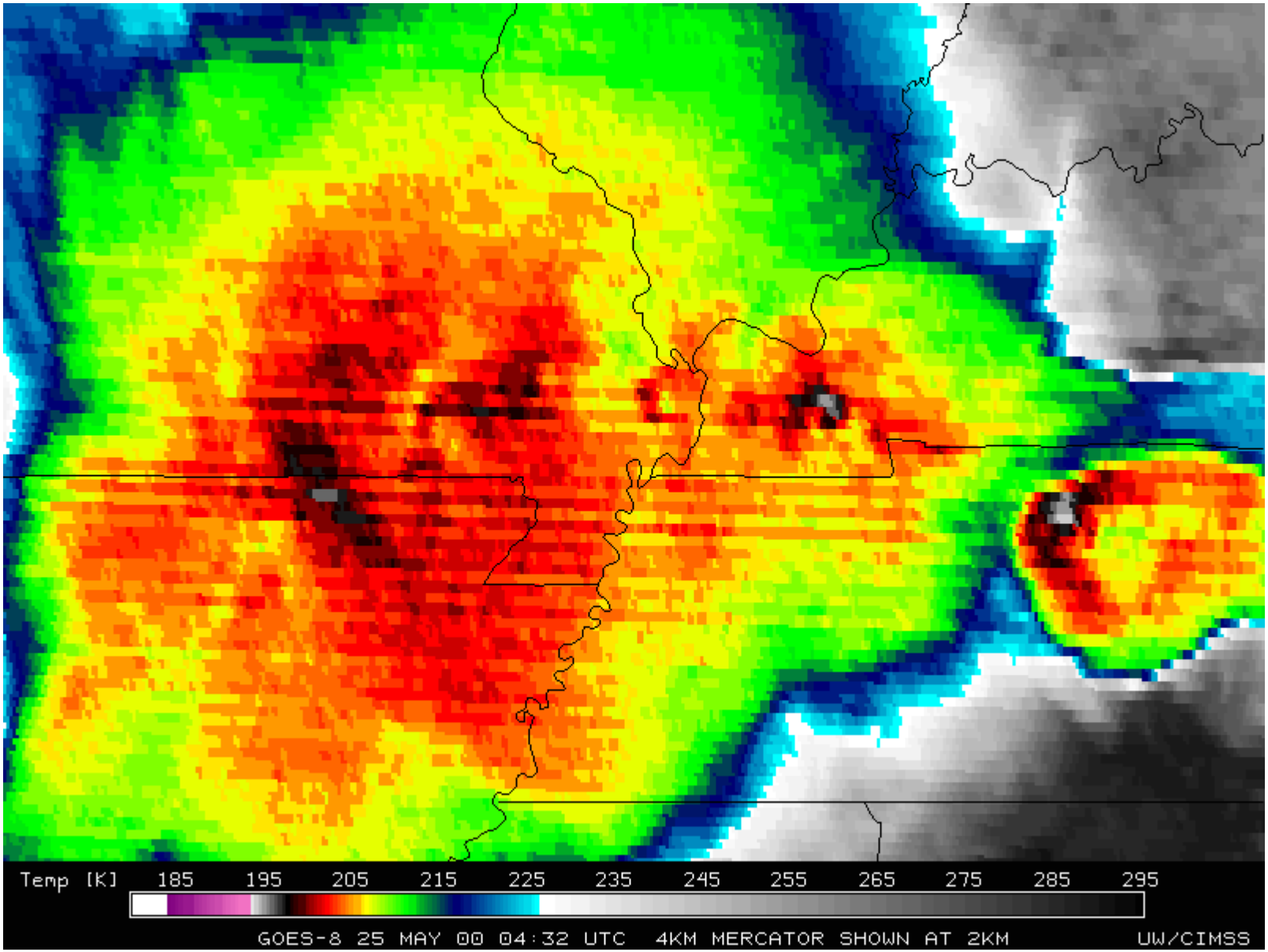
Both images are shown in GOES projection.

UW/CIMSS


“ABI”
1710Z FL140 INT 4
1711Z FL120 INT 3
1628Z FL370 INT 3
1651Z FL330 INT 4
1711Z FL

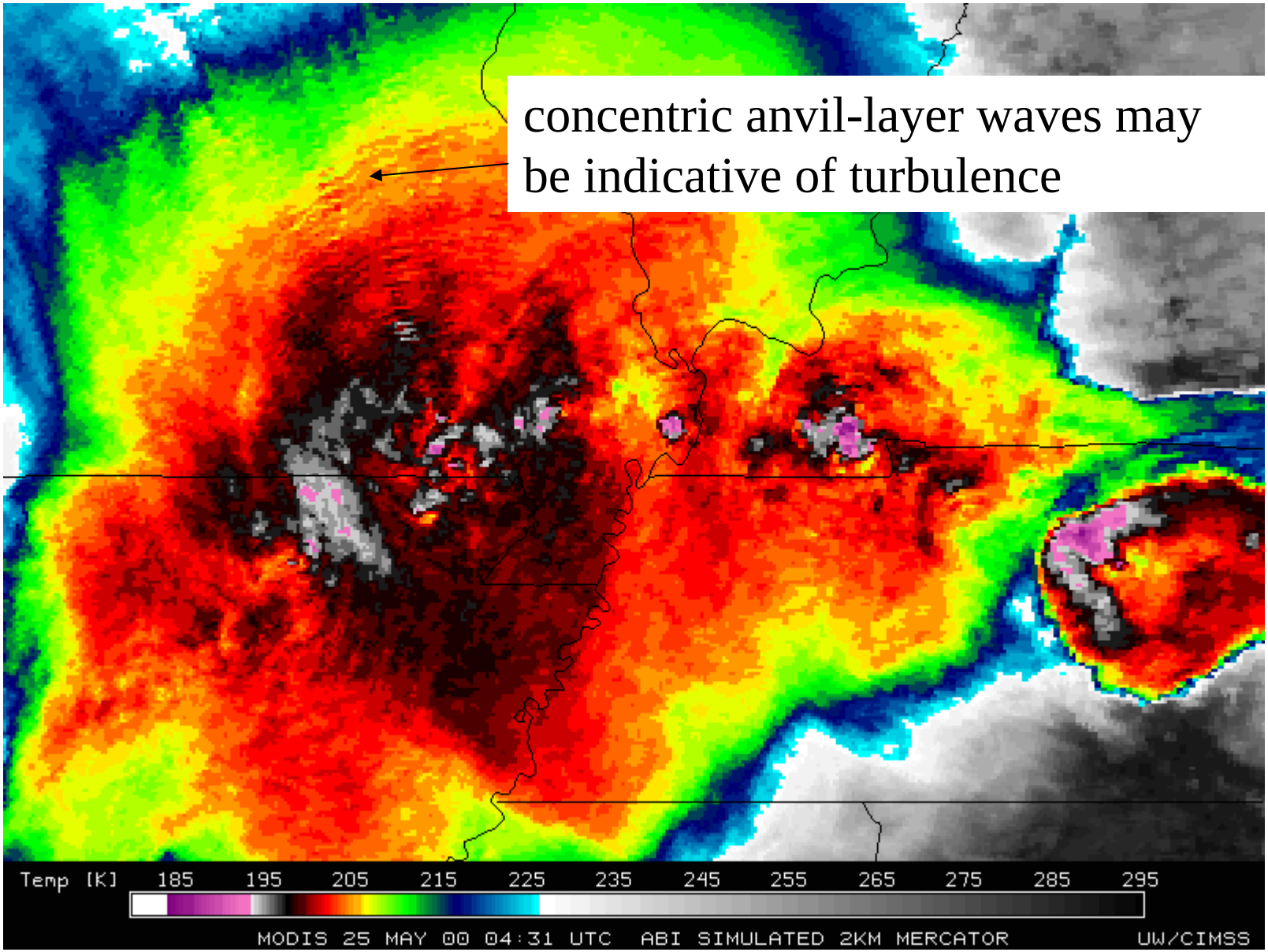

GOES
1710Z FL140 INT 4
1711Z FL120 INT 3
1628Z FL370 INT 3
1651Z FL330 INT 4
1711Z F

GOES-8



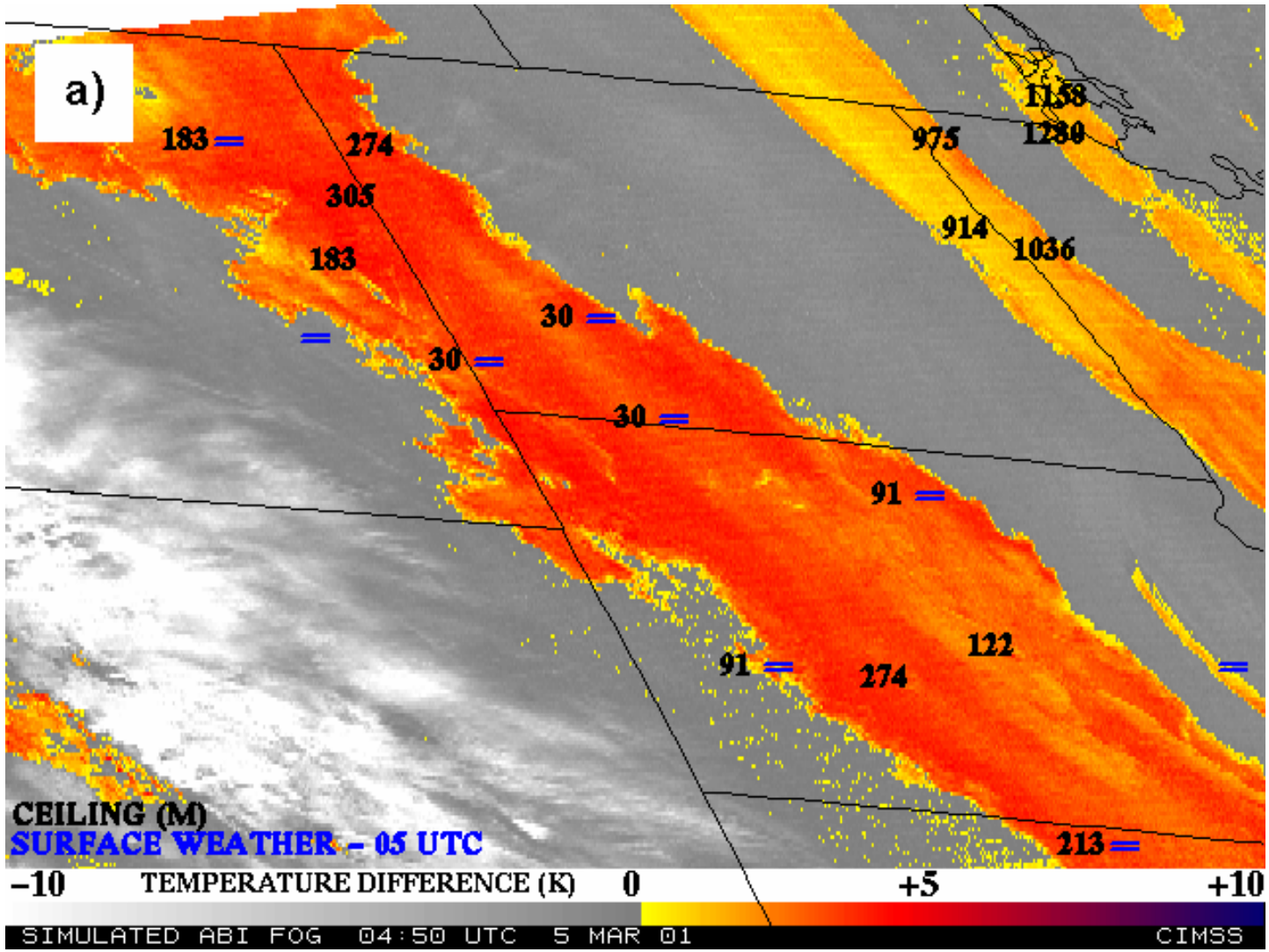
Enhanced “V”: IR window May 25, 2000

“ABI” (simulated from MODIS)



Enhanced “V”: IR window May 25, 2000

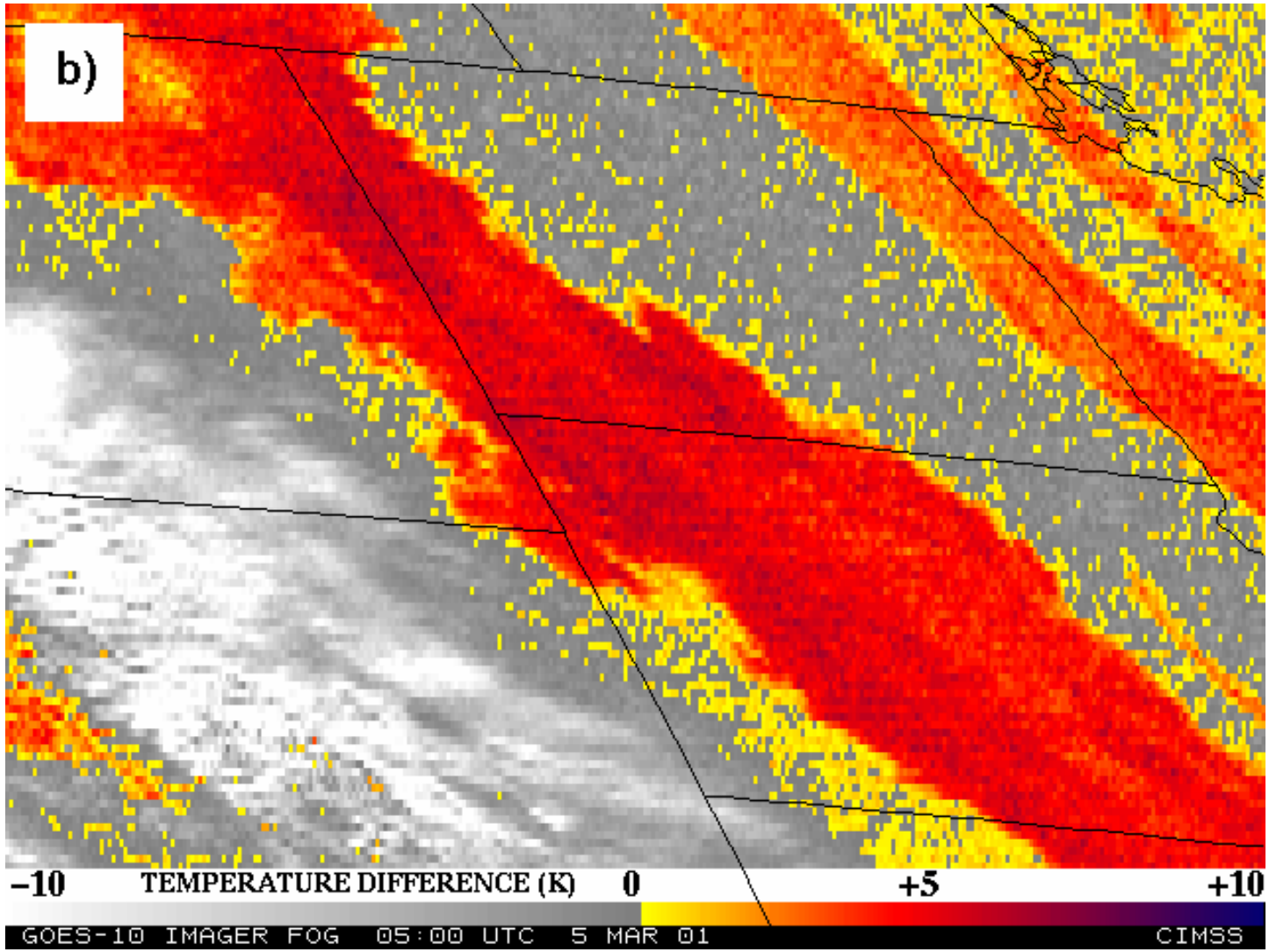
5 March 2001 - Nocturnal Fog/Stratus Over the Northern Plains



"ABI" 4 minus 11 μm Difference

ABI image (from MODIS) shows greater detail in structure of fog.

5 March 2001 - Nocturnal Fog/Stratus Over the Northern Plains



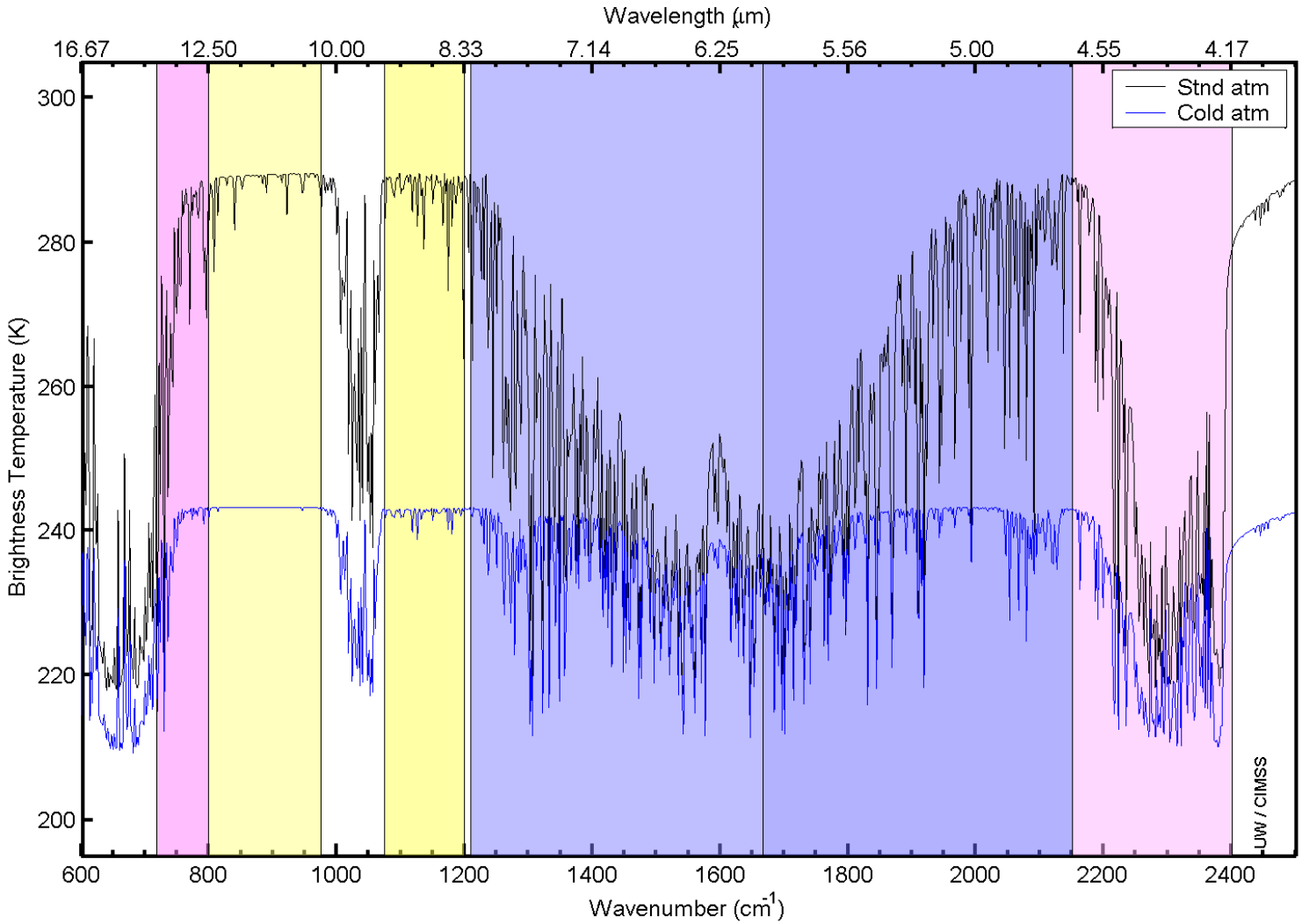
GOES-10 4 minus 11 μm Difference

ABI image (from MODIS) shows greater detail in structure of fog.

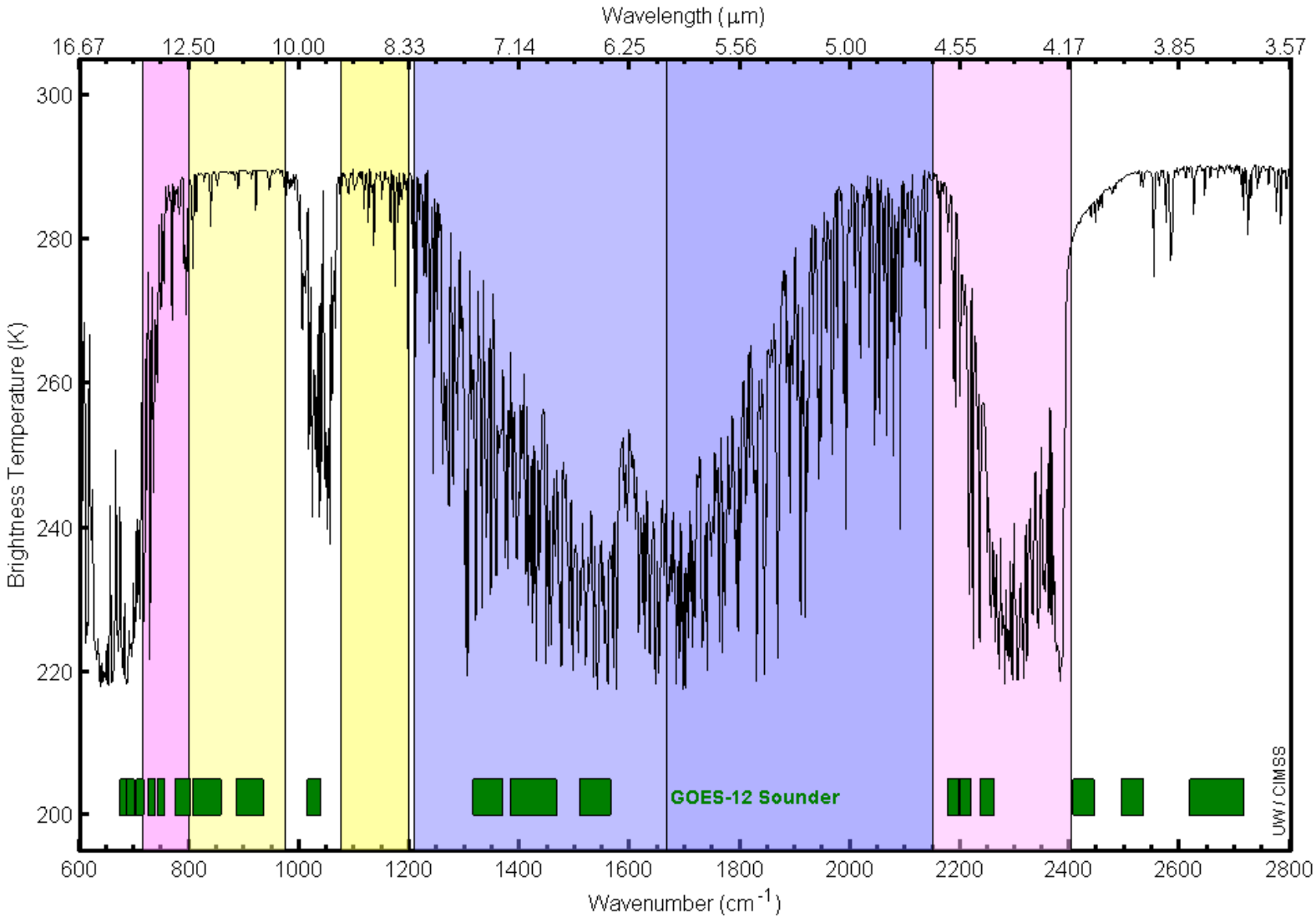
Sounder Comparison (GOES-Current to HES-Req)

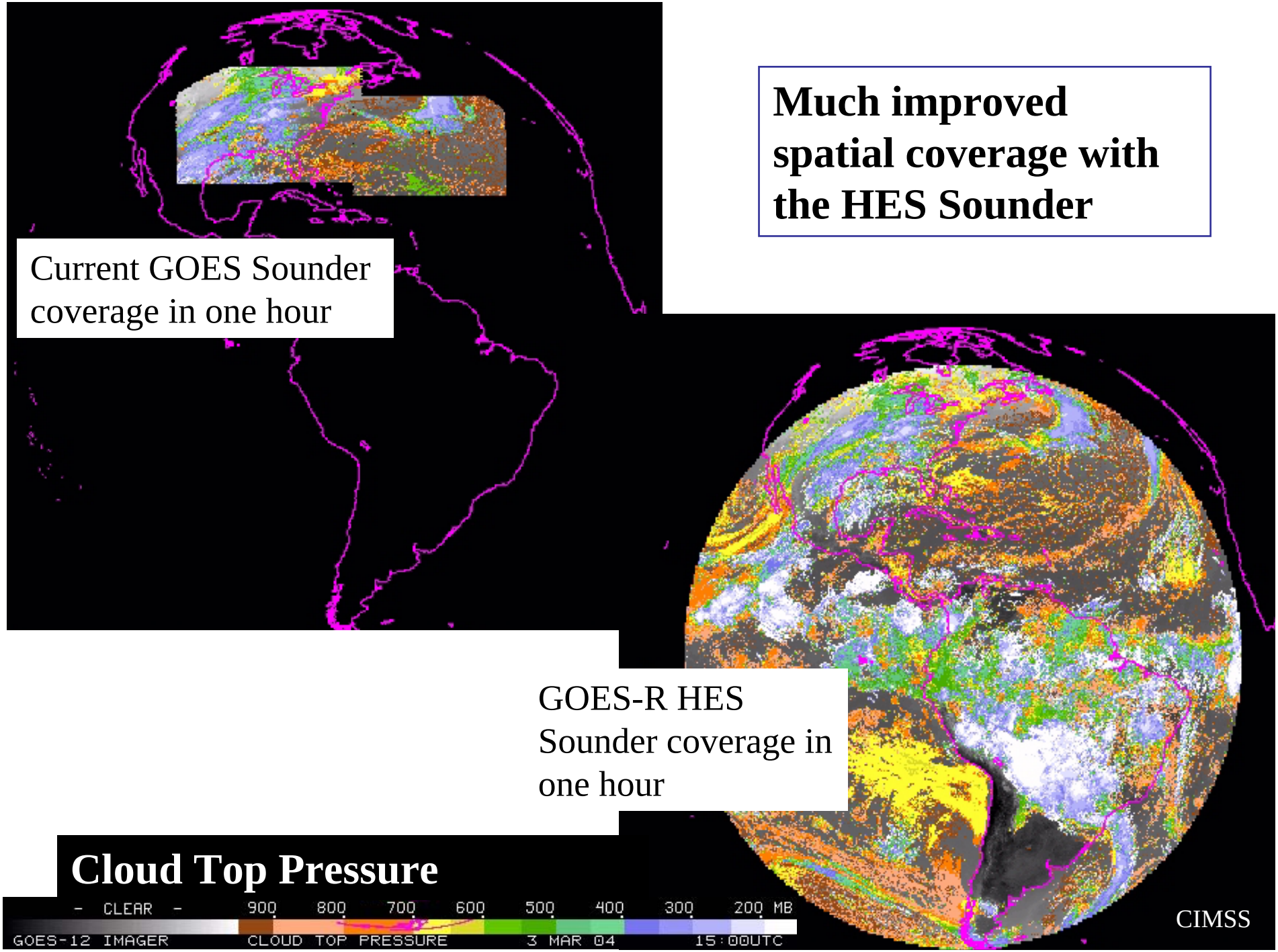
	Current	Requirement
Coverage Rate	CONUS/hr	Sounding Disk/hr
Horizontal Resolution		
- Sampling Distance	10 km	10 km
- Individual Sounding	30-50 km	10 km
Vertical resolution	~3 km	1 km
Accuracy		
Temperature	2 deg. K	1 deg. K
Relative Humidity	20%	10%

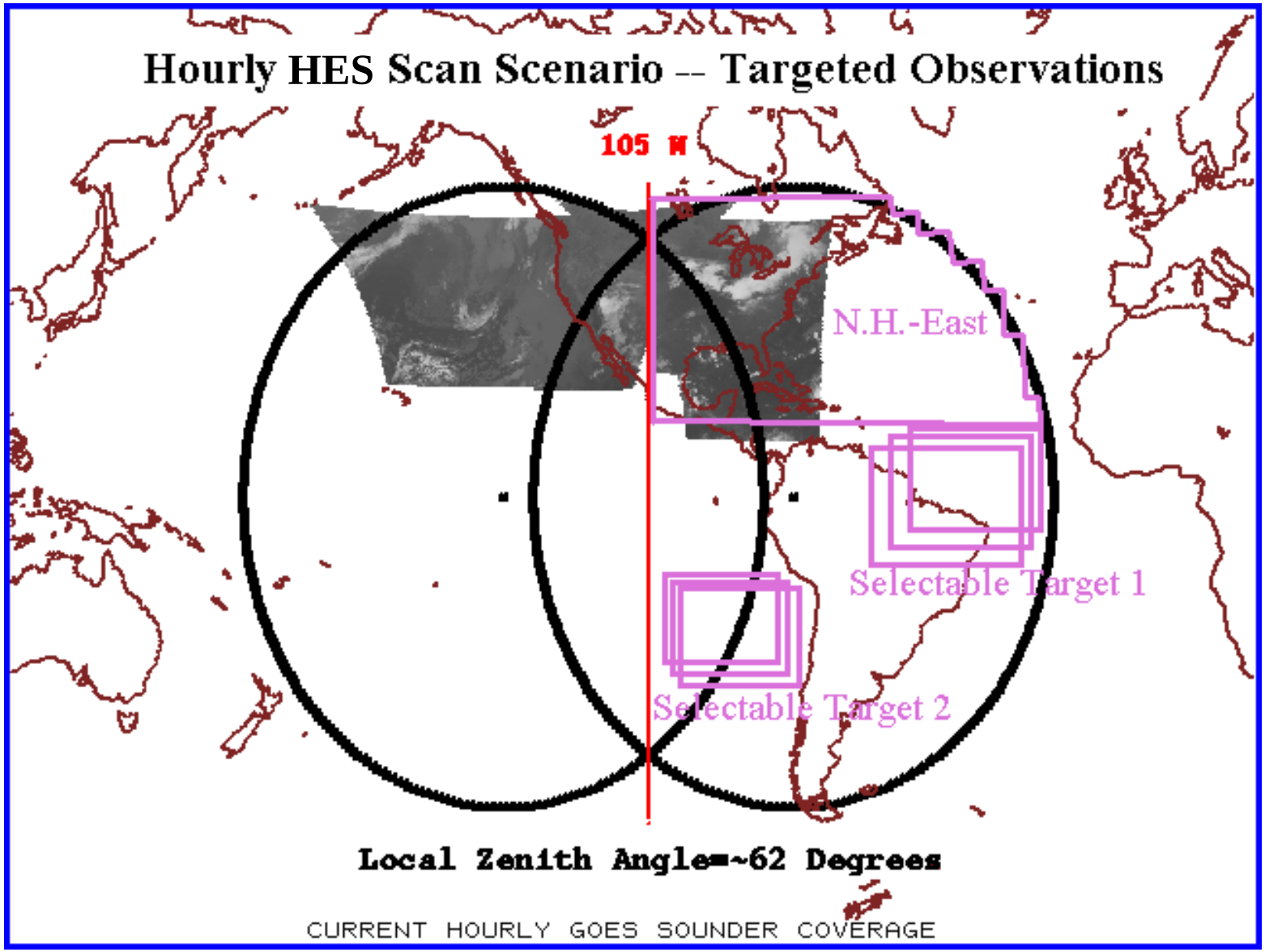
HES spectral coverage



HES spectral coverage

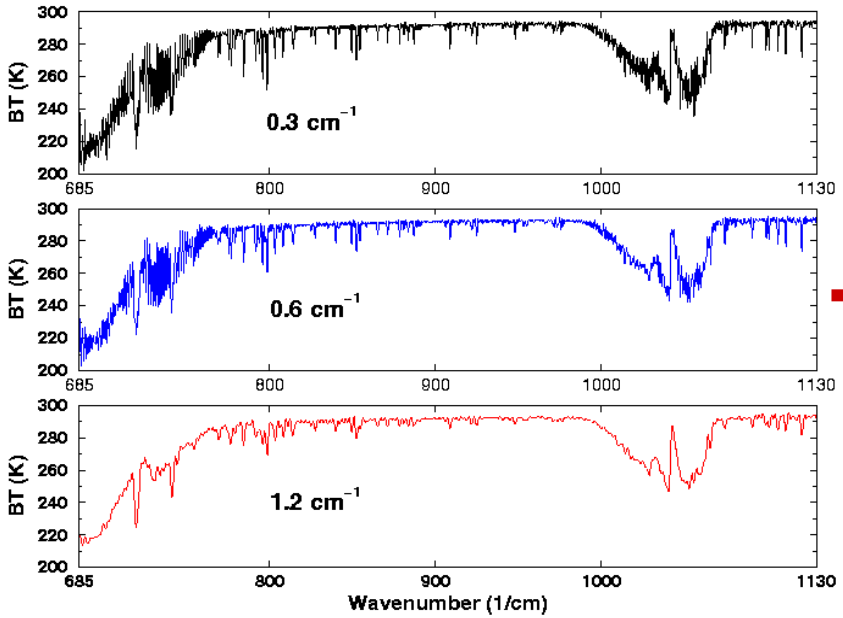



Much improved spatial coverage with the HES Sounder
Current GOES Sounder coverage in one hour
GOES-R HES Sounder coverage in one hour
Cloud Top Pressure
- CLEAR -
900
800
700
600
500
400
300
200 MB
GOES-12 IMAGER
CLOUD TOP PRESSURE
3 MAR 04
15:00UTC
CIMSS

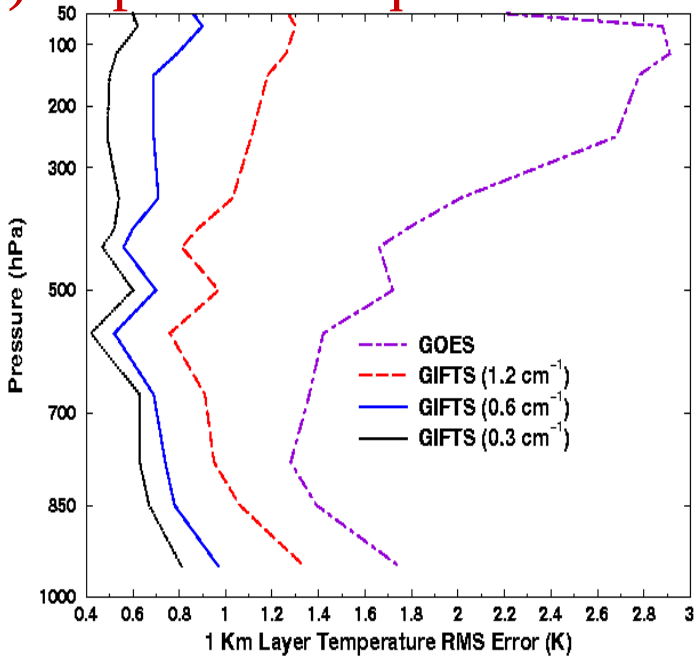


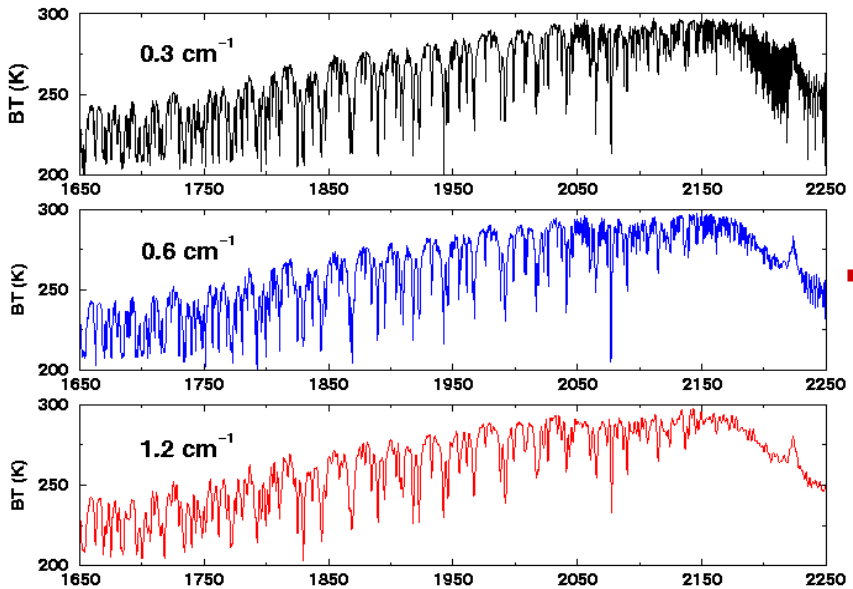
Targeted observations -- look where we need the information

Spectral resolution (0.3, 0.6, 1.2 cm**-1) impact on T/q retrieval

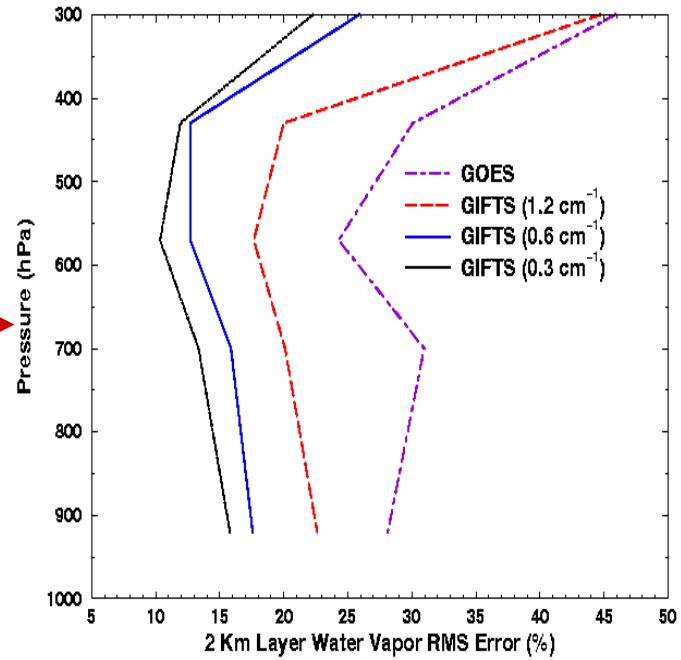


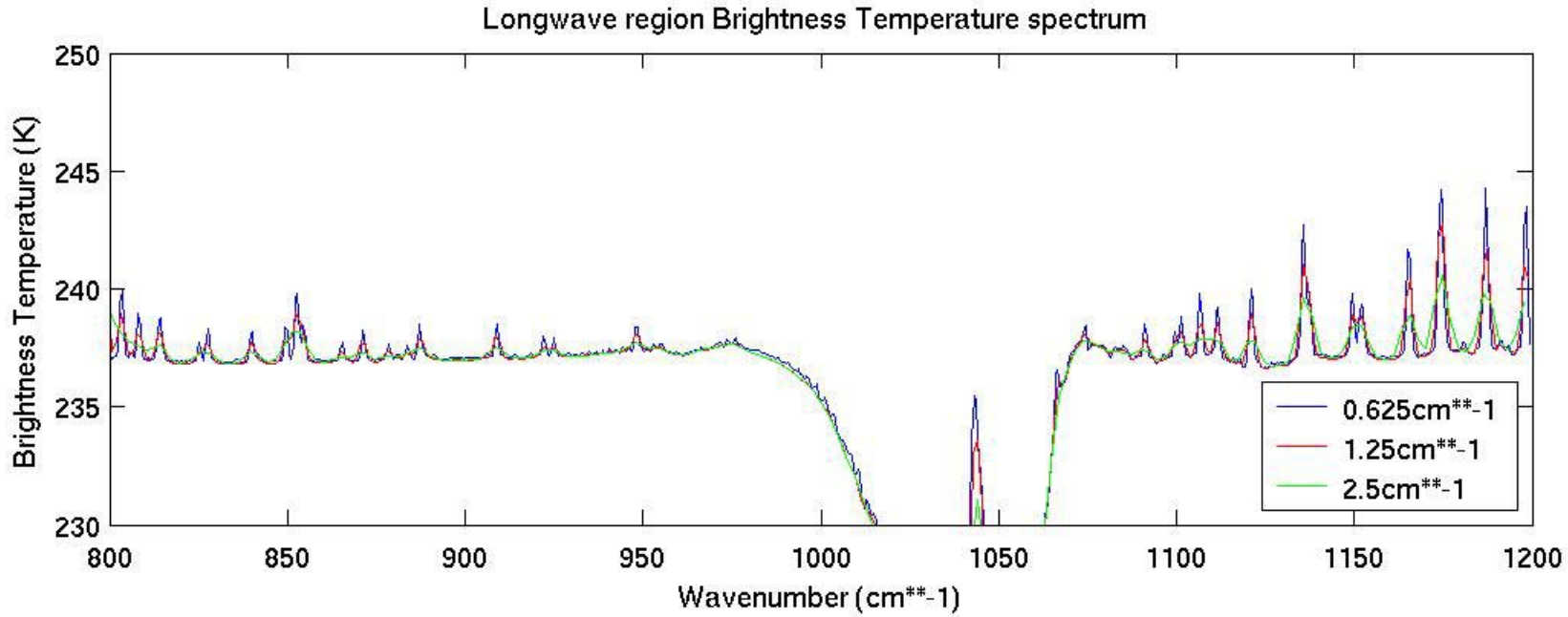
LW

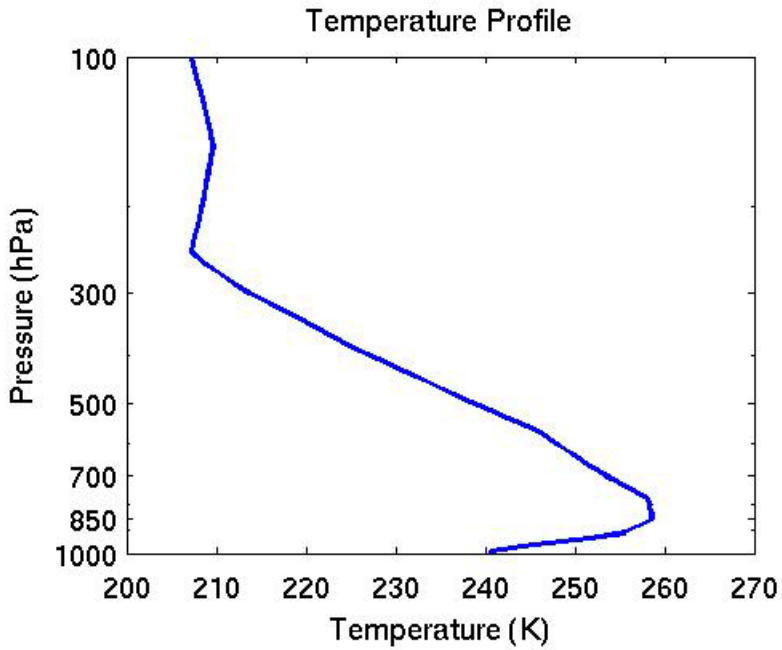


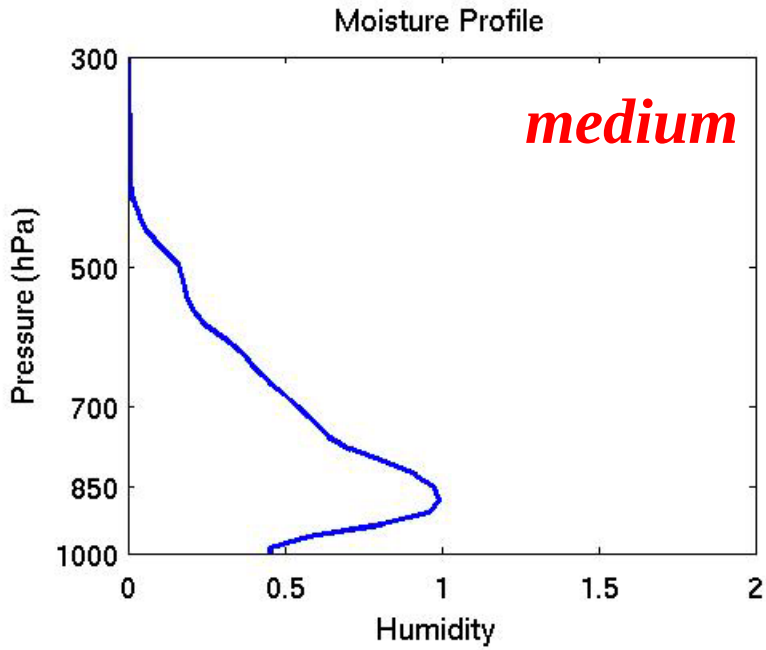


SMW



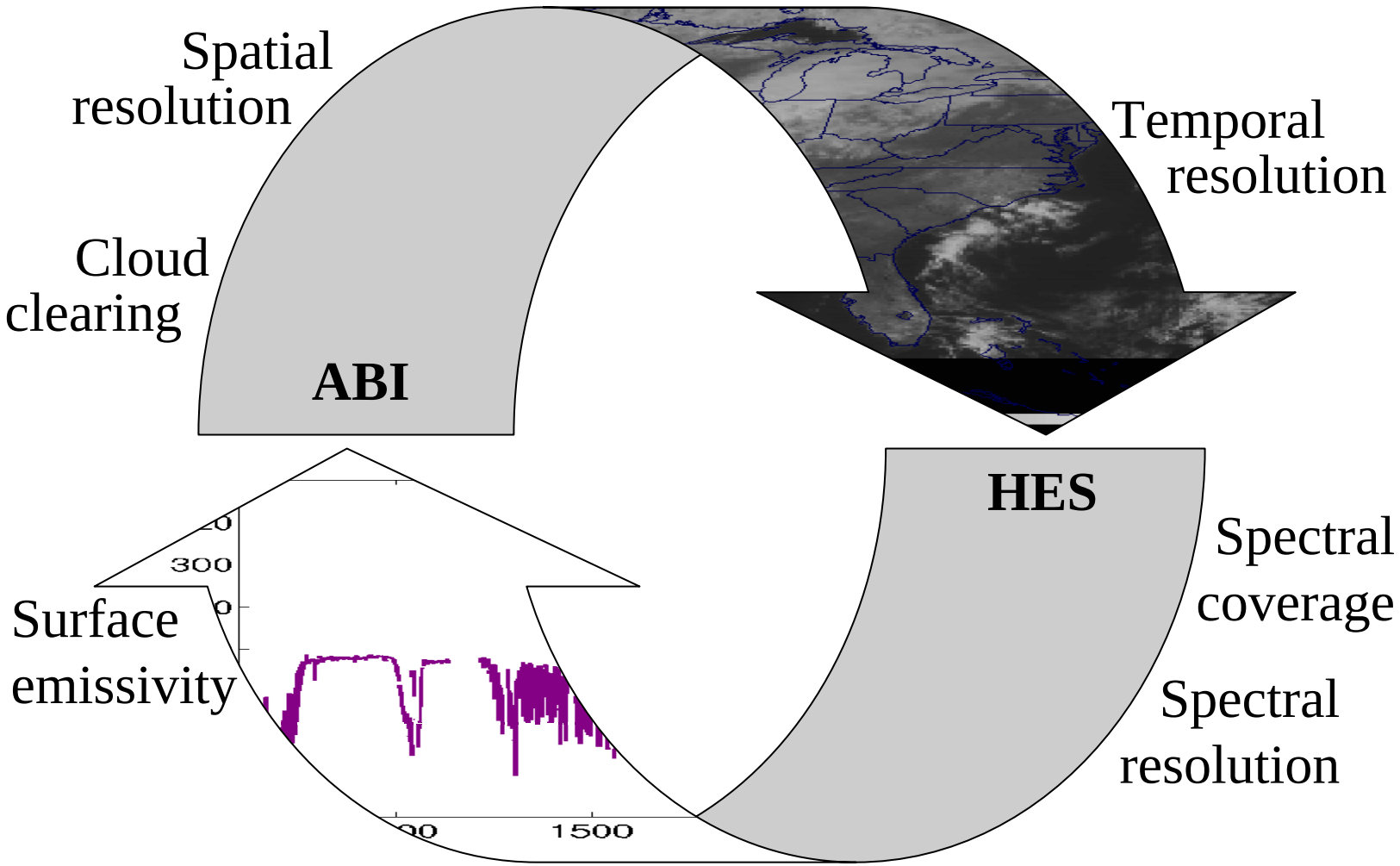

Longwave region Brightness Temperature spectrum
Brightness Temperature (K)
250
245
240
235
230
800
850
900
950
1000
1050
1100
1150
1200
Wavenumber (cm**-1)
0.625cm**-1
1.25cm**-1
2.5cm**-1


Temperature Profile
Pressure (hPa)
100
300
500
700
850
1000
200
210
220
230
240
250
260
270
Temperature (K)


Moisture Profile
Pressure (hPa)
300
500
700
850
1000
0
0.5
1
1.5
2
Humidity

medium

Improved products will be realized from combinations of ABI *and* HES (Hyperspectral Environmental Suite) data (IR and Visible/near IR on the HES-Coastal Water)!



GOES-R HES Coastal Waters Capability

Christopher W. Brown, Michael Ondrusek and Richard P. Stumpf

Current GOES: None

- Hazardous material and harmful algal blooms
- Water quality and clarity
- Health of shallow water corals
- Bathymetry relevant to navigation safety and locate coastal hazards
- Initialize and validate coastal ocean models
- Quantify the response of marine ecosystems
- Enhance the development and implementation of new products for coastal fisheries

True-color image with high resolution MODIS imagery.

HES CW bands

(0.3 km Threshold, 0.15 km Goal)

Band	HES Band	Channel Center Wavelength (um)	Reso-lution (um)	Threshold tolerance on center wavelength (um)
Reflected Solar < 1 um (Threshold)	5	0.412 (T)	0.02 (T)	+/- 0.002 (TBR)
		0.443 (T)	0.02 (T)	+/- 0.0011 (TBR)
		0.477 (T)	0.02 (T)	+/- 0.002 (TBR)
		0.490 (T)	0.02 (T)	+/- 0.0012 (TBR)
		0.510 (T)	0.02 (T)	+/- 0.0015 (TBR)
		0.530 (T)	0.02 (T)	+/- 0.0012 (TBR)
		0.550 (T)	0.02 (T)	+/- 0.005 (TBR)
		0.645 (T)	0.02 (T)	+/- 0.004 (TBR)
		0.667 (T)	0.01 (T)	+0.001-0.002 (TBR)
		0.678 (T)	0.01 (T)	+/- 0.001(TBR)
		0.750 (T)	0.02 (T)	+/- 0.002 (TBR)
		0.763 (T)	0.02 (T)	+/- 0.0015 (TBR)
		0.865 (T)	0.02 (T)	+/- 0.0022 (TBR)
		0.905 (T)	0.035 (T)	+/- 0.0023 (TBR)
Hyperspectral Reflected Solar < 1 um (G)	5	0.407 - 0.987 (G)	0.01 (G)	+/- 0.001 (TBR), centered on 0.667+/- 0.001
0.570 (G)	5	0.570	0.01 (G)	+/- 0.001 (TBR), centered on 0.570+/- 0.001
Reflected Solar > 1 um (G)	6	1.38	0.03	+/- 0.005 (TBR)
Reflected Solar > 1 um (G)	6	1.61	0.06	+/- 0.005 (TBR)
Reflected Solar > 1 um (G)	6	2.26	0.05	+/- 0.005 (TBR)
LWIR (GOAL)	7	11.2 (893 cm^{-1})	0.8 (64 cm^{-1})	+/- 0.05 (TBR) (+/- 40 cm^{-1})
LWIR (GOAL)	7	12.3 (813 cm^{-1})	1.0 (60 cm^{-1})	+/- 0.05 (TBR) (+/- 40 cm^{-1})

Geostationary LIGHTNING MAPPER Requirements

3.4.5.41	Lightning Detection: CONUS	GOES R Baseline	T	C	Surface to cloud top	10 km	5 km	Real time	70-90% total strikes detection	continuous	1 min	tbd
			O	C	Surface to cloud top	0.5 km	100 m	Real time	99% total strikes detection	continuous	<10 sec	tbd
3.4.5.42	Lightning Detection: Hemispheric	GOES R Baseline	T	FD	Surface to cloud top	10 km	5 km	Real time	70-90% total strikes detection	continuous	1 min	tbd
			O	H	Surface to cloud top	0.5 km	100 m	Real time	99% total strikes detection	continuous	<10 sec	tbd
3.4.5.43	Lightning Detection: Mesoscale	GOES R Baseline	T	M	Surface to cloud top	10 km	5 km	Real time	70-90% total strikes detection	continuous	1 min	tbd
			O	M	Surface to cloud top	0.5 km	100 m	Real time	99% total strikes	continuous	<10 sec	tbd

0.5 (goal) to 10 km (threshold) spatial resolution

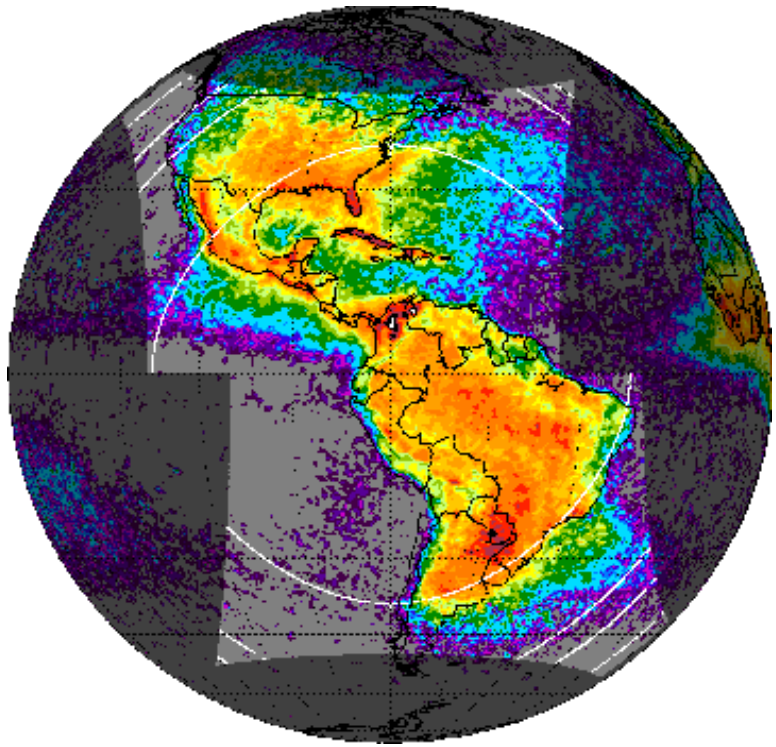
Geostationary Lightning Mapper (GLM)

H J Christian
Huntsville, Alabama

GLM : Field of View at GOES

(climatology indicates lightning density)

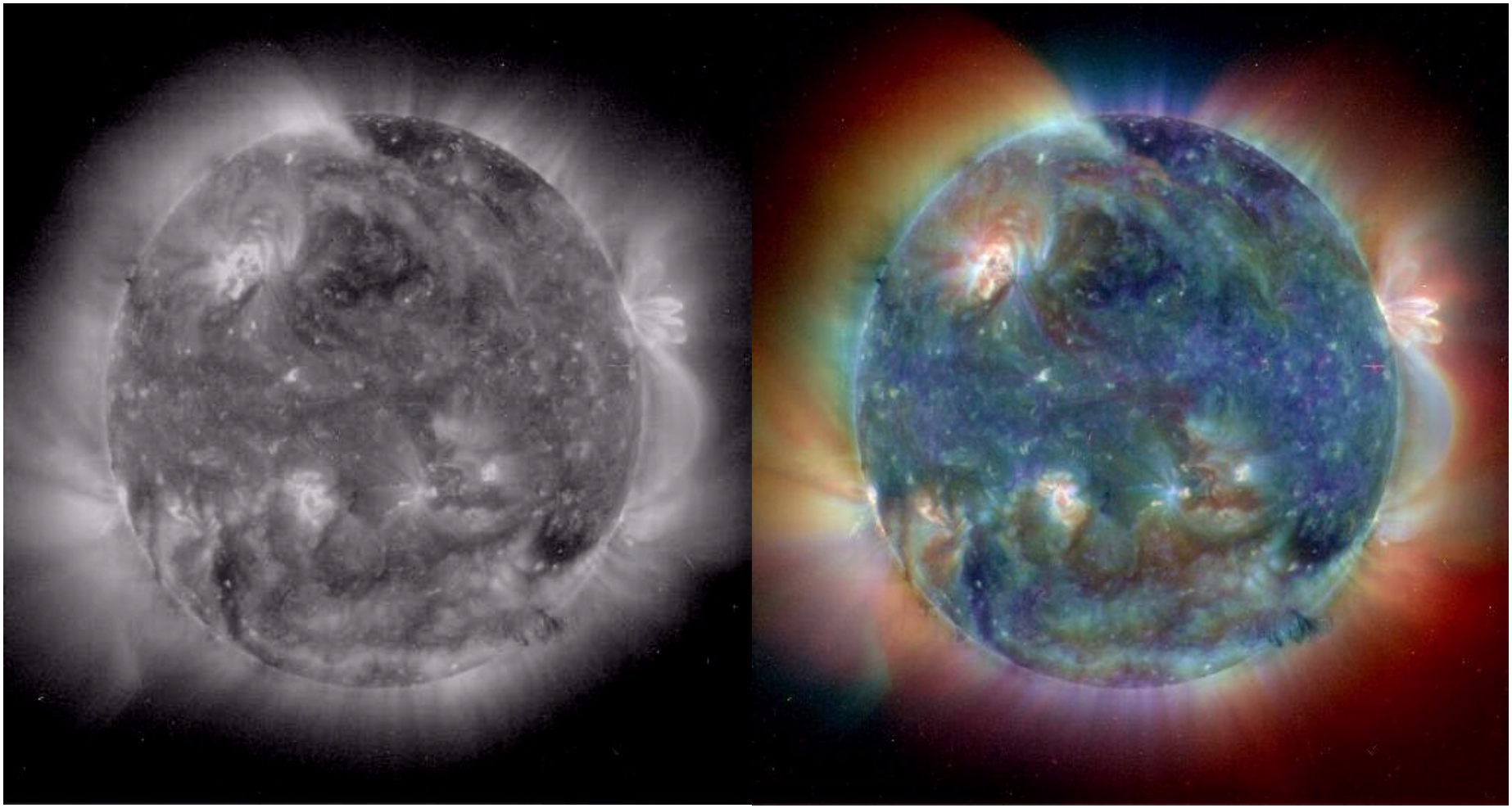
Current GOES: None



GOES E (135ºW)

Geostationary LIGHTNING MAPPER

- New NOAA Instrument
  - Severe Storm Warning Times
  - Lightning Danger Alerts
  - Nitrogen Production
- Detects Total Strikes: In Cloud, Cloud To Cloud, And Cloud To Ground
  - Compliments Today's Land Based Systems That Only Measures Cloud To Ground (About 15% Of The Total Lightning)
- Increased Coverage Over Oceans And Lands
  - Currently No Ocean Coverage, And
  - Limited Land Coverage In Dead Zones
- Parameters
  - Hemispheric Or CONUS Coverage
  - 10 km Spatial Resolution (~0.5 km Goal)



Simulated SXI (Solar X-ray Imager) images: GOES R will produce multi-band "color" images at the same rate as GOES N/P produces single band images. (Images courtesy of SOHO EIT, a joint NASA/ESA program; and Steve Hill/NOAA SEC).

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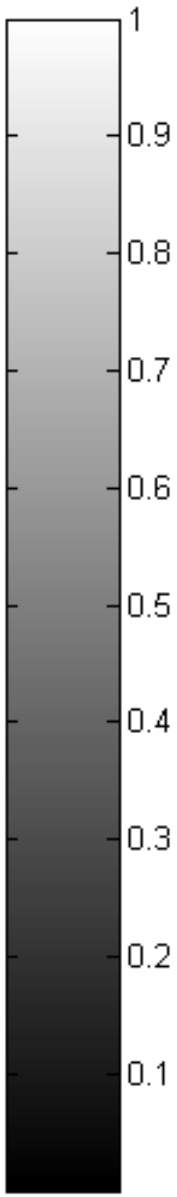
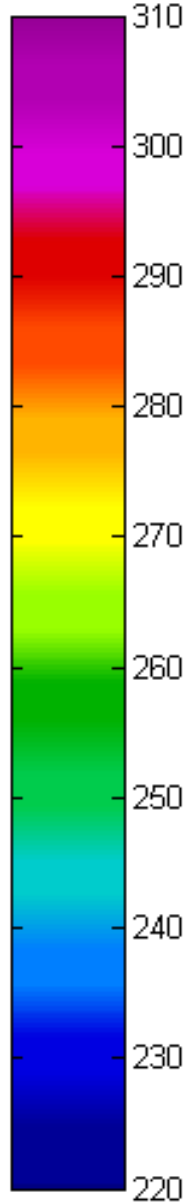
Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)



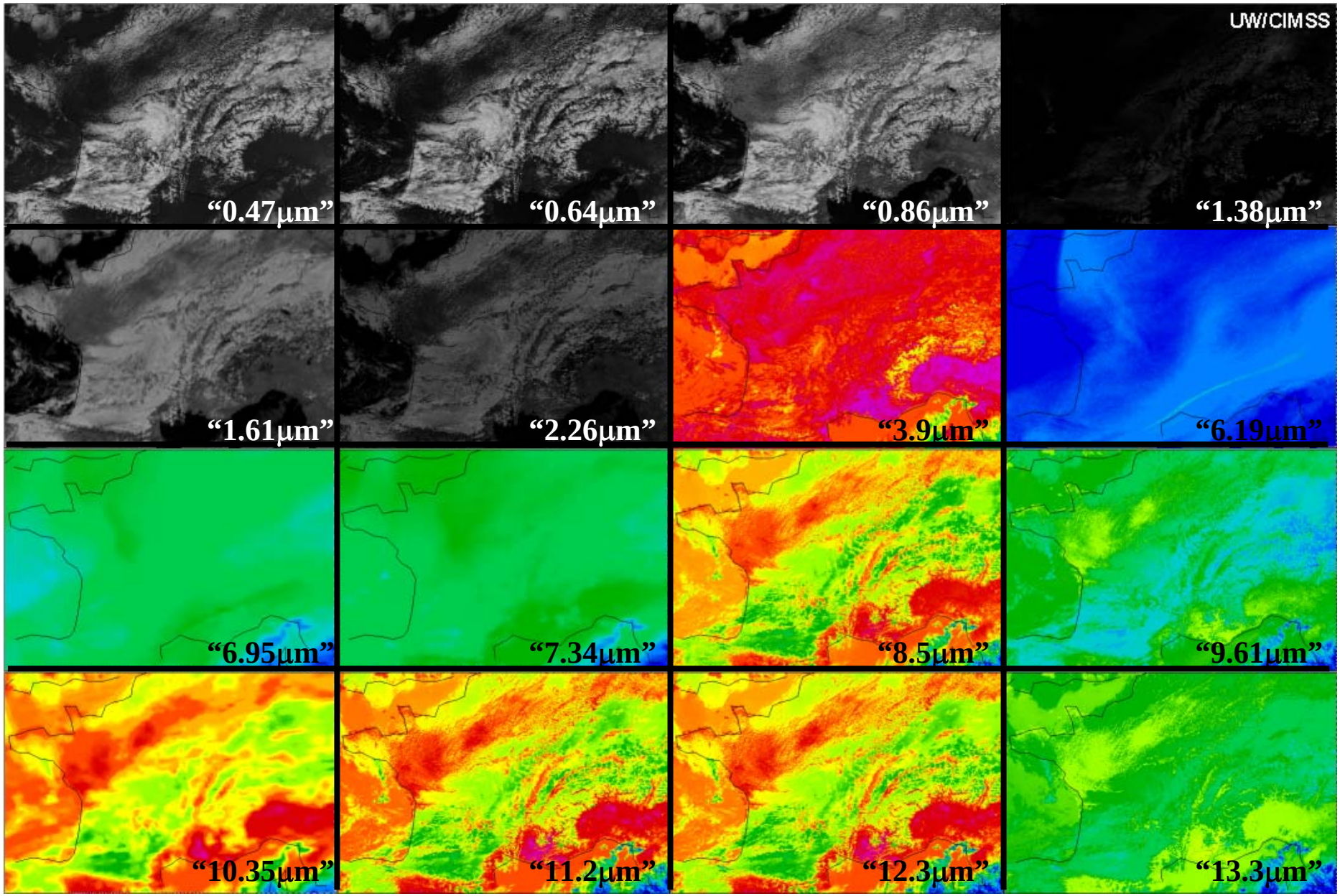
(reflectance)

“0.47μm” (MODIS)	**“0.64μm” (MODIS)**	**“0.86μm” (MODIS)**	**“1.38μm” (MODIS)**
“1.61μm” (MET-8)	**“2.26μm” (MODIS)**	**“3.9μm” (MODIS)**	**“6.19μm” (MET-8)**
“6.95μm” (AIRS)	**“7.34μm” (AIRS)**	**“8.5μm” (MODIS)**	**“9.61μm” (MODIS)**
“10.35μm” (AIRS)	**“11.2μm” (MODIS)**	**“12.3μm” (MODIS)**	**“13.3μm” (MODIS)**

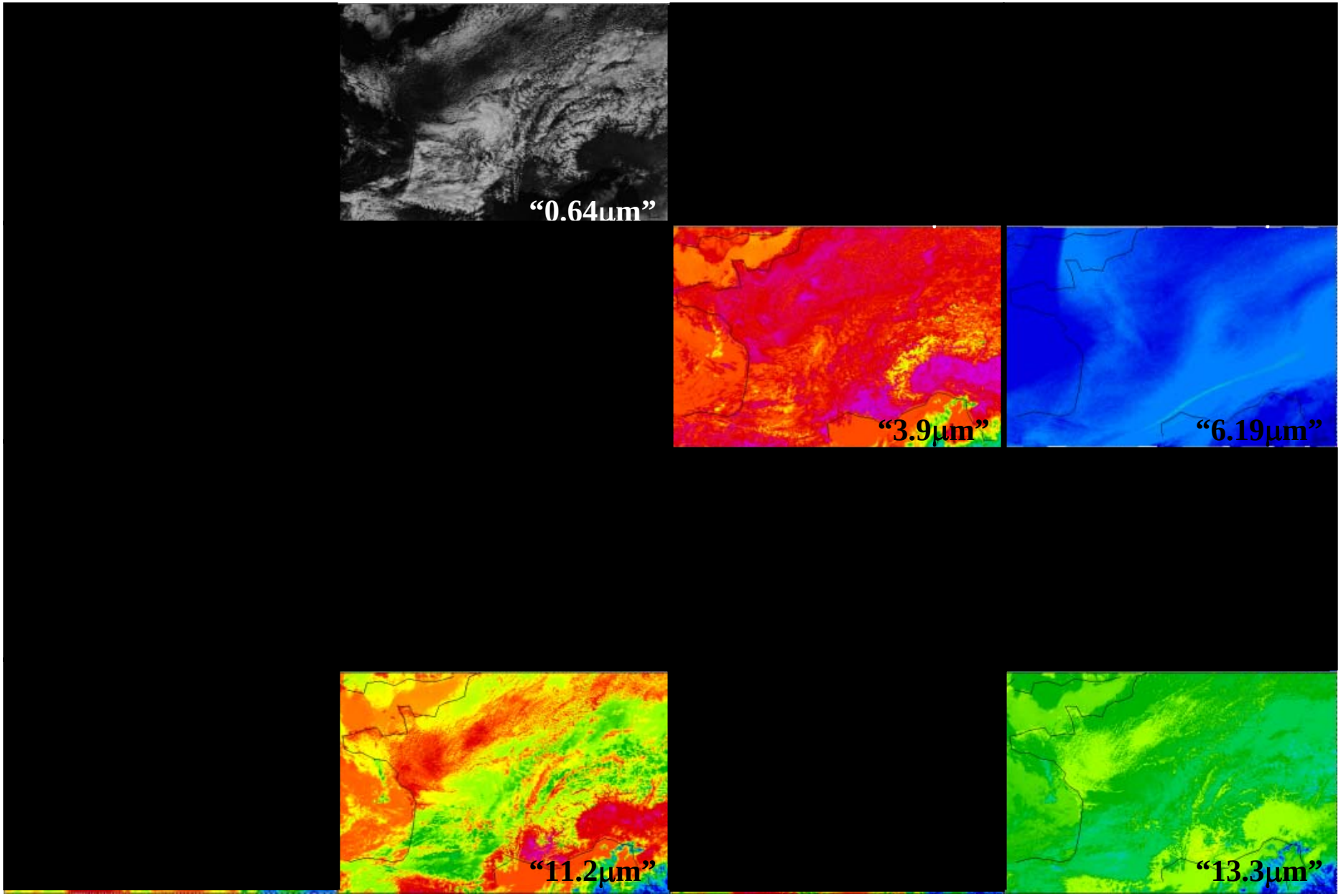


(K)

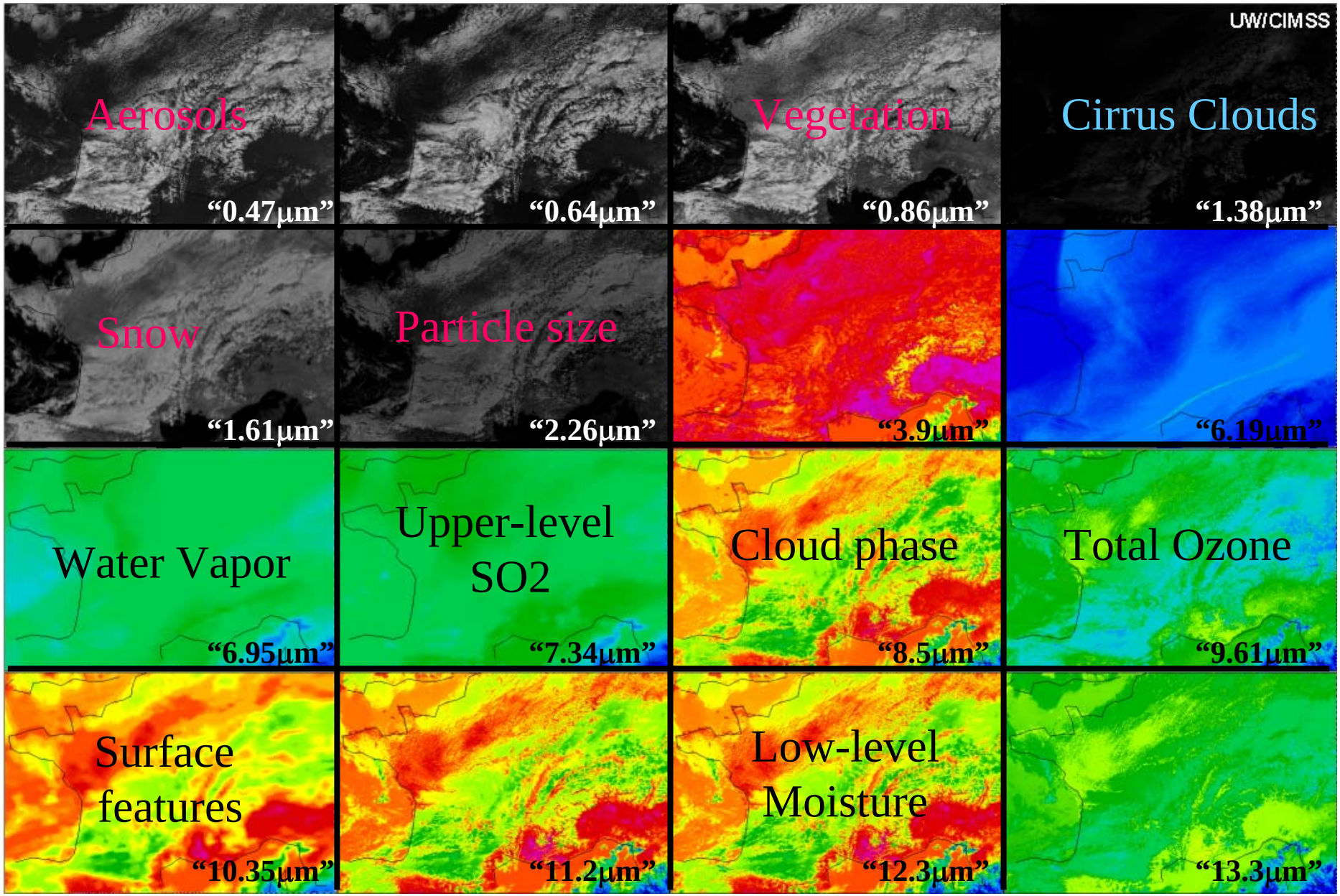
Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)



Similar bands on the GOES-12 Imager



Using MODIS, MET-8 and AIRS to simulate the spectral bands on the Advanced Baseline Imager (ABI)



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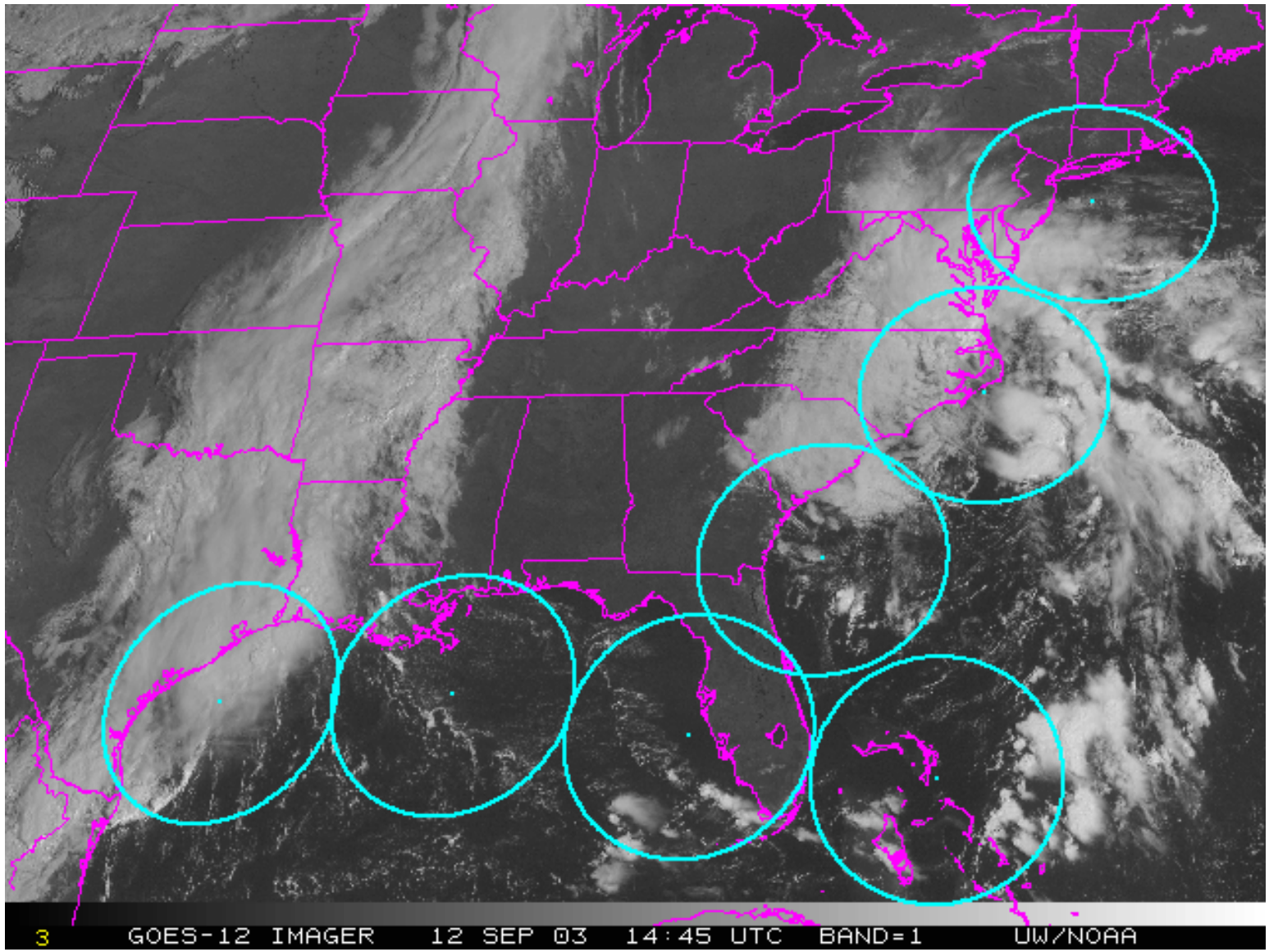
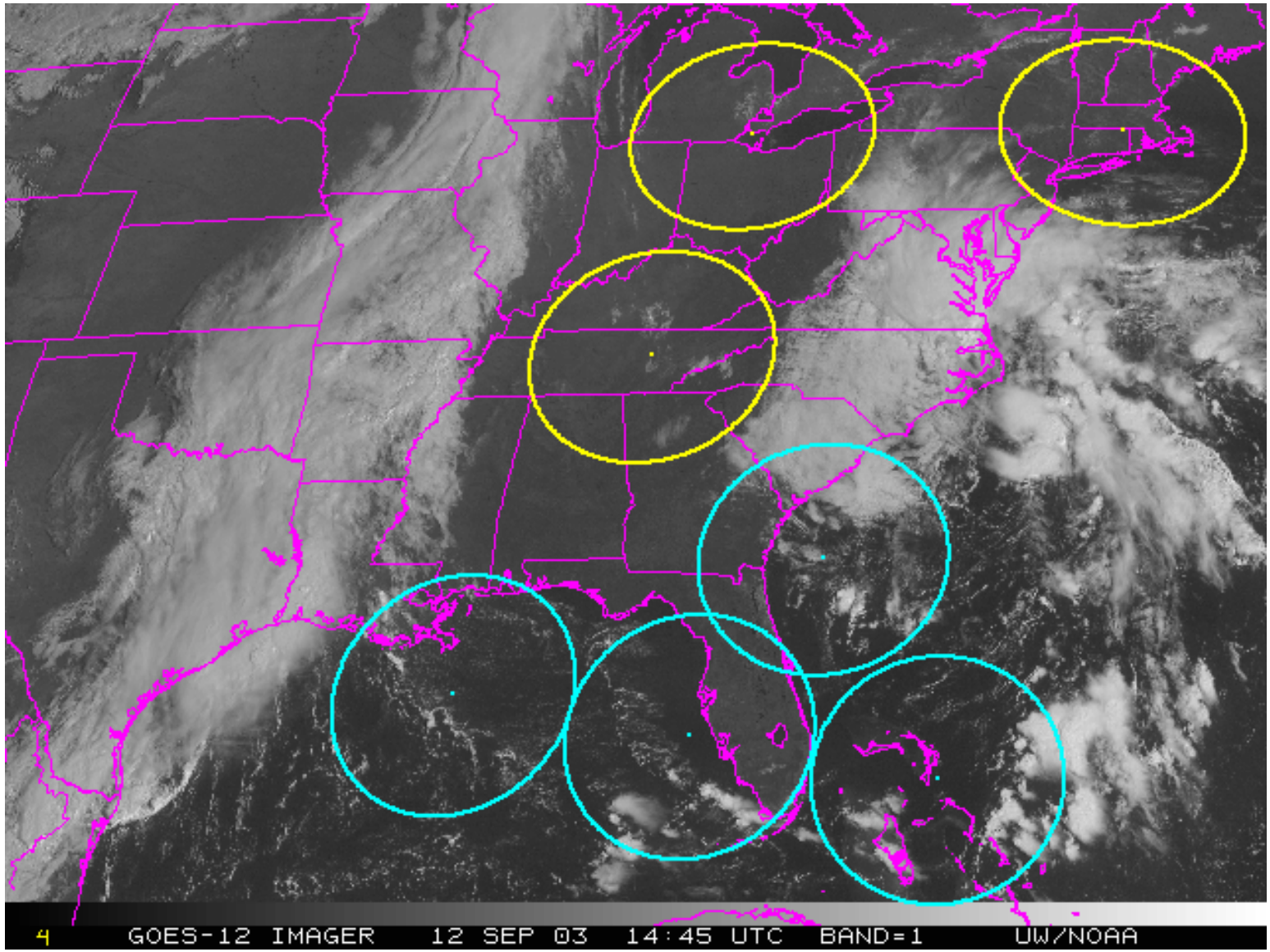
HES-CW coverage *without* cloud mask information from the ABI



Default schedule might be to scan along entire coast.

HES-CW coverage *with* cloud mask information from the ABI



Cloud mask from ABI would suggest to not scan over cloudy regions and hence other regions could be scanned.

Sample GOES-R 3-hour schedule for the ABI and (1 telescope design) HES

MSS = Mesoscale Scans from the ABI

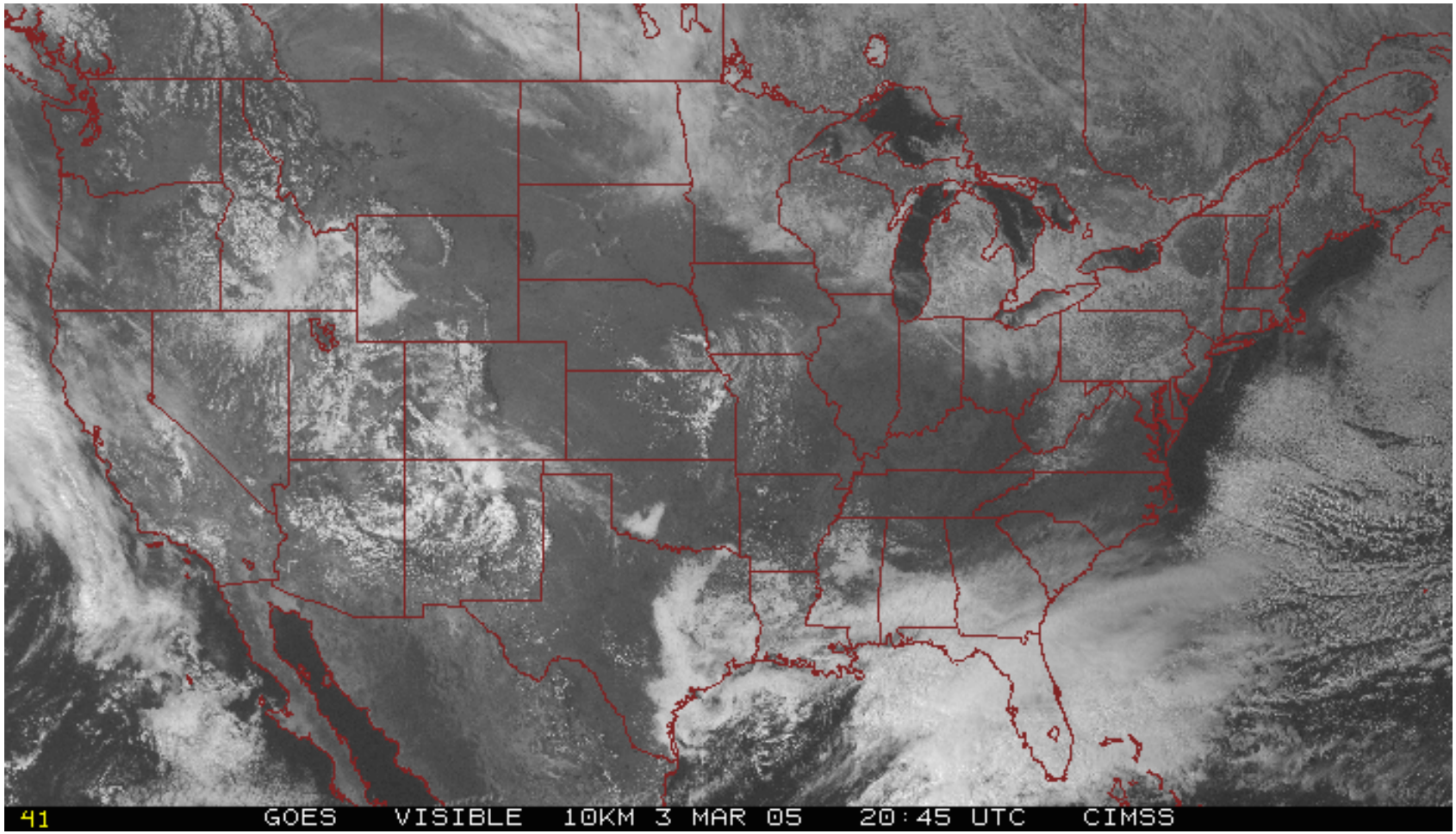
MS = HES-Sounder mesoscale mode

FD = Full imaging disk scan

FSD = Full “sounding” disk scan

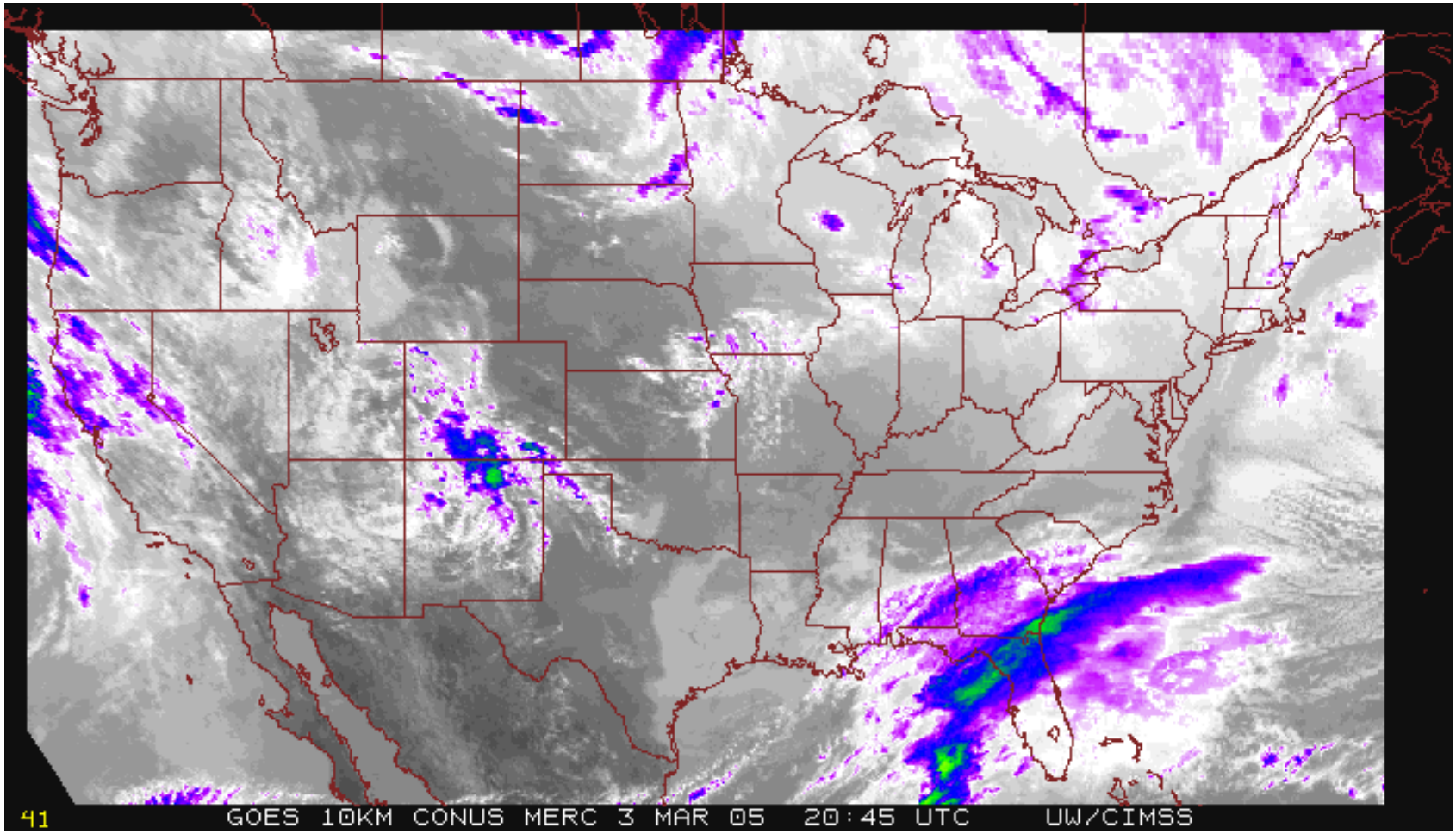
Time (UTC)	ABI	HES-Sounder	HES-CW
12:45	FD	10km-CONUS	
12:50	FD		
12:55	FD		CW area
13:00	CONUS+MSS	4km-MS	
13:05	CONUS+MSS		CW area
13:10	CONUS+MSS	4km-MS	
13:15	FD		CW area
13:20	CONUS+MSS	4km-MS	
13:25	CONUS+MSS		CW area
13:30	FD	4km-MS	
13:35	CONUS+MSS		CW area
13:40	CONUS+MSS	4km-MS	
13:45	FD	10km-CONUS	
13:50	FD		
13:55	FD		CW area
14:00	CONUS+MSS	4km-MS	
14:05	CONUS+MSS		CW area
14:10	CONUS+MSS	4km-MS	
14:15	FD		CW area
14:20	CONUS+MSS	4km-MS	
14:25	CONUS+MSS		CW area
14:30	FD	4km-MS	
14:35	CONUS+MSS		CW area
14:40	CONUS+MSS	4km-MS	
14:45	FD	10km-CONUS	
14:50	FD		
14:55	FD		CW area
15:00	CONUS+MSS	4km-MS	
15:05	CONUS+MSS		CW area
15:10	CONUS+MSS	4km-MS	
15:15	FD		CW area
15:20	CONUS+MSS	4km-MS	
15:25	CONUS+MSS		CW area
15:30	FD	4km-MS	
15:35	CONUS+MSS		CW area
15:40	CONUS+MSS	4km-MS	
15:45	FD	10km-CONUS	
15:50	FD		
15:55	FD	4km-MS	
16:00	CONUS+MSS		Land mode (1200kmx1200km)

Visible image example



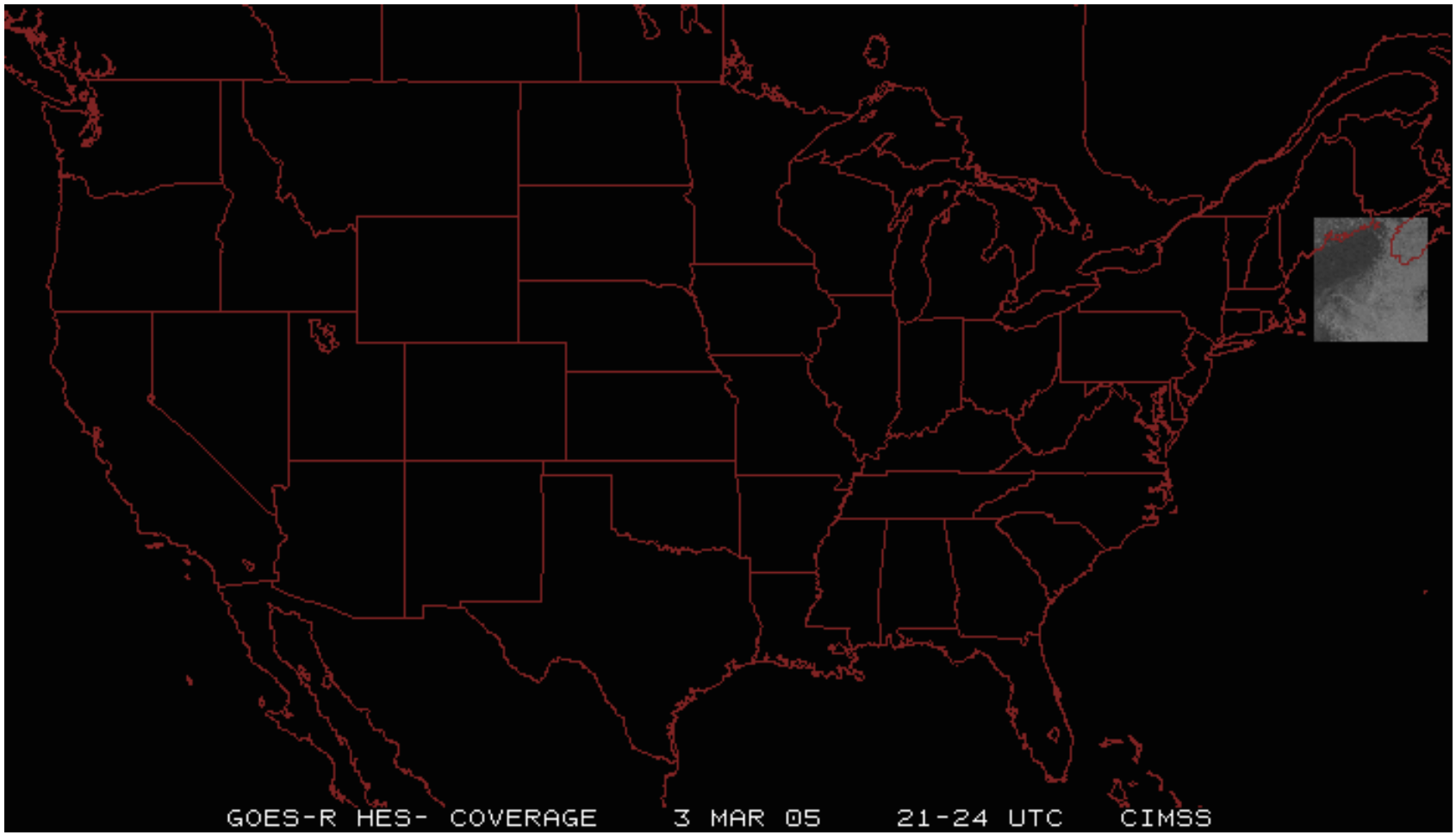
- Visible image to show the cloud cover (GOES-East Example).
- What follows is a HES example coverage loop.

HES-Sounding simulation at 10 km



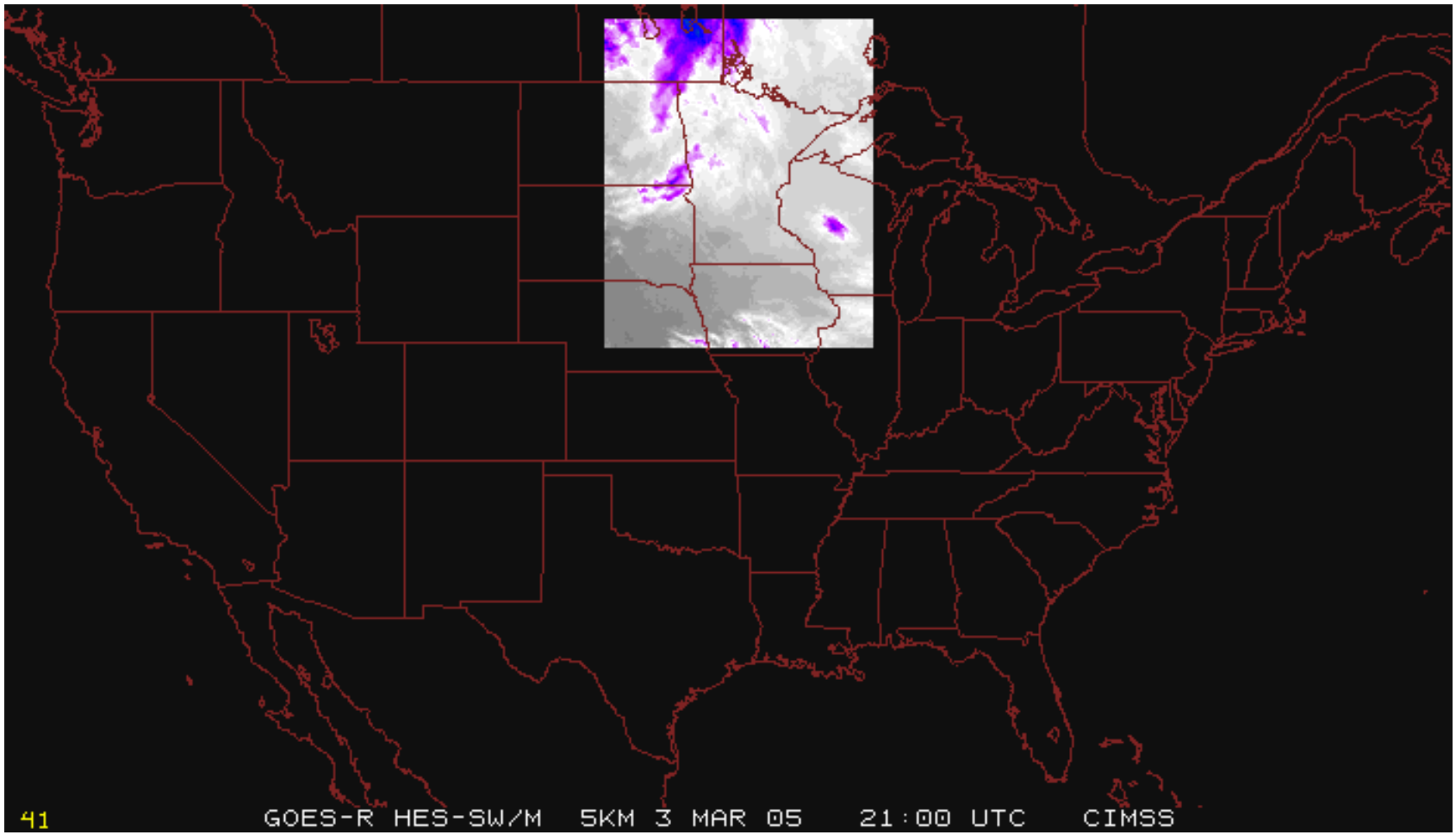
20:45 UTC

HES-Coastal Waters



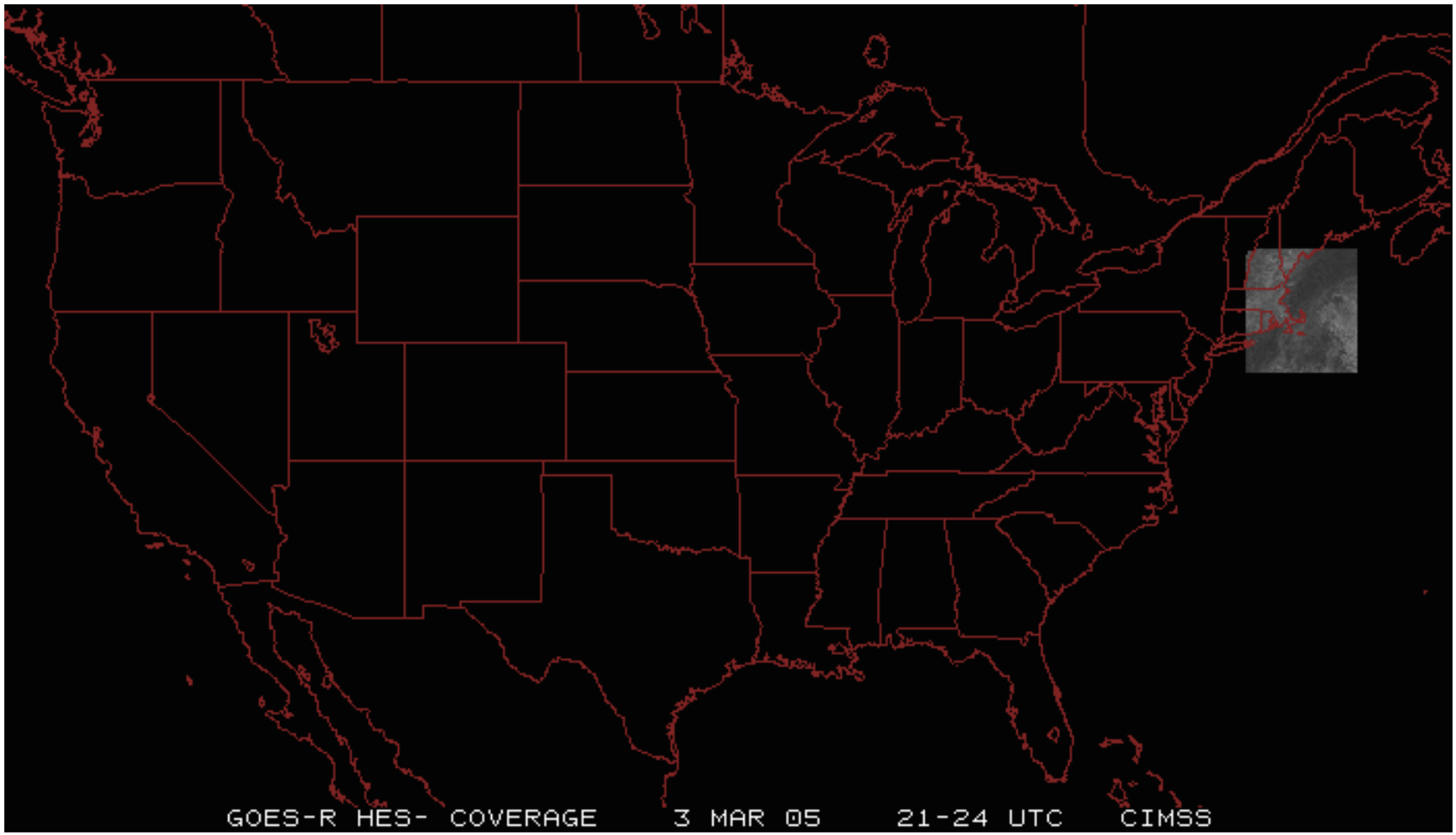
20:55 UTC

HES-Sounding at 4 km



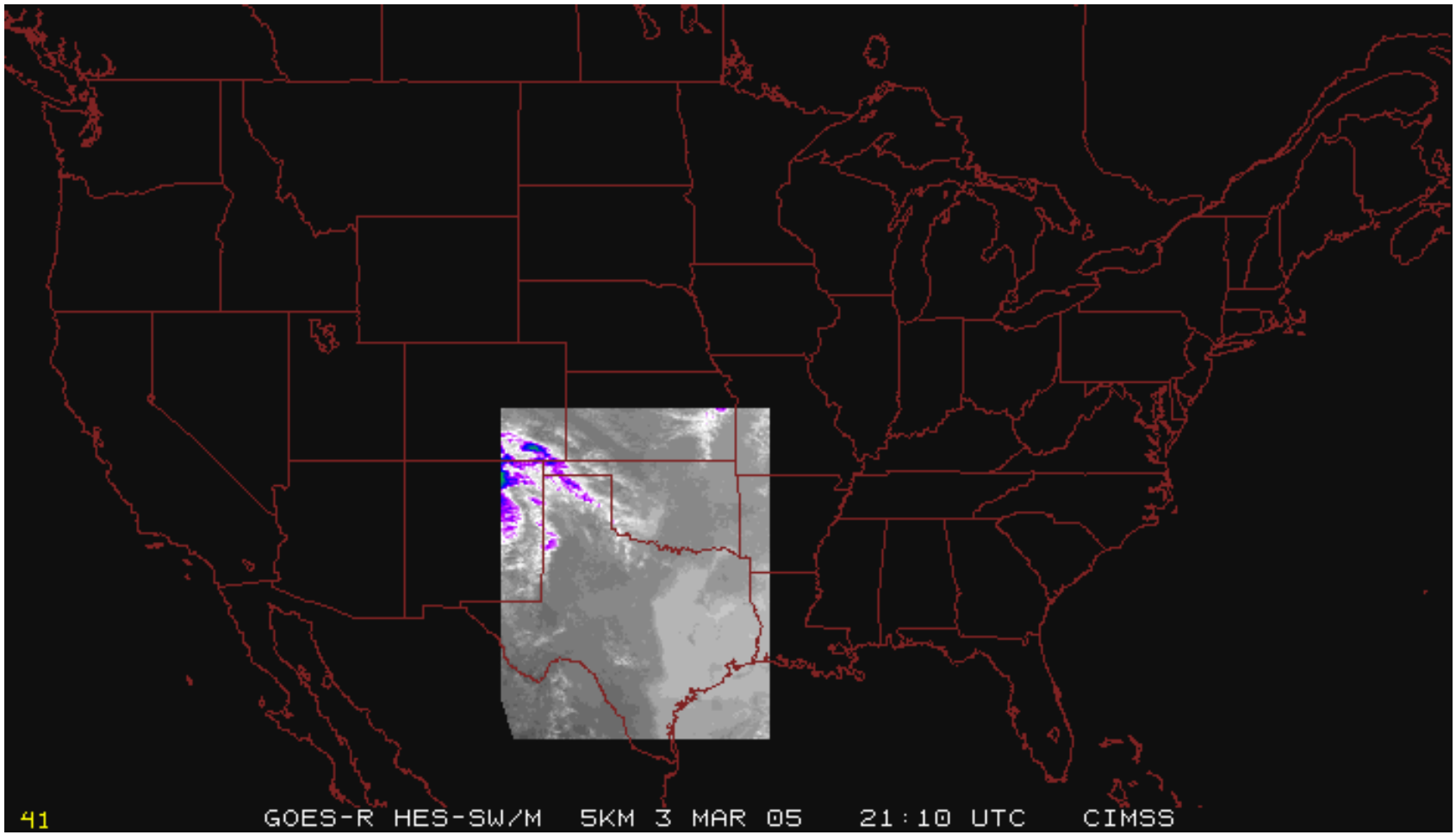
21:00 UTC

HES-Coastal Waters



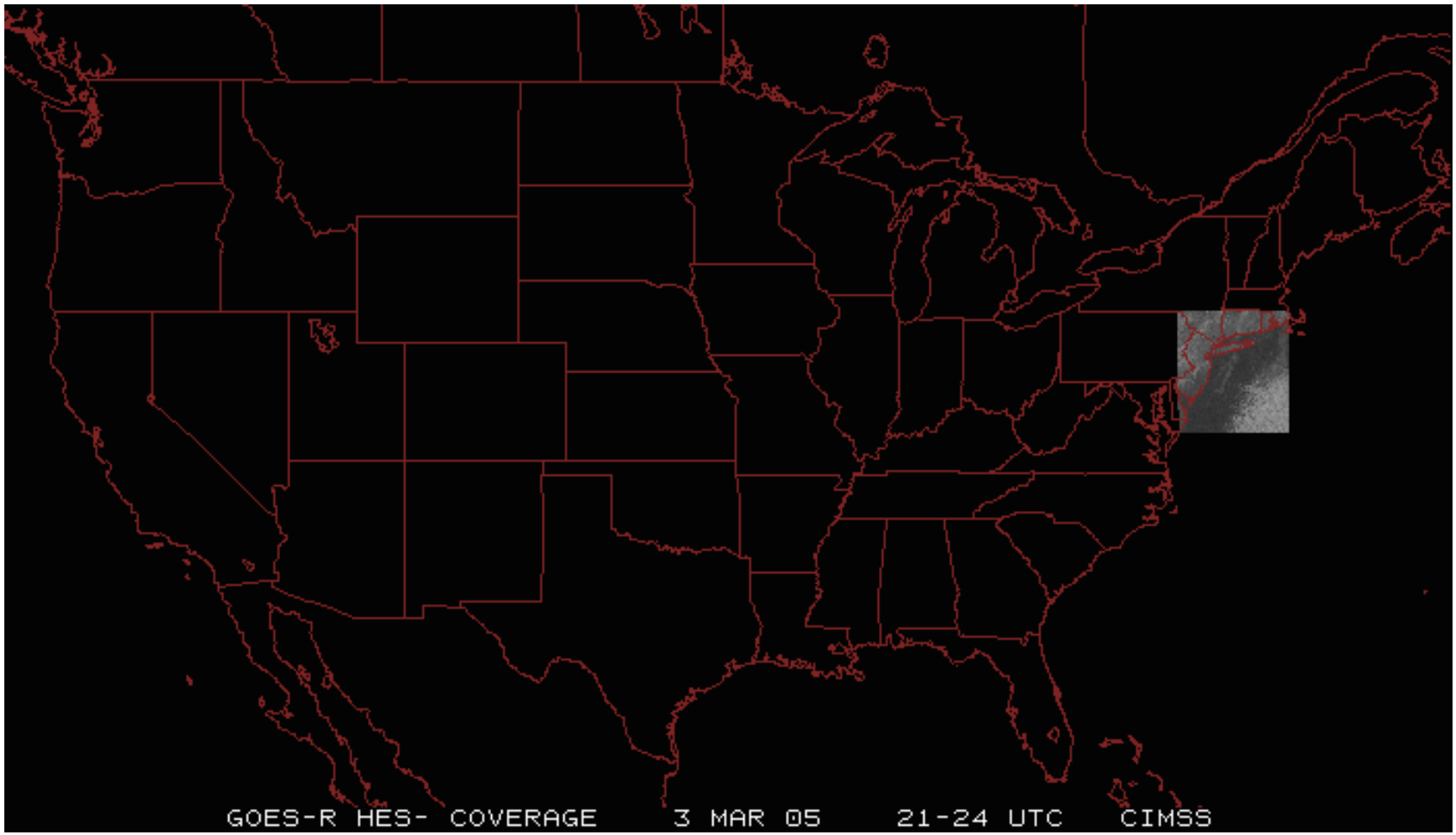
21:05 UTC

HES-Sounding 4 km



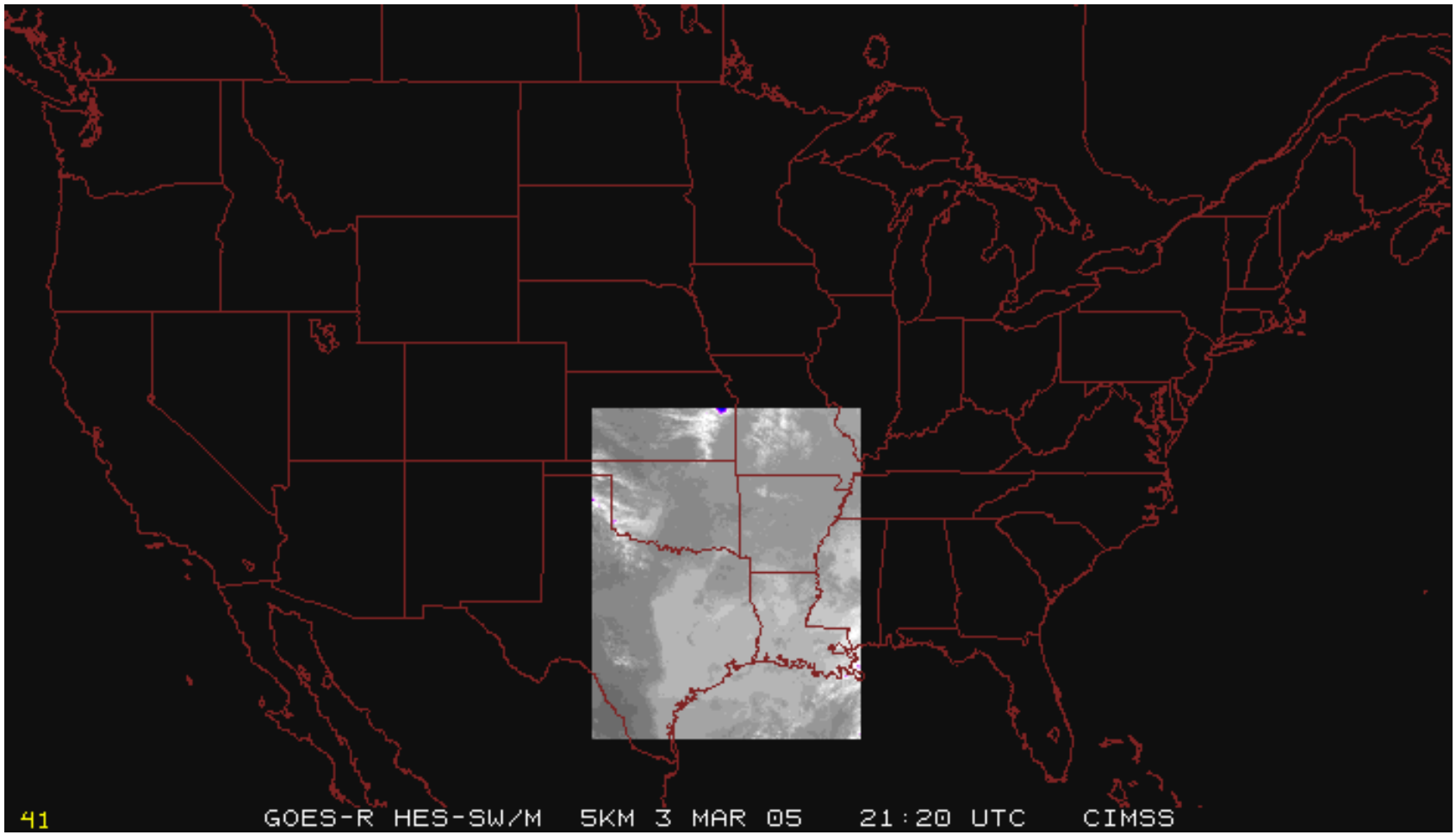
21:10 UTC

HES-Coastal Waters



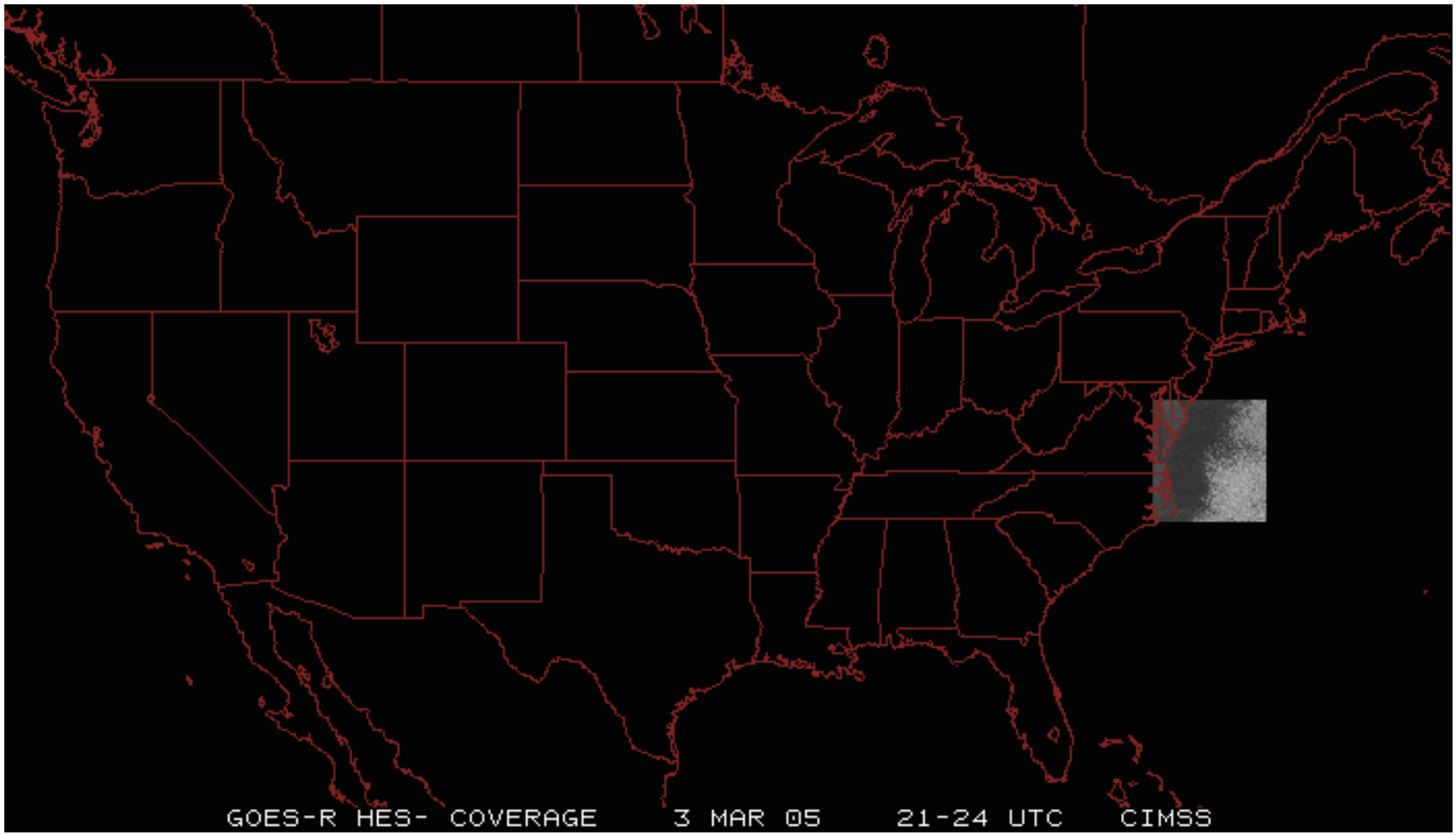
21:15 UTC

HES-Sounding 4 km



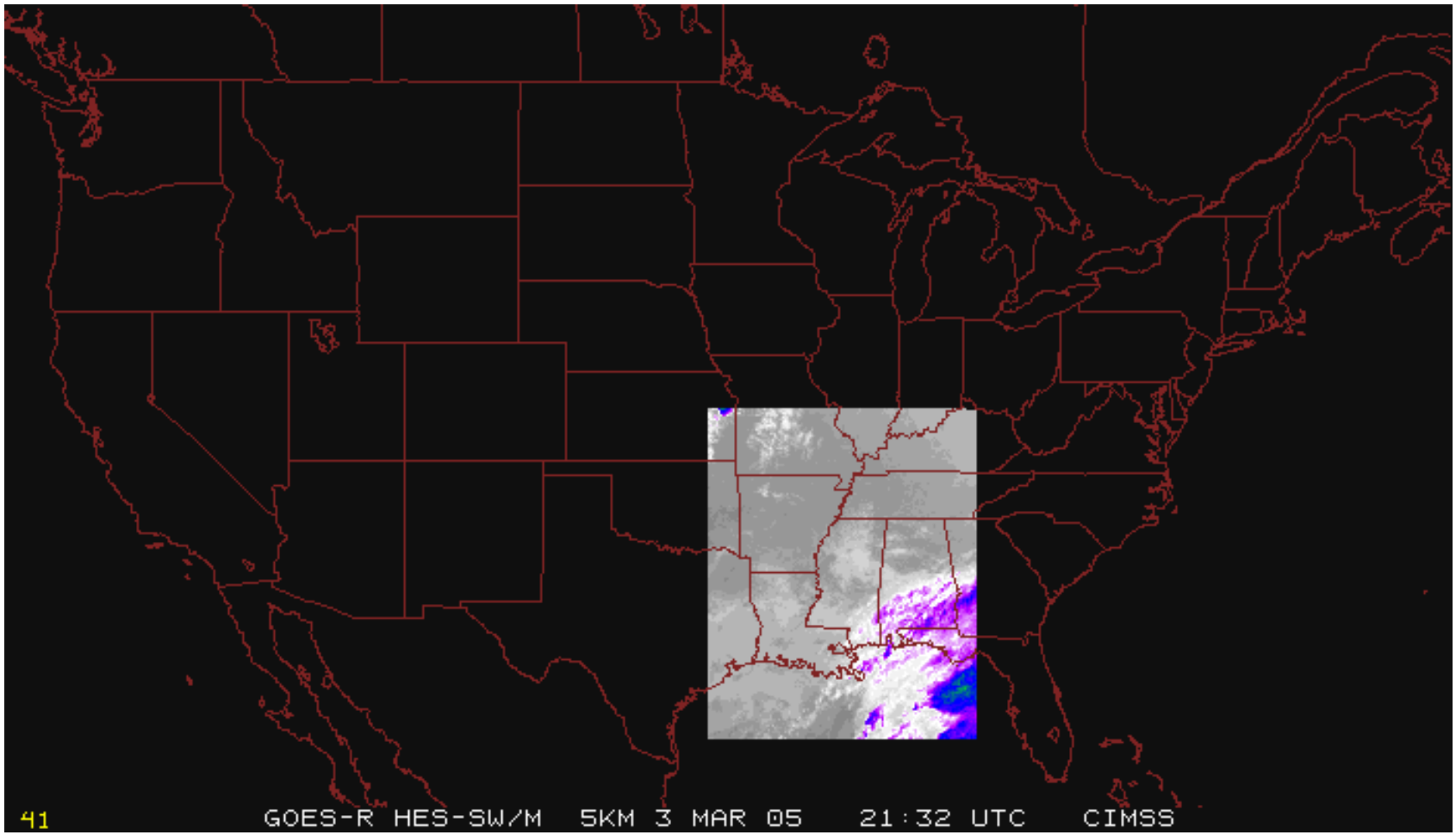
21:20 UTC

HES-Coastal Waters



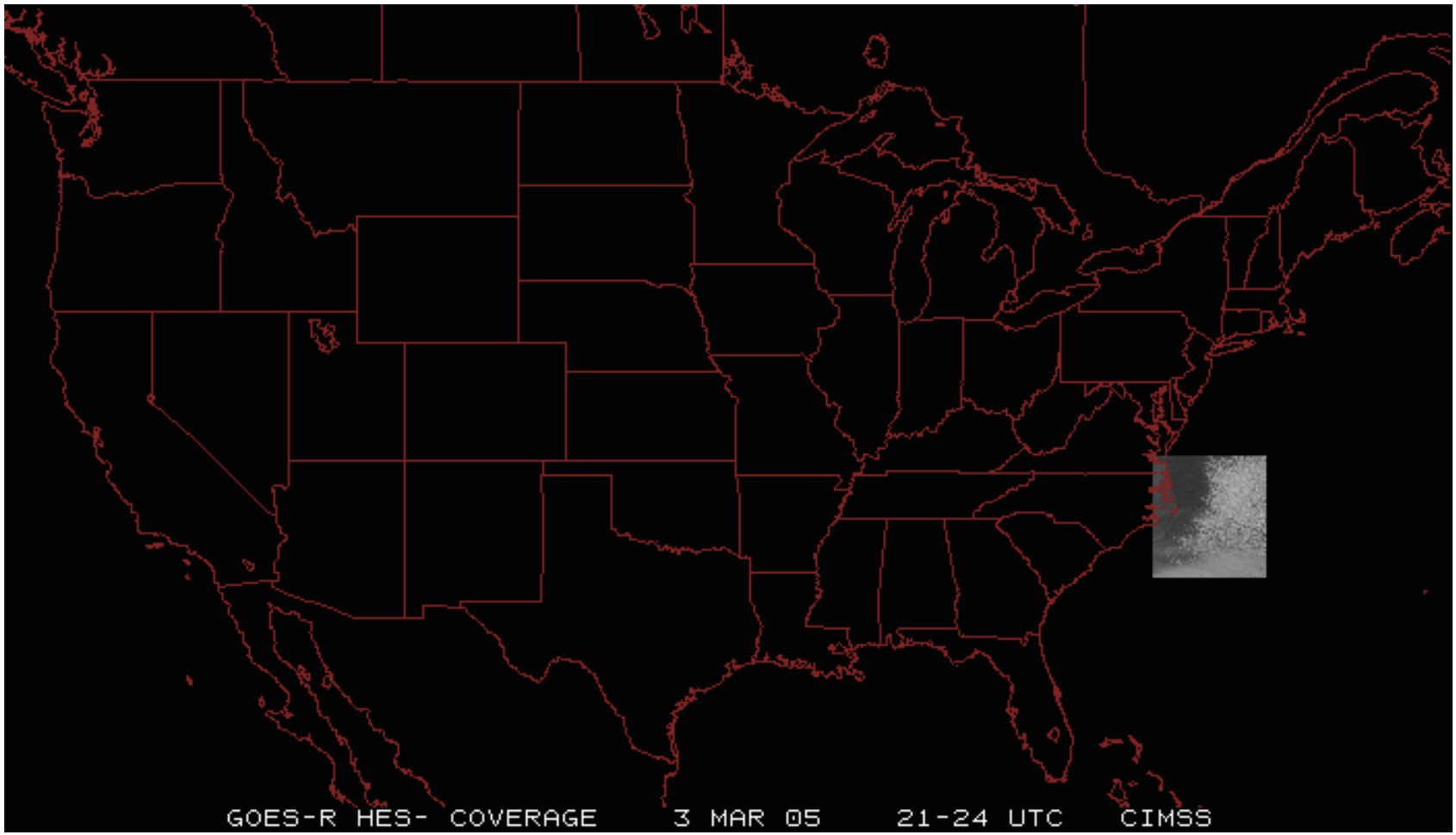
21:25 UTC

HES-Sounding 4 km



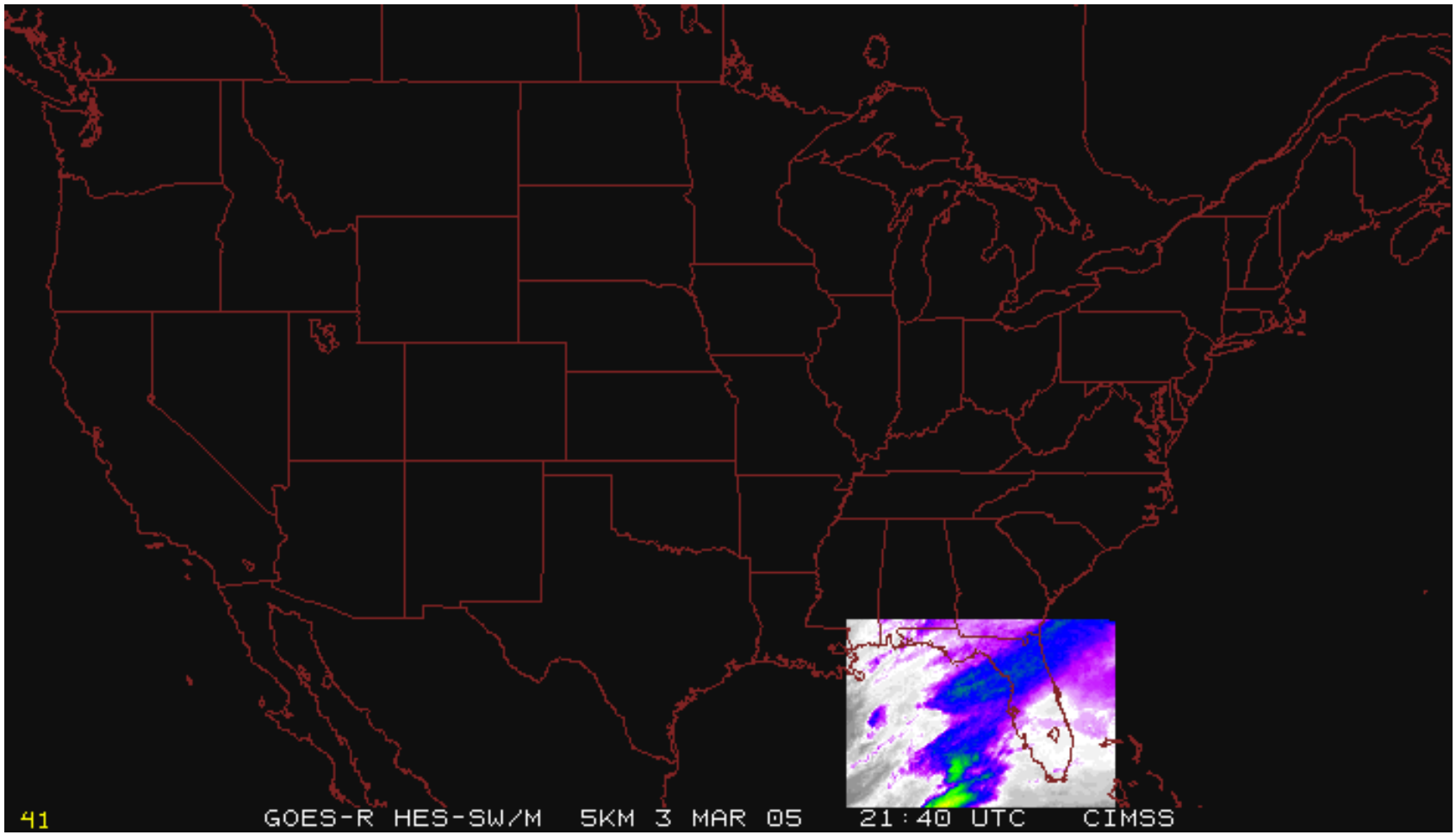
21:30 UTC

HES-Coastal Waters



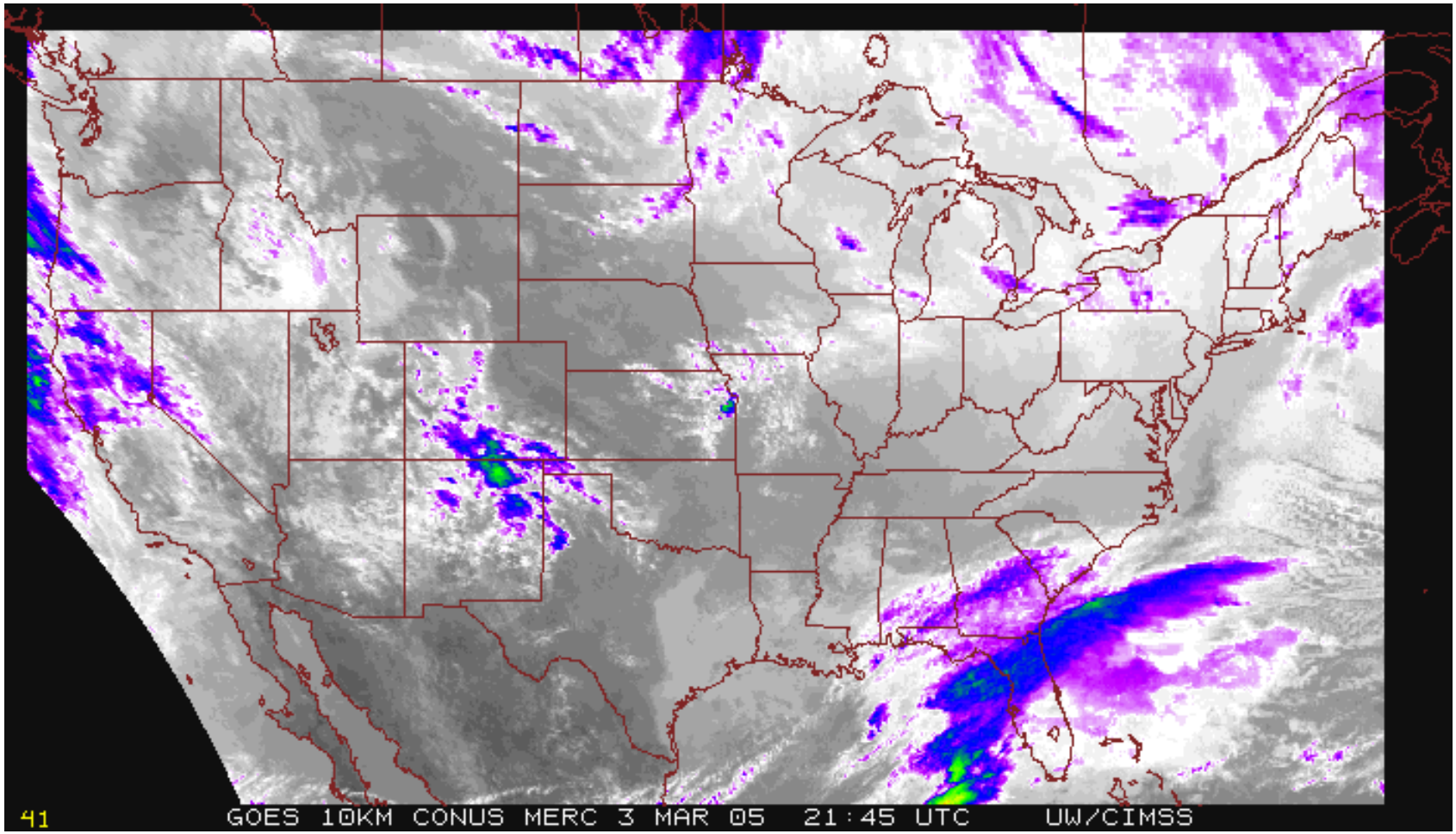
21:35 UTC

HES-Sounding 4 km



21:40 UTC

HES-Sounding 10 km



21:45 UTC

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GOES-R

The **great amount of information** from the GOES-R series will both offer a **continuation of current product and services**, but also allow for **improved or new capabilities**.

These products, based on validated requirements, will cover a wide range of phenomena. This includes applications relating to: weather, ocean, coastal zones, land, hazards, solar and space.

The Advanced Baseline Imager (ABI), the Hyperspectral Environmental Suite (HES), the Geostationary Lightning Mapper (GLM), the space and solar instrument suites (Solar Imaging Suite (SIS) and the Space Environment In-Situ Suite (SEISS) on GOES-R will enable much improved monitoring compared to current capabilities.

More information -- ABI

ABI Research Home page (with a link to all these links):

- http://cimss.ssec.wisc.edu/goes/abi/

NOAA GOES-R page:

- http://osd.goes.noaa.gov/

GOES and MODIS Galleries:

- http://cimss.ssec.wisc.edu/goes/misc/interesting_images.html
- http://www.ssec.wisc.edu/~gumley/modis_gallery/

ABI Documentation from NASA:

- http://goespoes.gsfc.nasa.gov/abihome.htm

ABI Simulated Spectral Response functions:

- ftp://ftp.ssec.wisc.edu/ABI/SRF

http://cimss.ssec.wisc.edu/goes/hes/
http://osd.goes.noaa.gov/
http://www.osd.noaa.gov/
http://goespoes.gsfc.nasa.gov/goesr_industry.htm

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Schmit, T. J., M. M. Gunshor, W. Paul Menzel, J. Li, S. Bachmeier, and J. Gurka, 2005: Introducing the next-generation advanced baseline imager (ABI) on Geostationary Operational Environmental Satellites (GOES)-R. Bulletin of the AMS

Li, J., T. J. Schmit, C.-Y. Liu, W. P. Menzel, and J. Gurka, 2004: Studies on the Hyperspectral Environmental Suite (HES) on GOES-R. 13th Conference on Satellite Meteorology, Norfolk, VA, 20 - 23 September 2004 (preprints). P1.11, American Meteorological Society.

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Li, J., H.-L. Huang, C.-Y. Liu, P. Yang, T. J. Schmit et al., 2004: Retrieval of cloud microphyiscal properties from MODIS and AIRS. J. Appl. Meteorol., (manuscript submitted)

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Schmit, Timothy J., J. Gurka, W. P. Menzel, M. M. Coakley, A. Mostek, K. Schrab, M. M. Gunshor and A. Wimmers, 2005: Possible scanning scenarios of the GOES-R HES (Hyperspectral Environmental Suite), SPIE, March 31, 2005.