GOES-R Overview

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NOAA/NESDIS/Satellite Applications and Research

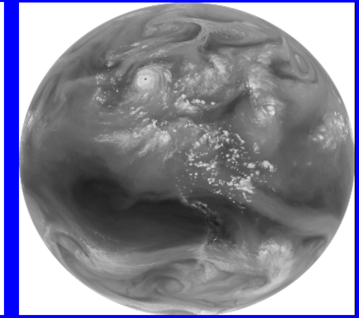
Advanced Satellite Products Branch (ASPB)

Madison, WI

James Gurka

GOES Program Office

and many, many others



NGATS Satellite Observations Sub-group

Madison, WI

July 27, 2006

UW-Madison

Thanks to…

Program Overview: *Anthony Comberiate*

System Program Director

The IR Hyperspectral Environmental Suite (HES): *W. Paul Menzel*

Satellite Applications and Research

Coastal Waters Imaging: *Curtiss Davis, Mark Abbott*

Oregon State University

Solar and Space Environment Data: *H.J. Singer, Steven Hill, T. Onsager*

NOAA Space Environment Center

GLM: *Tom Dixon, Dennis Boccippio, Joseph Schaefer, [NOAA / SPC]*

GLM Instrument Manager, NASA

Data Dissemination: *Thomas Renkevens*

Office of Systems Development

GOES-N: *Tom Wrublewski*

NOAA-NESDIS Technical Acquisition Manager

GOES-R Images: *Mat Gunshor, Jun Li, Elaine Prins, Wayne Feltz, etc.*

CIMSS

NASA GOES-R Team:

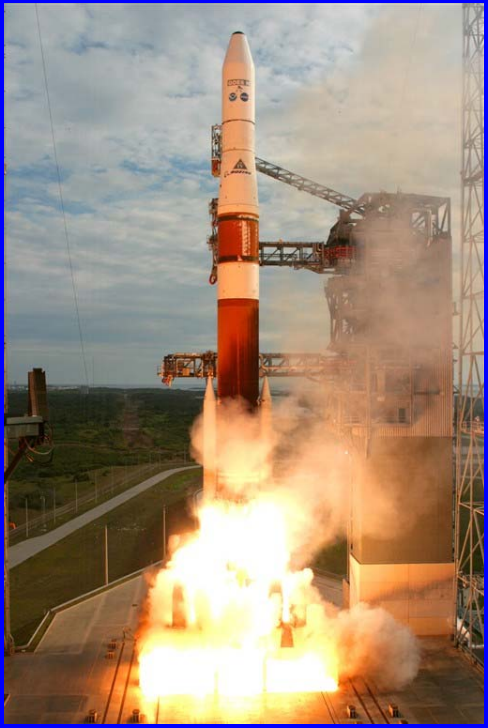
Goddard SFC, etc.

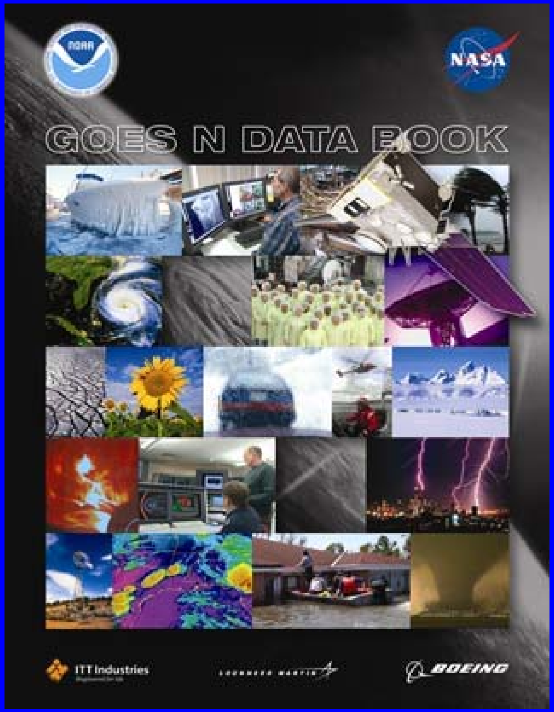
GOES-N Launched!

GOES-N (now GOES-13) Launched on May 24th, 2006

More information in the GOES-N Data Book:

http://goes.gsfc.nasa.gov/text/goes.databookn.html



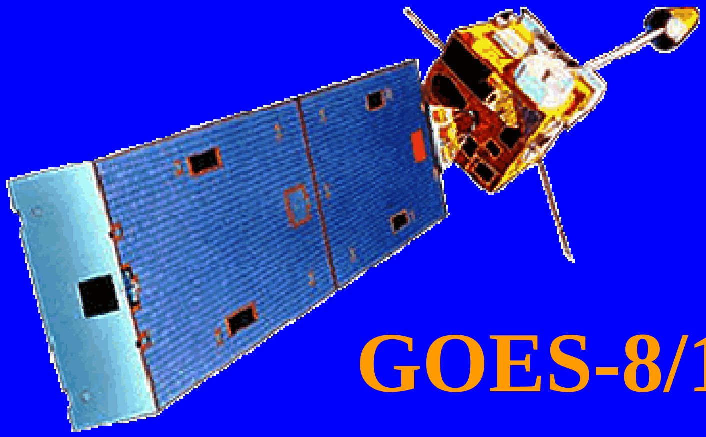


GOES-N

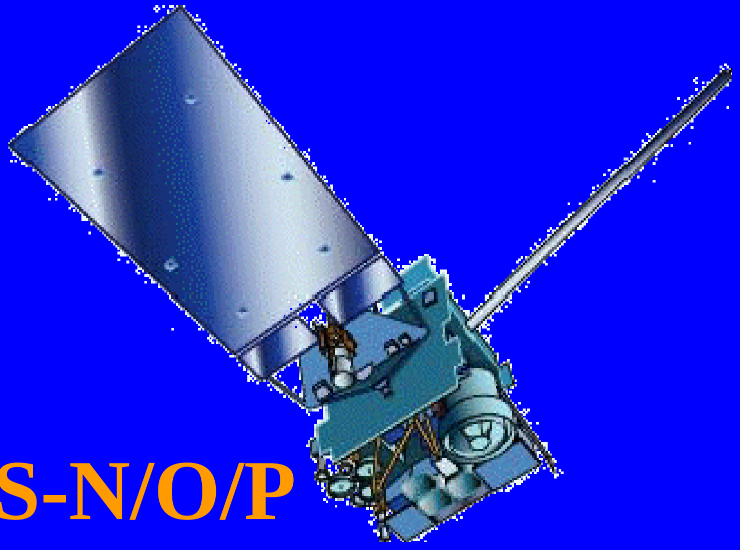
GOES-N/O/P will have similar instruments to GOES-8-12, but will be on a different spacecraft bus. The new bus will allow improvements to the navigation, registration, and the radiometrics.

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

The GOES-N PLT (Post Launch Test) is an important step in preparing for operational use of the radiances and products.

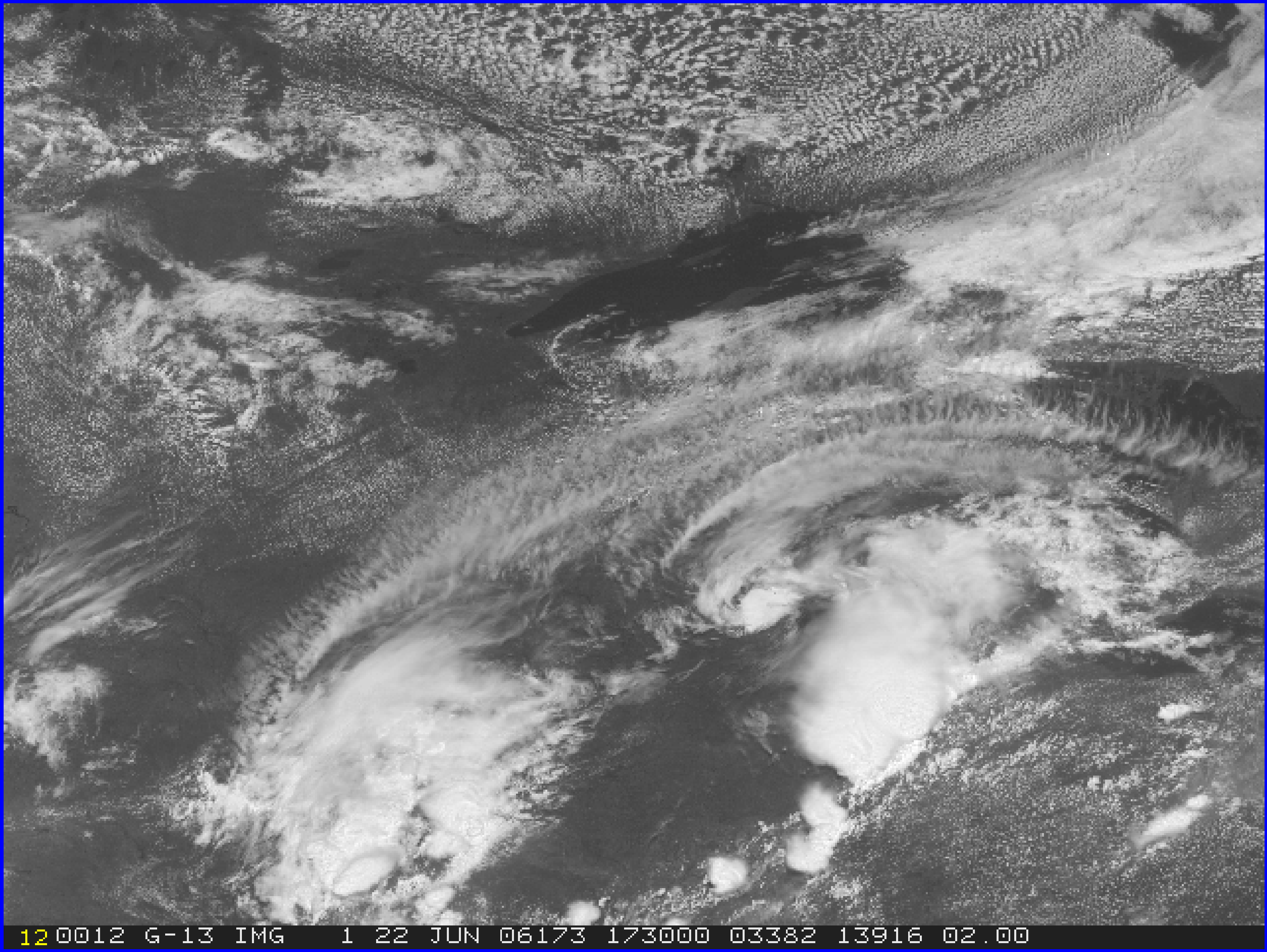


GOES-8/12

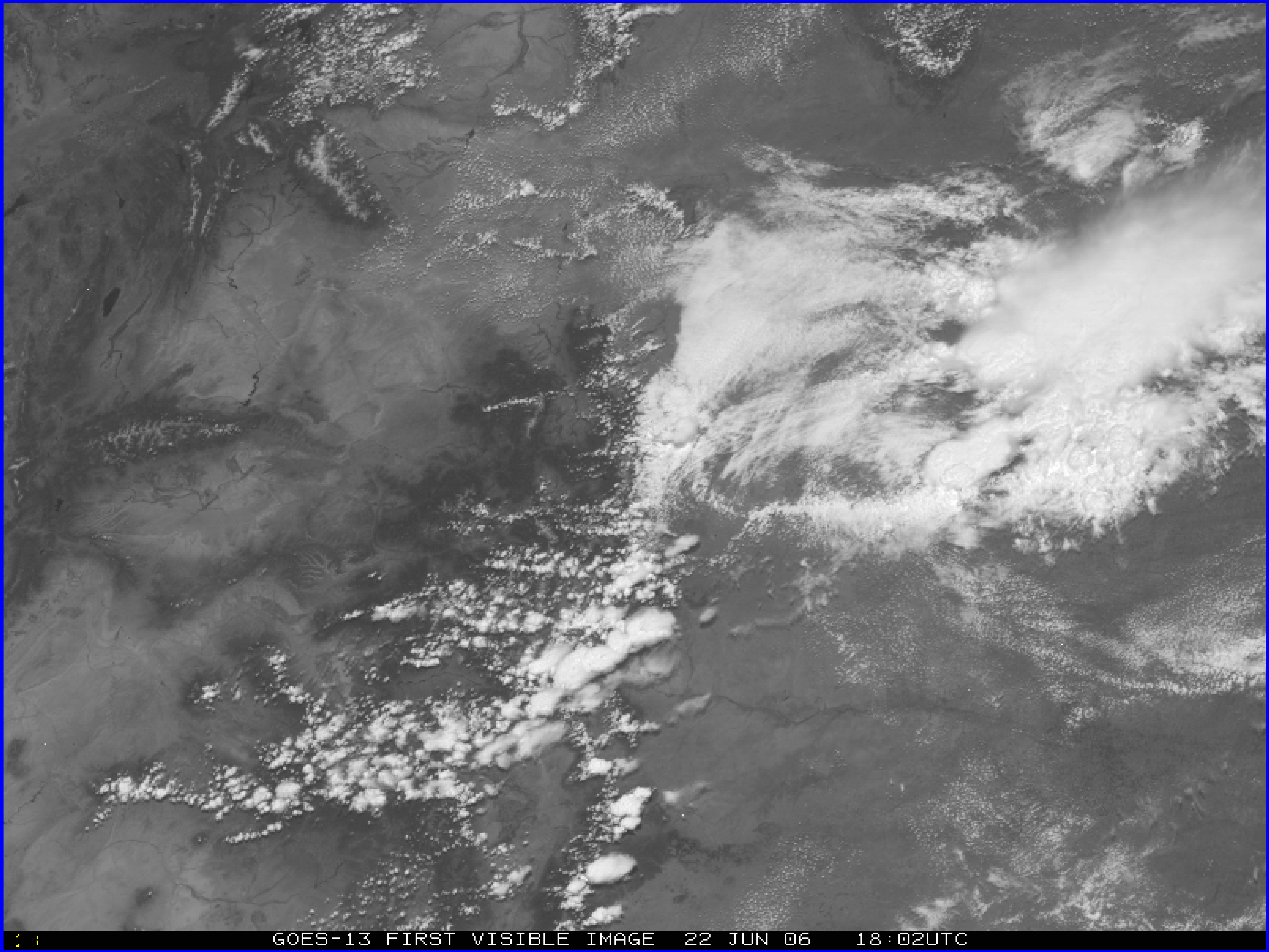


GOES-N/O/P

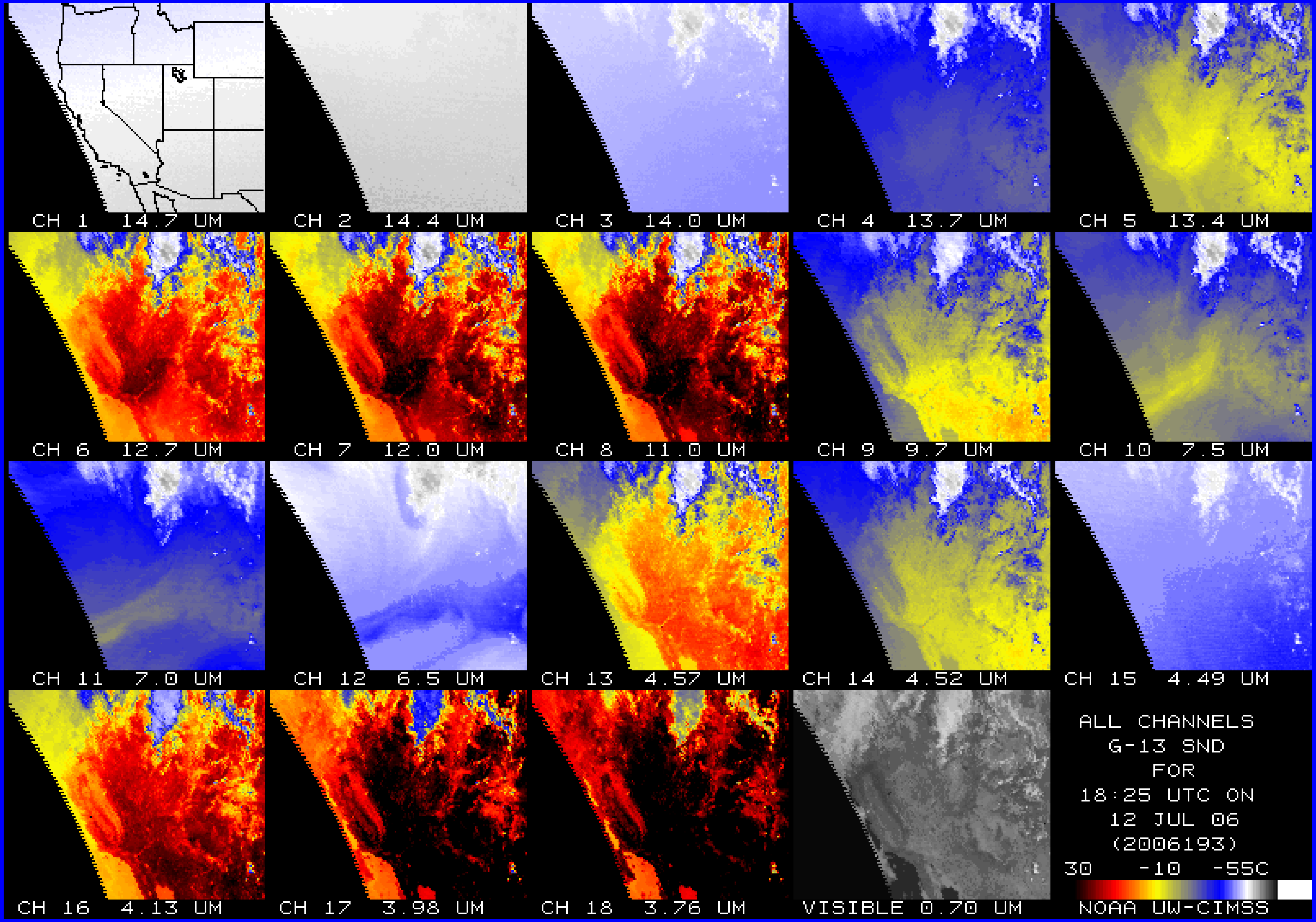
GOES-13 (Imager Visible)



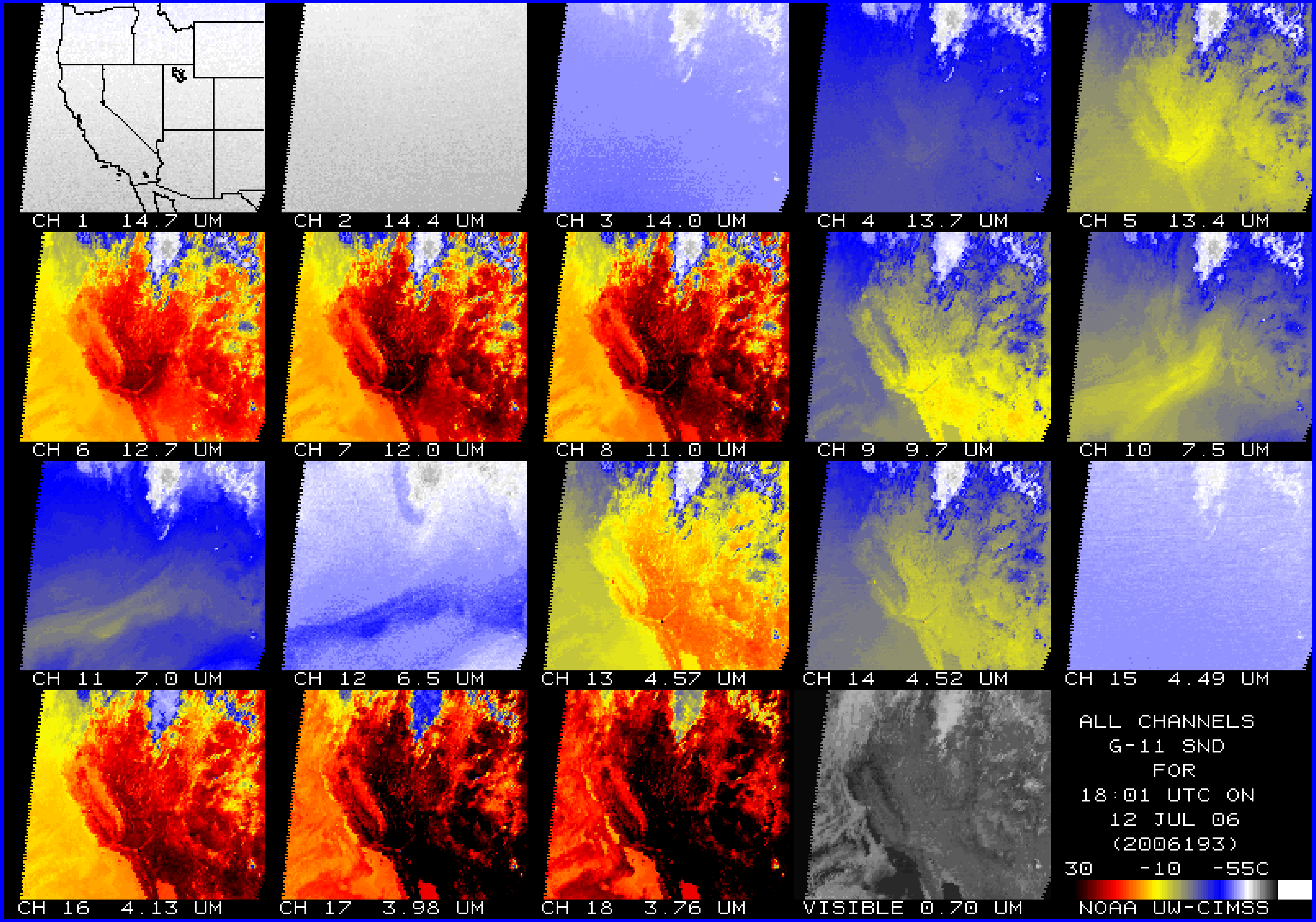
GOES-13 (Imager Visible)



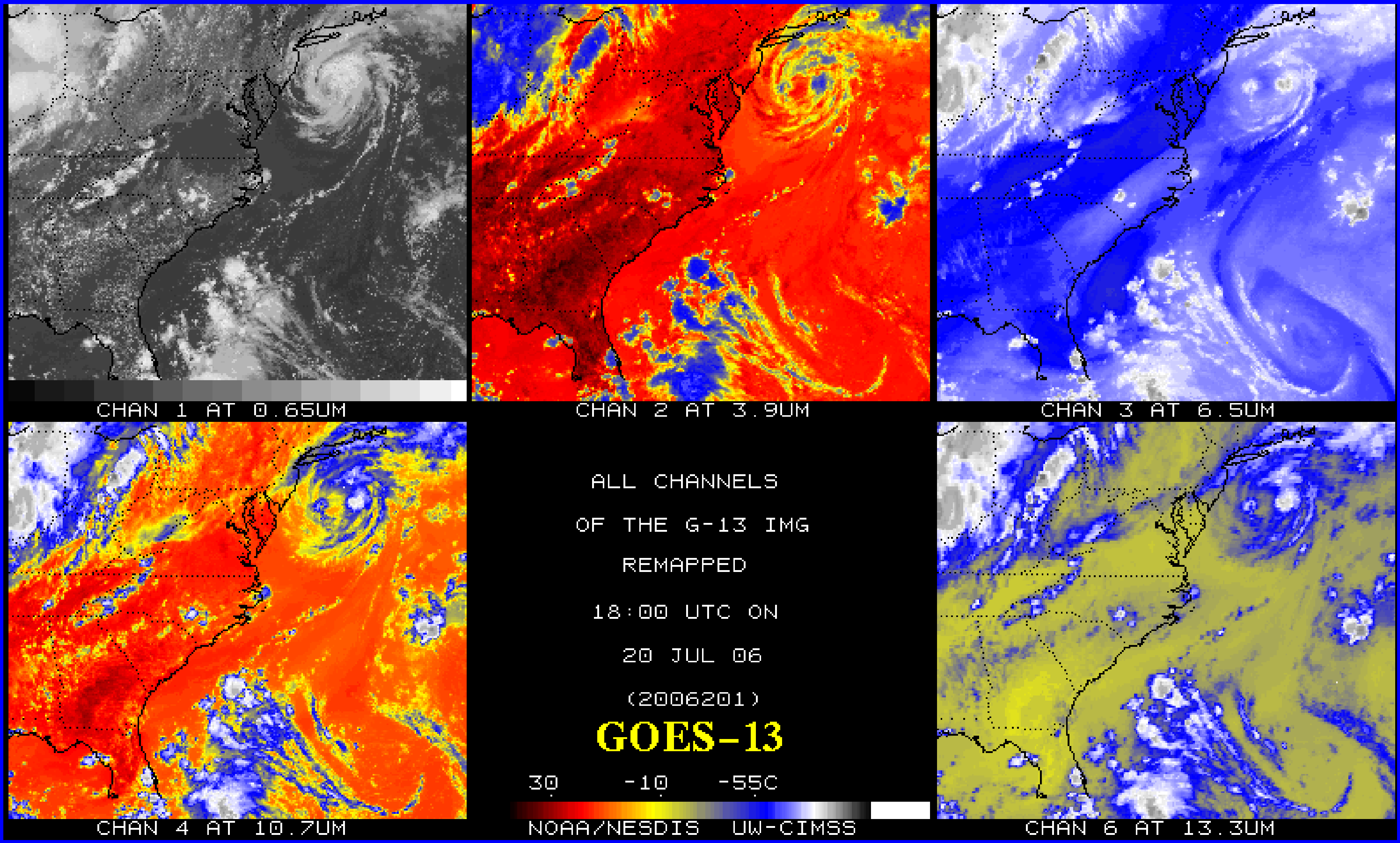
GOES-13 (Sounder)



GOES-11 (Sounder)

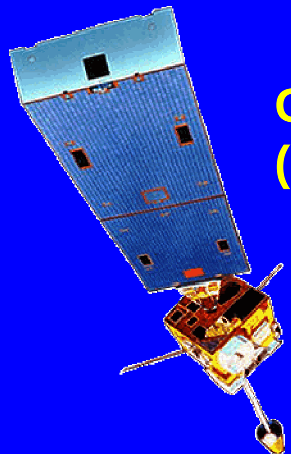


GOES-13 (Imager)

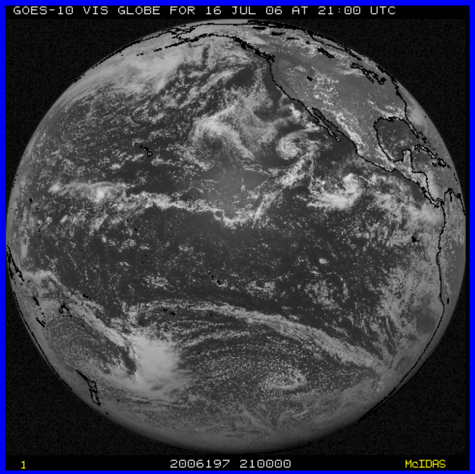


GOES Constellation

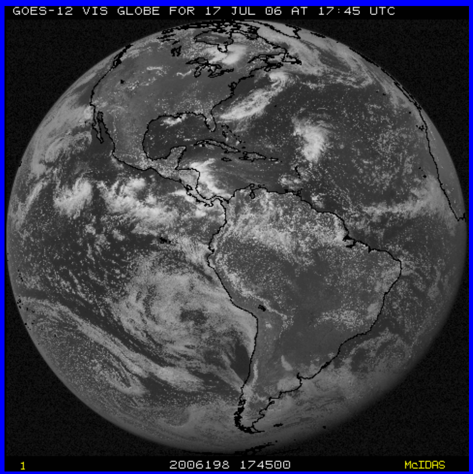
Operational

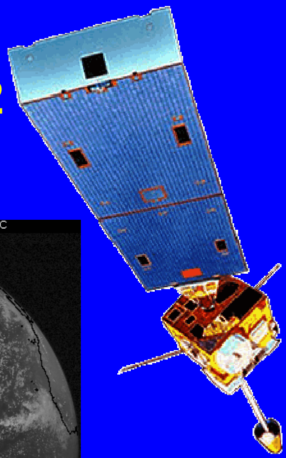


GOES-11
(135W)

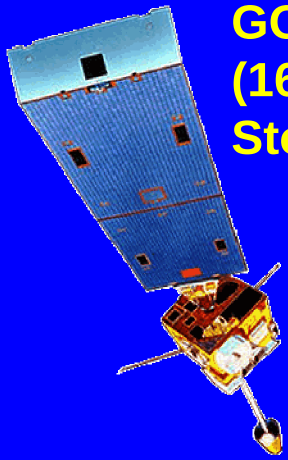


GOES-12
(75W)





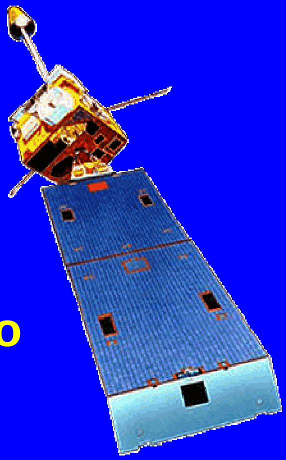
Operational



GOES-9
(160E)
Storage

GOES-13
(90W)
Testing

GOES-10
(Moving to
60W)
EOPA



GOES-R Series Baseline Instruments

- Advanced Baseline Imager (ABI)
- Hyperspectral Environmental Suite (HES)
- Geostationary Lightning Mapper (GLM)
- Solar Instrument Suite (SIS)
- Space Environment In Situ Suite (SEISS)
- *Auxiliary Services*

GOES-R Contractors:

System Program Definition and Risk Reduction (PDRR): Boeing, Lockheed Martin, Northrop-Grumman

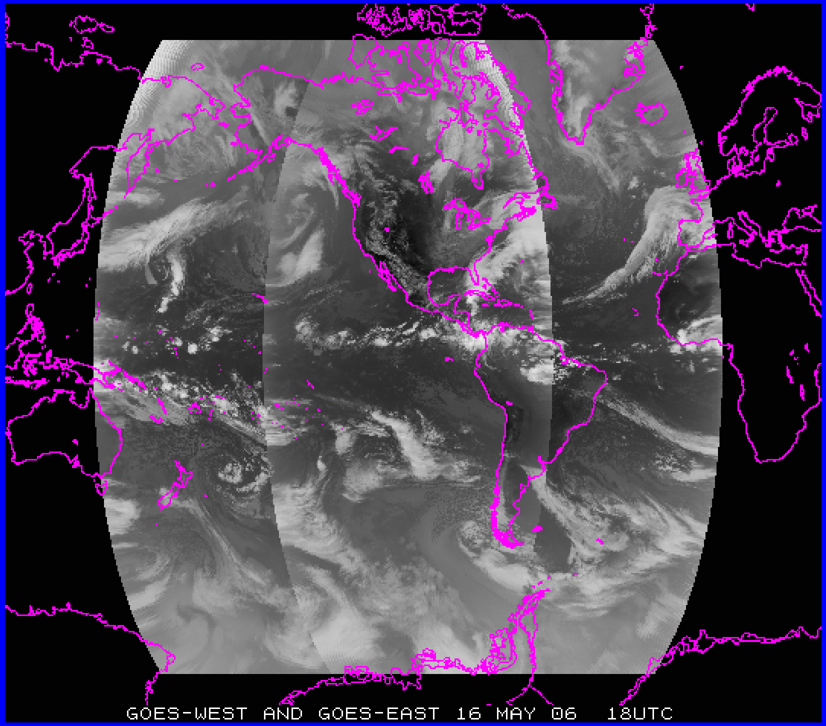
System Acquisition Contract: to be competitively awarded in August 2007

Instruments: ITT, BAE, Ball Aerospace, Lockheed Martin Advanced Technology Center

GOES-R Series Status

GOES-R

- **GOES-R series being developed to replace GOES-N series.**
- **First launch is no earlier than 2012**
- **Significant improvement in technology over GOES-I and GOES-N series**



Improvements over current capabilities

- **Imager**
  - Better resolution (4X), faster coverage (5X), more bands (3X) and more coverage simultaneously
- **Infrared Sounder**
  - Faster geographic coverage rate (5X), improved (3X) in vertical resolution
- **Coastal Water Monitoring**
  - 0.375 km true color vs 1 km monochrome
  - Transition of ocean color research satellite capability to operational platform
- **Lightning detection**
  - Continuous coverage of total lightning flash rate over land and water
- **Solar/Space Monitoring**
  - Better Imager (UV over X-Ray)
  - Better Heavy Ion detection, adds low energy electrons and protons

GOES-R Baseline Instruments to Meet User Requirements

- **Advanced Baseline Imager (ABI)**
  - Monitors severe weather, winds, hurricanes, hazards, etc.
  - Images clouds to support forecasts

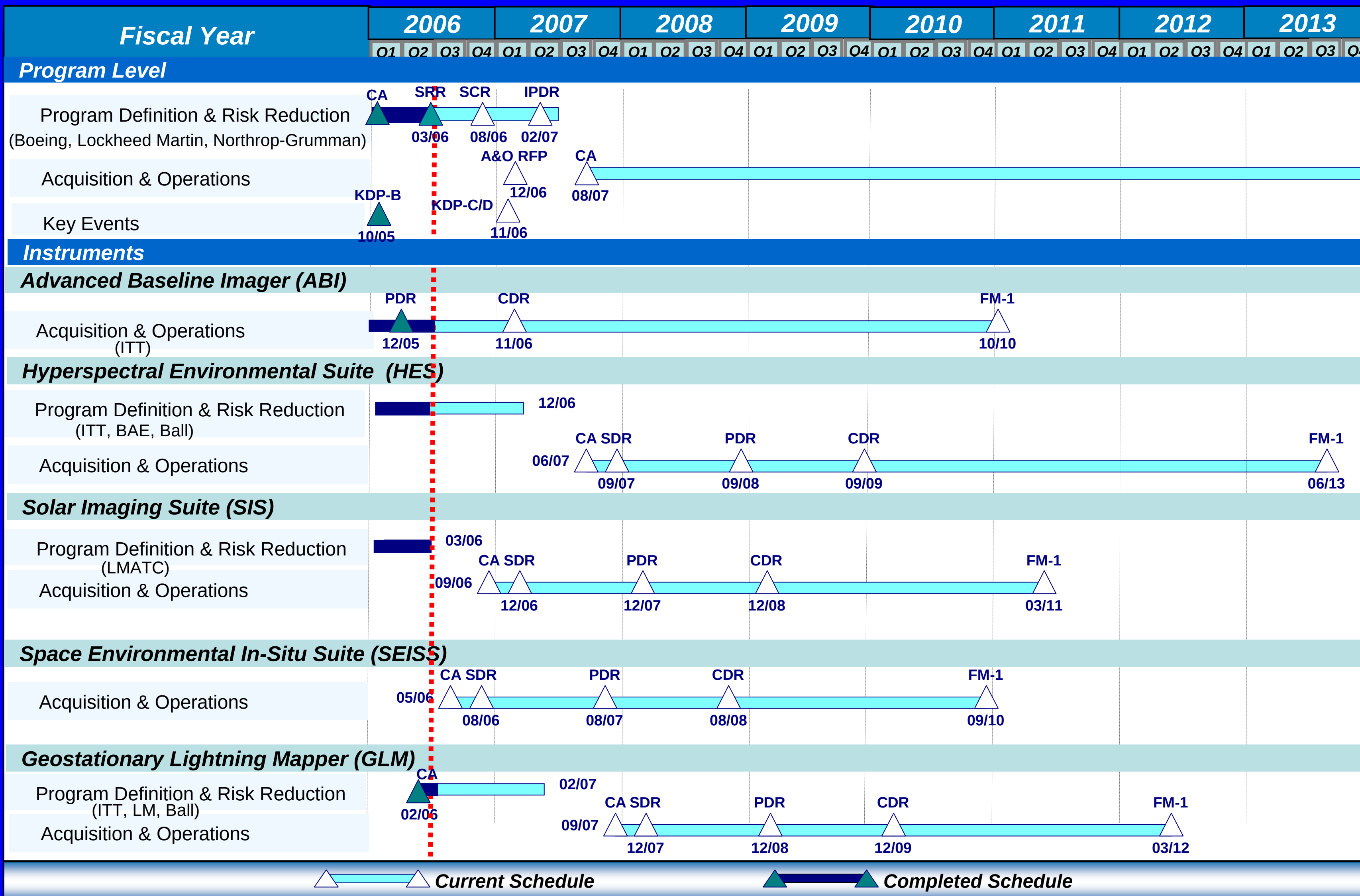
- **Hyperspectral Environmental Suite (HES)**
  - Provides atmospheric moisture and temperature profiles to support forecasts and climate monitoring
  - Monitors coastal regions for ecosystem health, water quality, coastal erosion, harmful algal blooms
  - Geostationary sampling of ocean color allows coastal resource management

- **Geostationary Lightning Mapper (GLM)**
  - Detects lightning strikes as an indicator of severe storms
  - Previous capability only existed on polar satellites

- **Solar Imaging Suite (SIS) and Space Environmental In-Situ Suite (SEISS)**
  - Images the sun and measures solar output to monitor solar storms (SIS)
  - Measures magnetic fields and charged particles (SEISS)
  - Enables early warnings for satellite and power grid operations, telecom services, astronauts, and airlines

Instrument Schedule

As of: 3/31/2006



Legend

CA: Contract Award **SDR**: System Design Review **PDR**: Preliminary Design Review **CDR**: Comprehensive Design Review **FM-1**: Flight Model 1 delivery

SRR: System Requirements Review SCR: System Concepts Review IPDR: Interim Preliminary Design Review

GOES-R Series Baseline Instruments

- **Advanced Baseline Imager (ABI)**
- Hyperspectral Environmental Suite (HES)
- Geostationary Lightning Mapper (GLM)
- Solar Instrument Suite (SIS)
- Space Environment In Situ Suite (SEISS)

Advanced Baseline Imager (ABI)

- ITT has been selected to build the ABIs
- Completed a successful System Preliminary Design Review (December 2005)

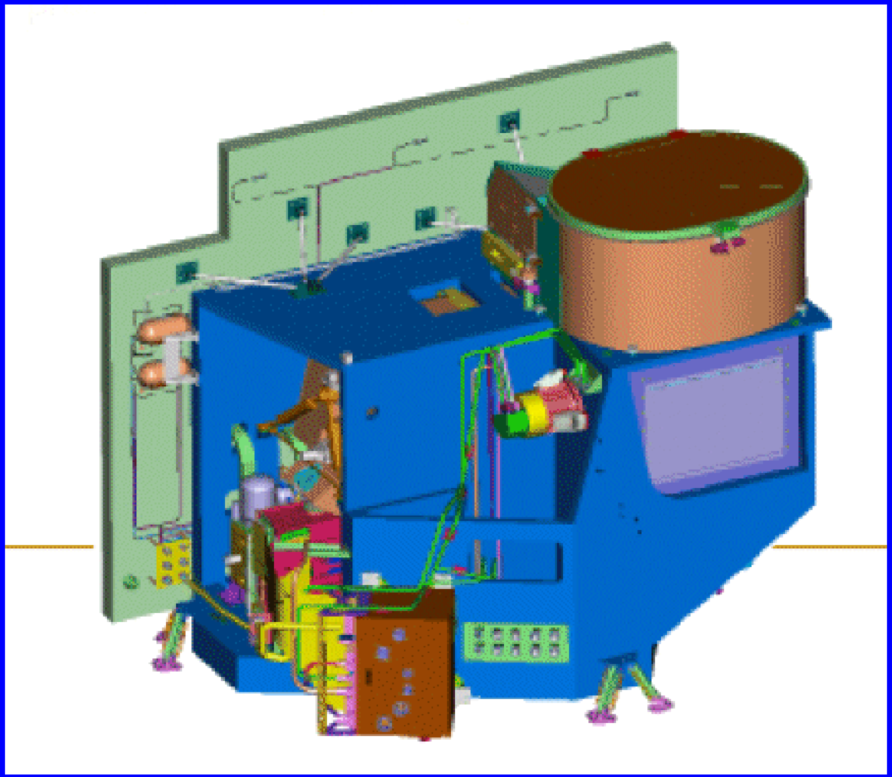
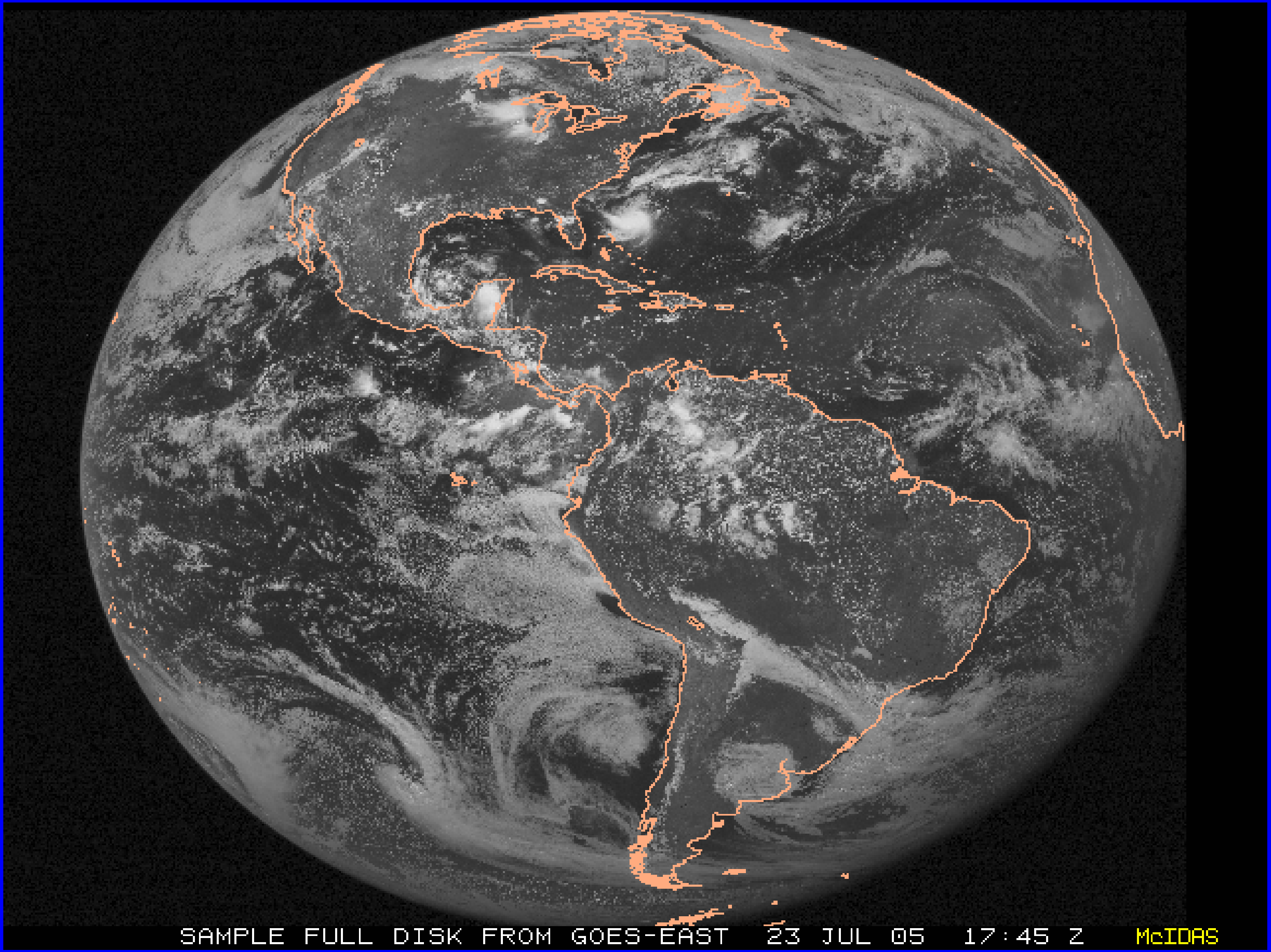


Figure courtesy of ITT Industries

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	Every 3 hours
CONUS	12 per hour	~4 per hour
Mesoscale	Every 30 sec	n/a
Visible (reflective bands)		
On-orbit calibration	Yes	No

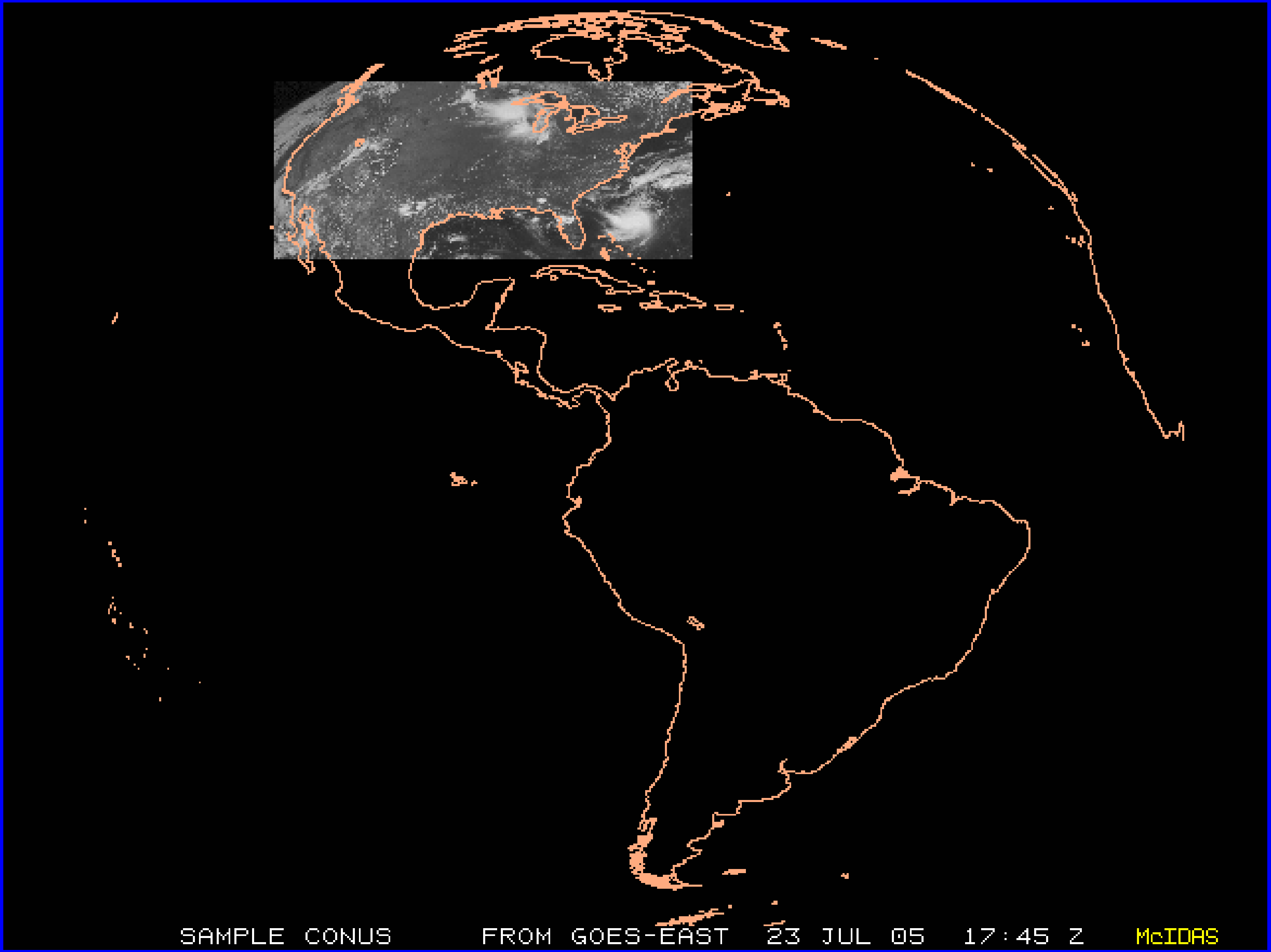


ABI scans about 5 times faster than the current GOES imager

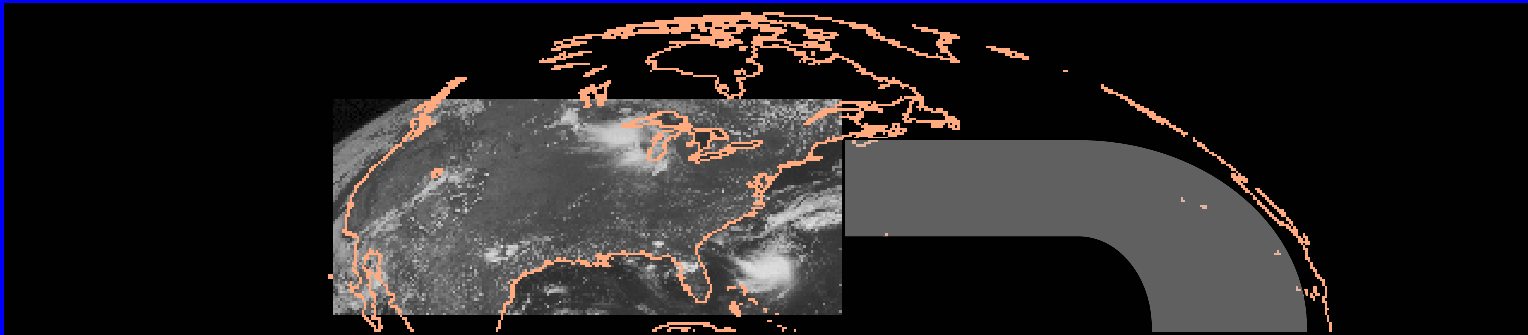
There are two anticipated scan modes for the ABI:

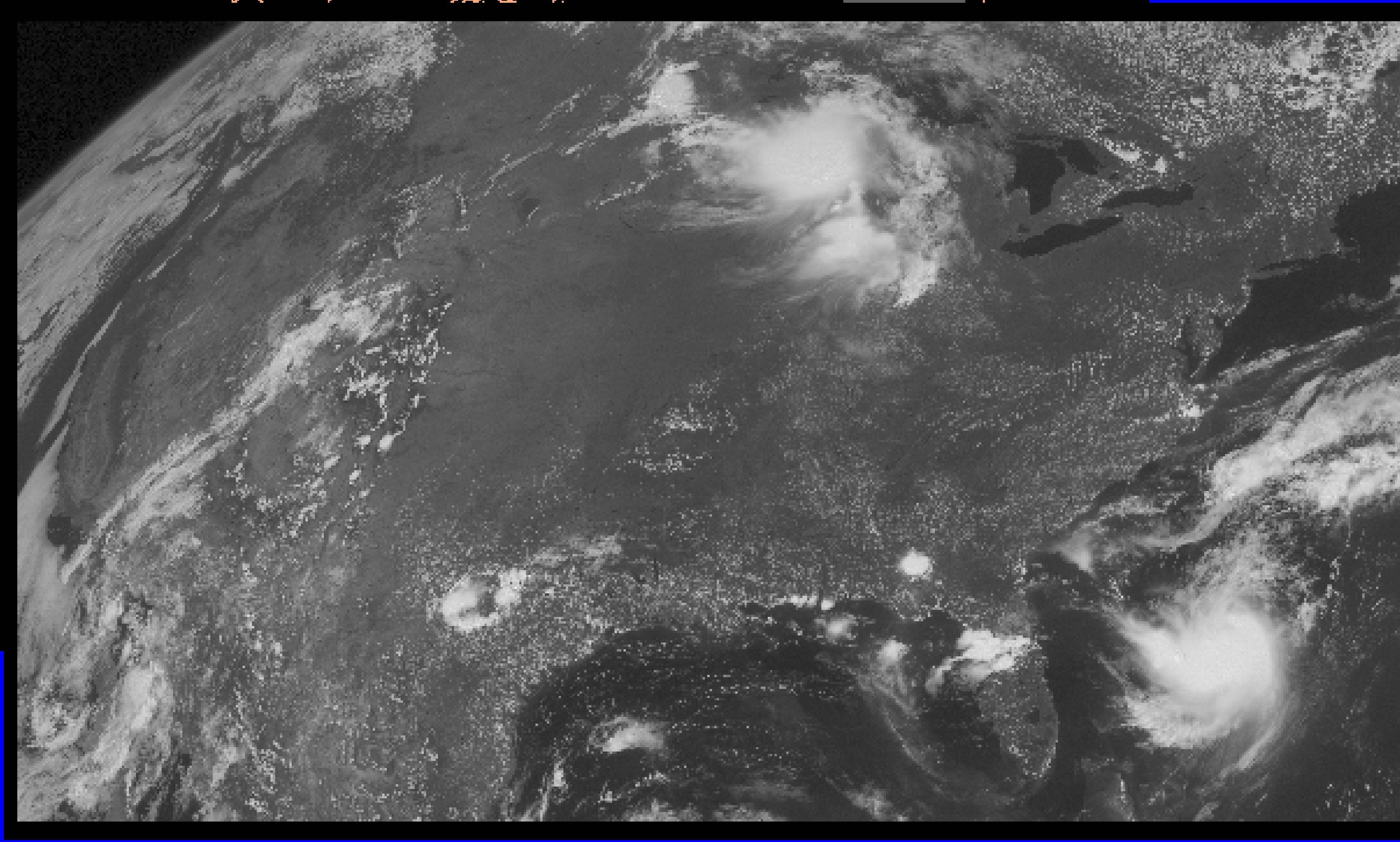
- Full disk images every 15 minutes + 5 min CONUS images + mesoscale.

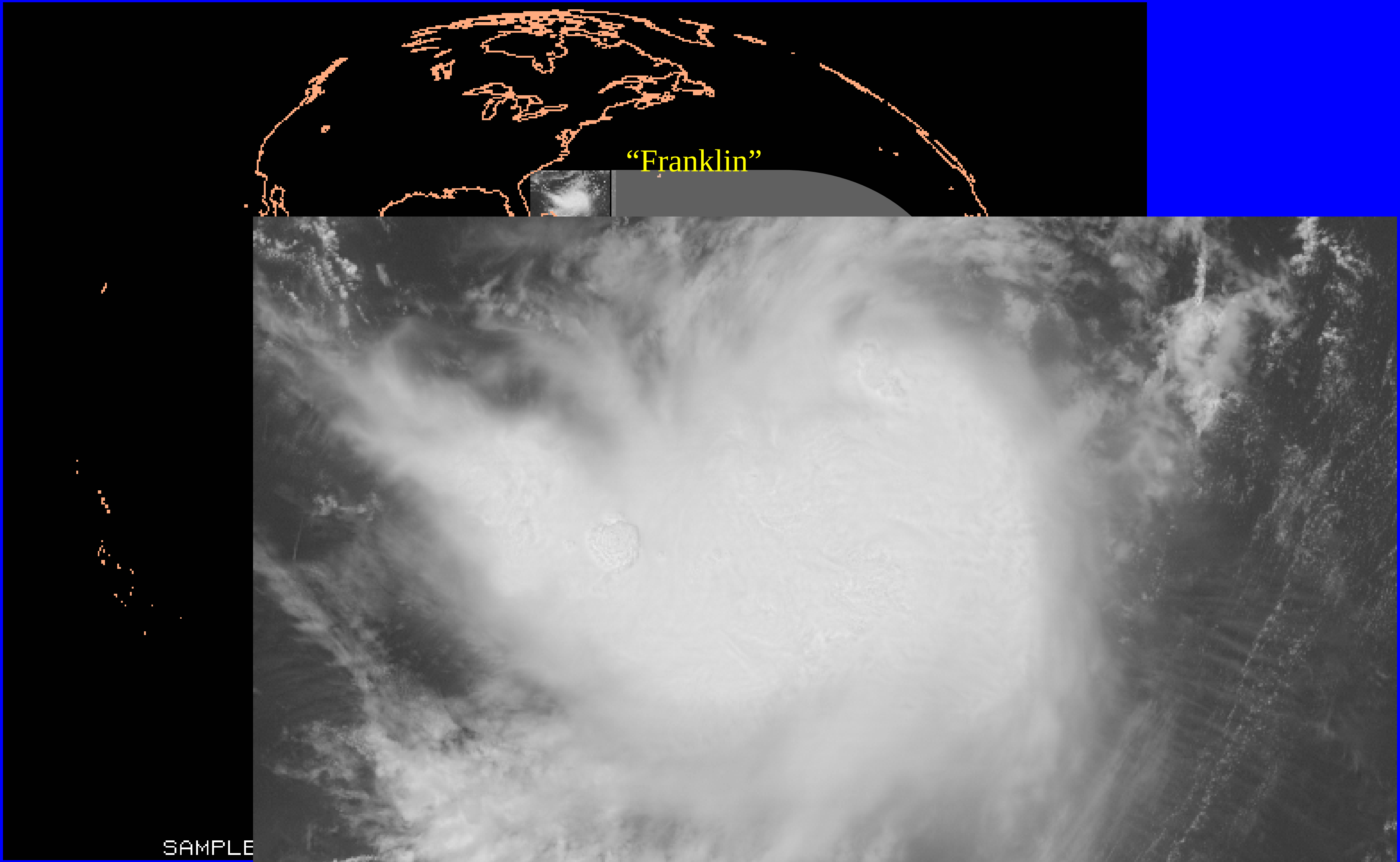
or - Full disk every 5 minutes.



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.



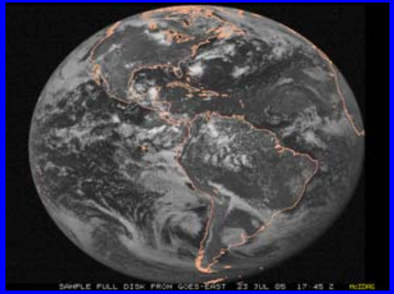


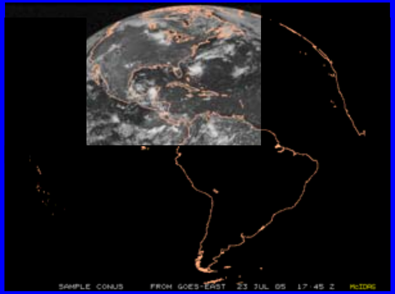


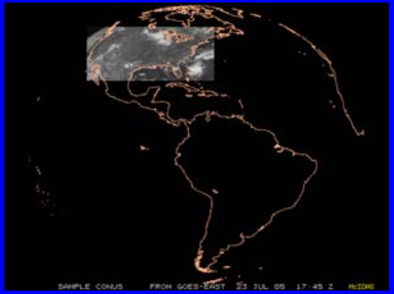
Mesoscale images every 30 seconds for rapidly changing phenomena (thunderstorms, hurricanes, fires, etc). Current GOES can not offer these rapid scans while still scanning other important regions

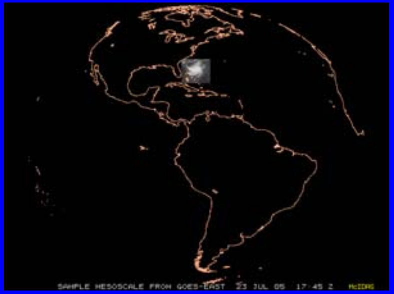
Imager Coverage in ~30 minutes

	Current Imager (Rapid Scan mode)	**Future Imager** ("Flex" mode)
Full Disk	0	2
Northern Hemi	1	-
CONUS	3	6
Mesoscale	0	60


Full Disk


N. Hemisphere


CONUS


Mesoscale

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

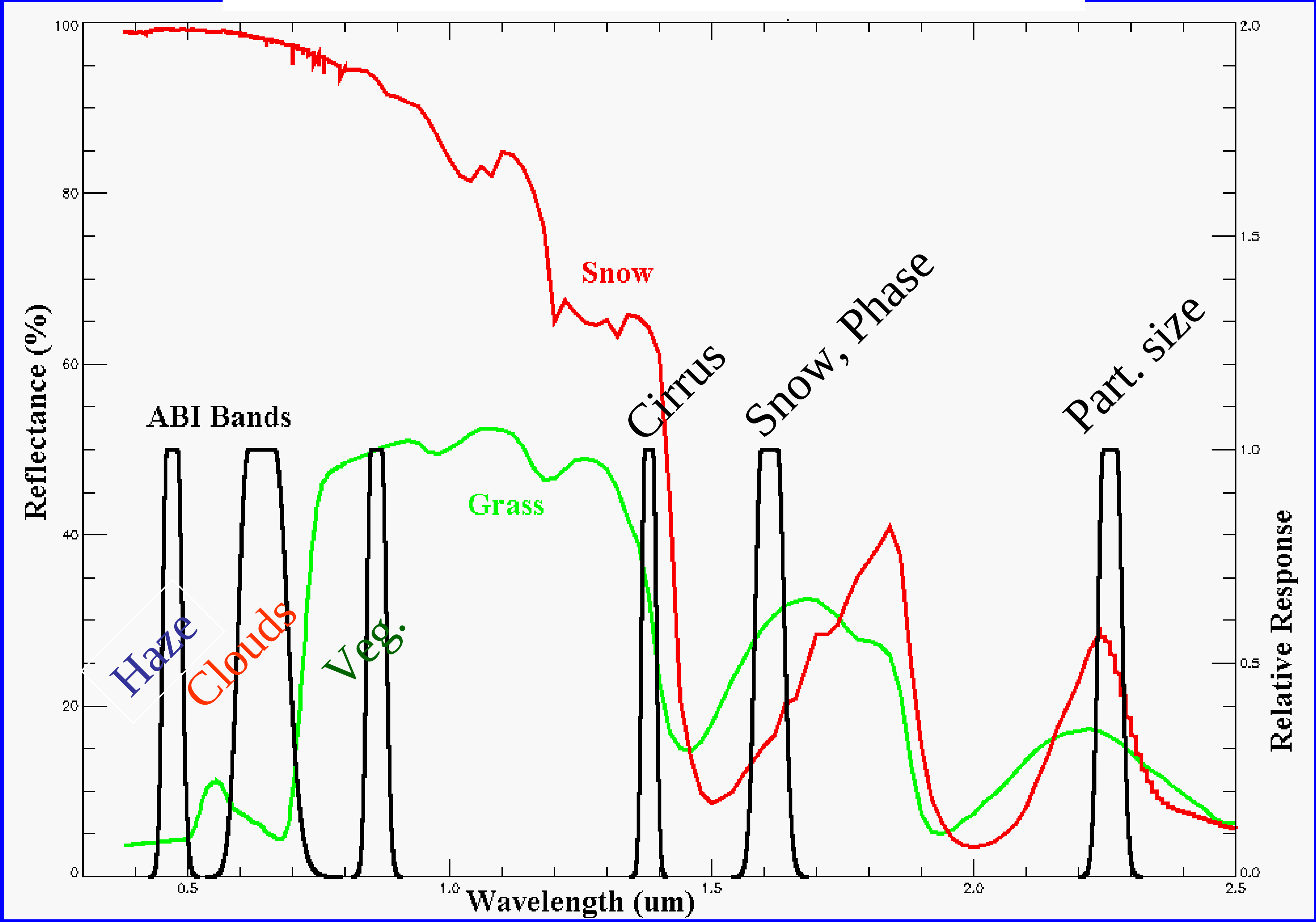
Schmit et al, 2005

ABI IR Bands

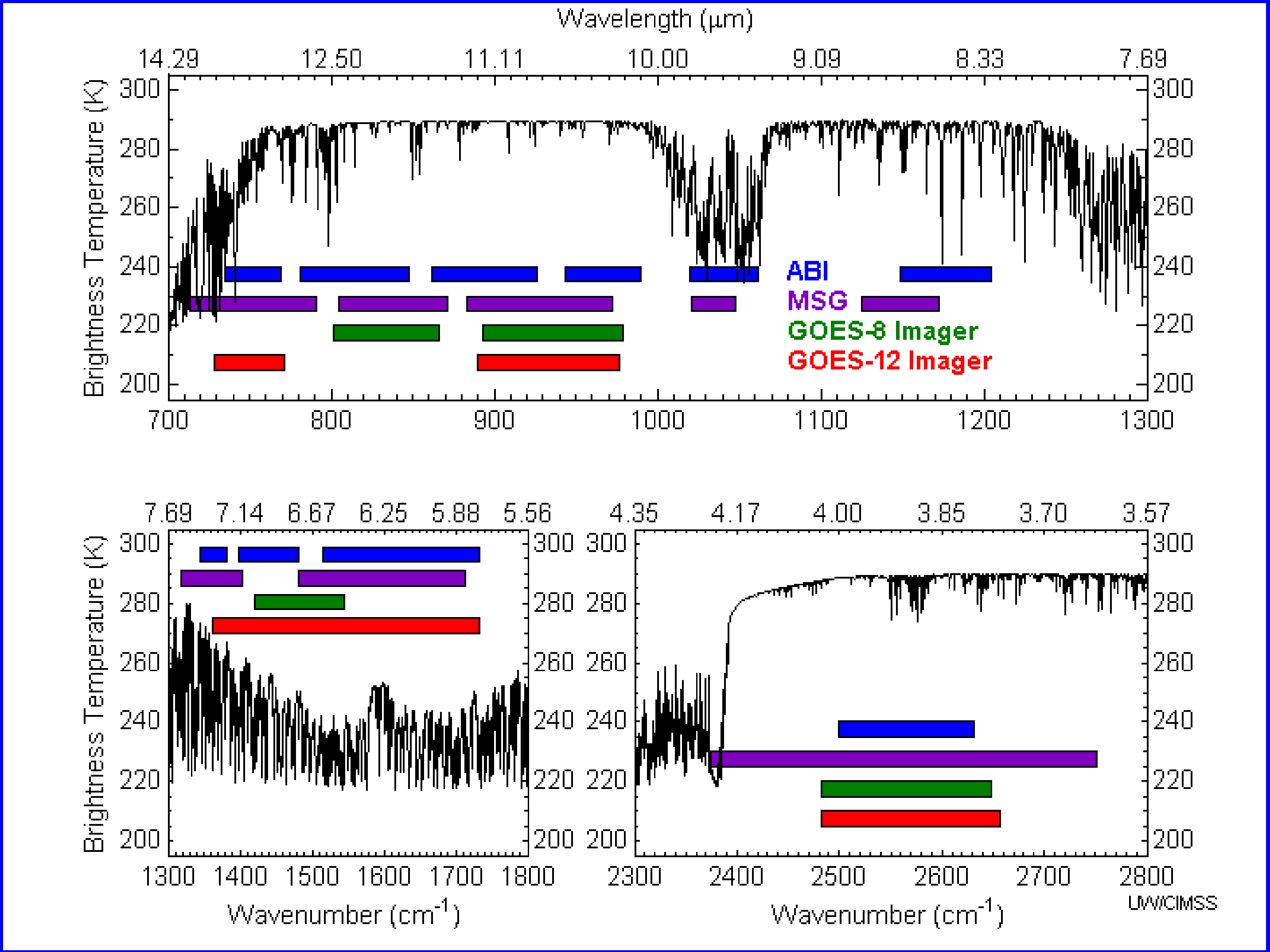
7	3.80–4.00	3.90	2	Surface and cloud, fog at night, fire, winds
8	5.77–6.6	6.19	2	High-level atmospheric water vapor, winds, rainfall
9	6.75–7.15	6.95	2	Midlevel atmospheric water vapor, winds, rainfall
10	7.24–7.44	7.34	2	Lower-level water vapor, winds, and SO_2
11	8.3–8.7	8.5	2	Total water for stability, 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

Visible and near-IR channels on the ABI

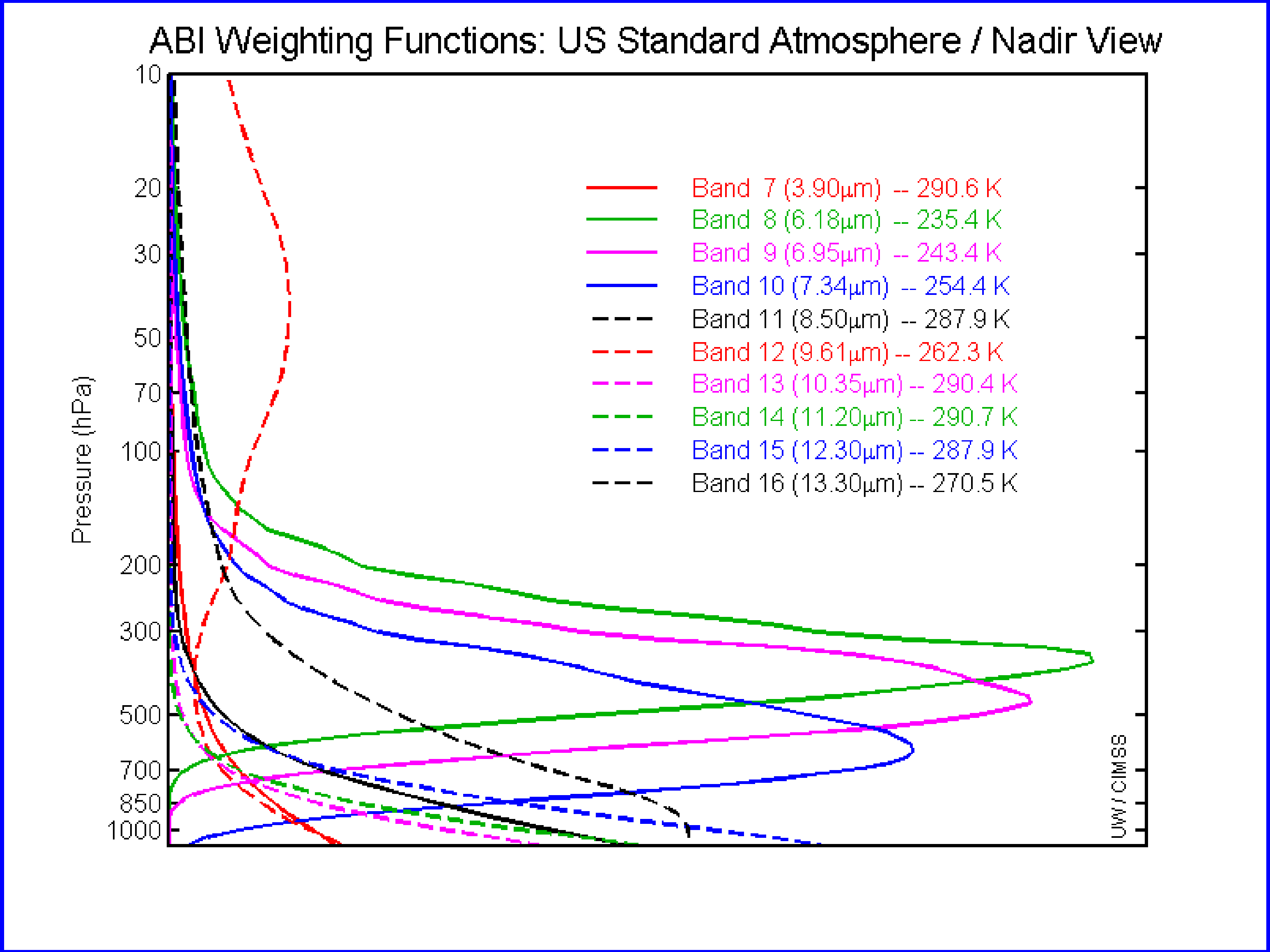


The ABI visible and near-IR bands have many uses.

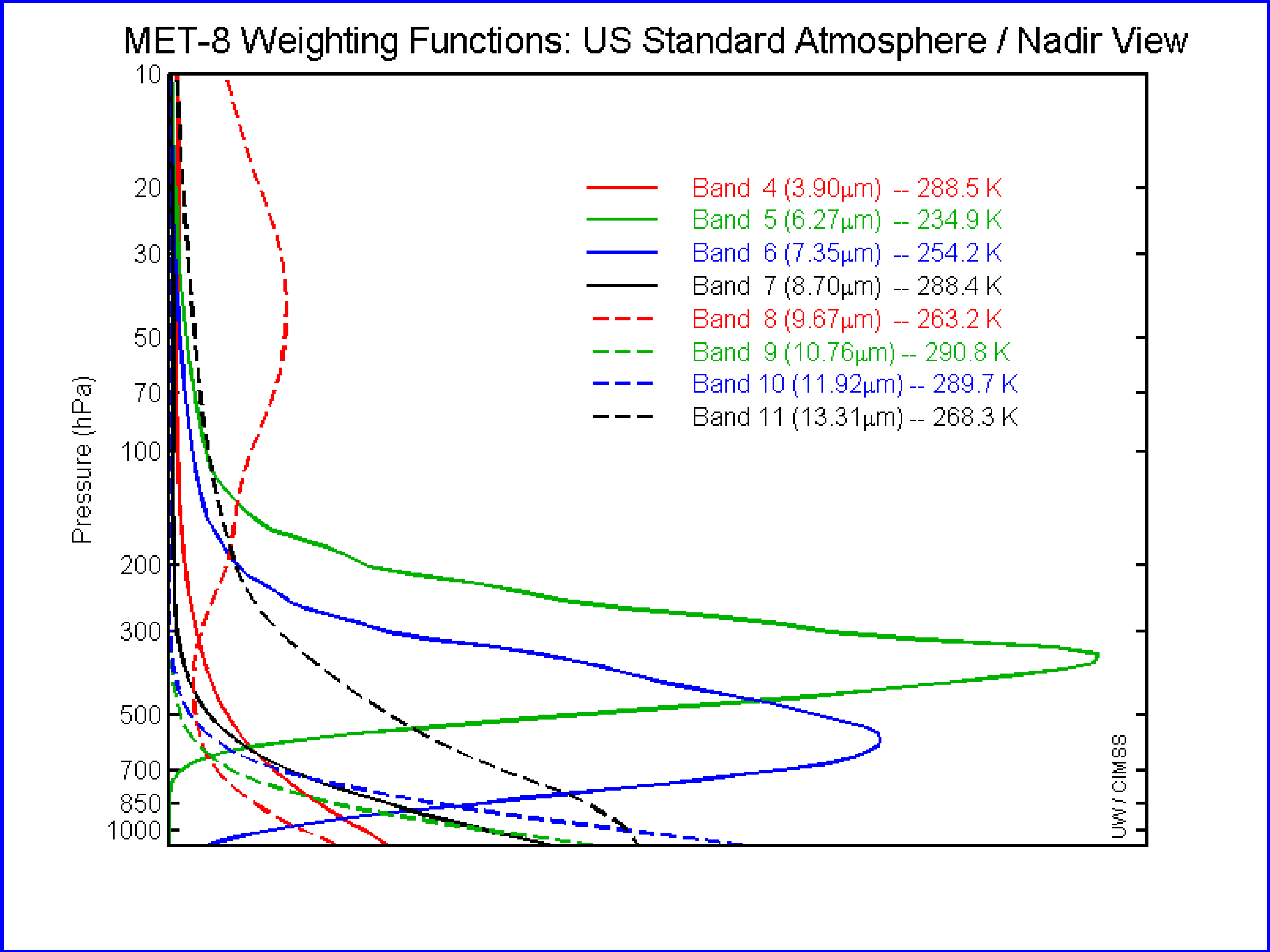


While there are differences, there are also many similarities for the spectral bands on MET-8 and the Advanced Baseline Imager (ABI). Both the MET-8 and ABI have many more bands than the current operational GOES imagers.

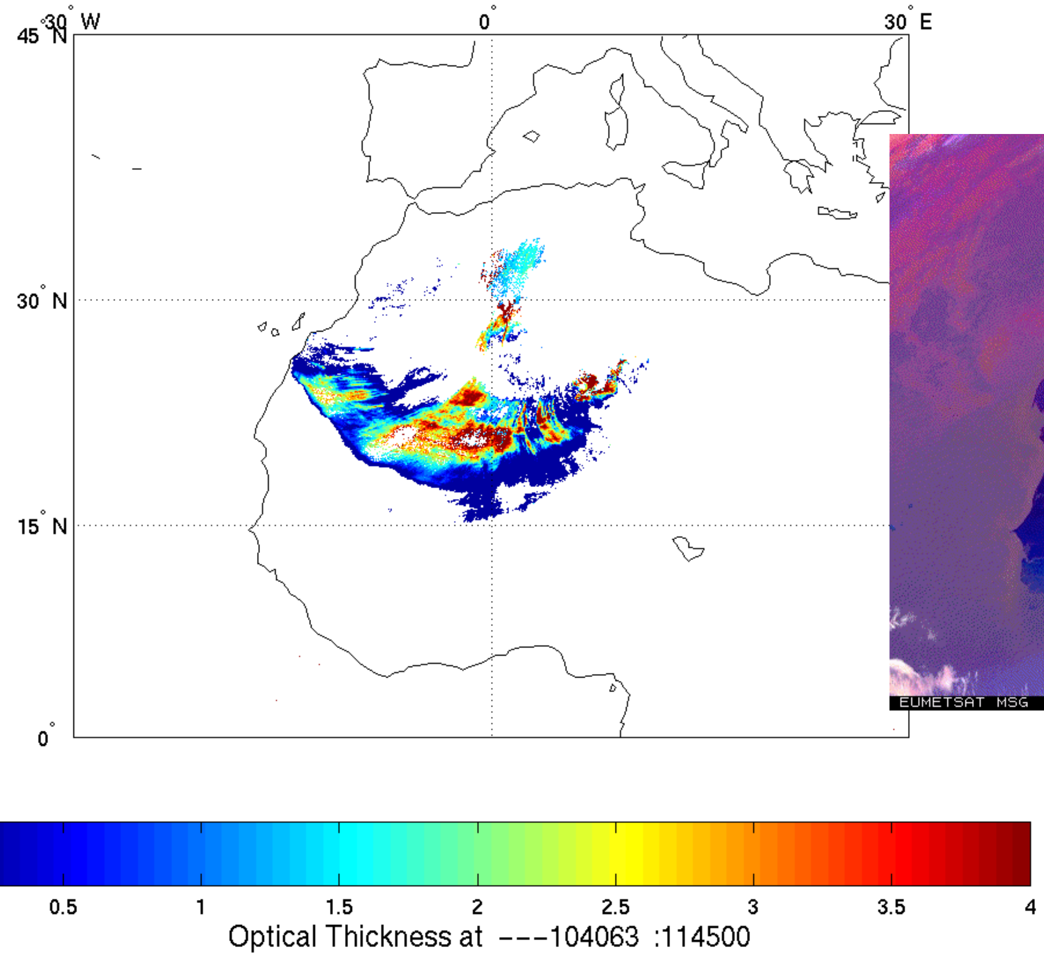
GOES-R ABI Weighting Functions



MET-8 IR Weighting Functions



Aerosol/Dust Optical Thickness Retrieval
Results from SEVIRI@EUMETSAT



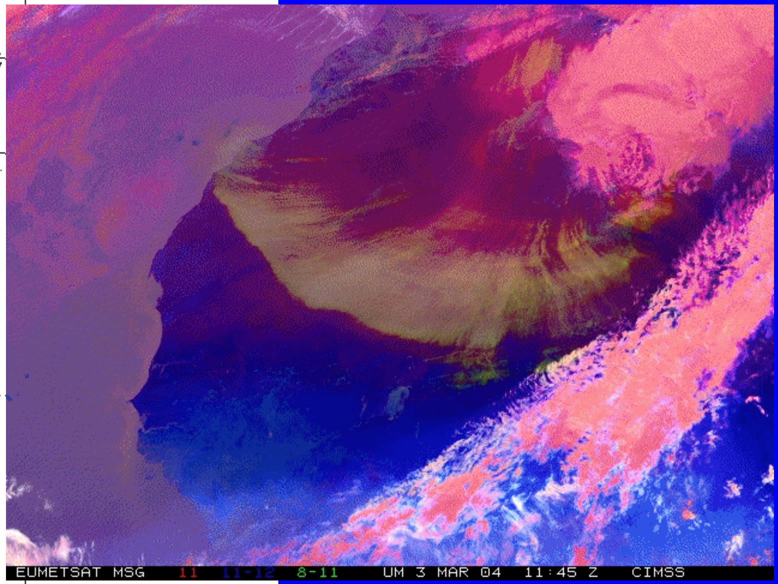
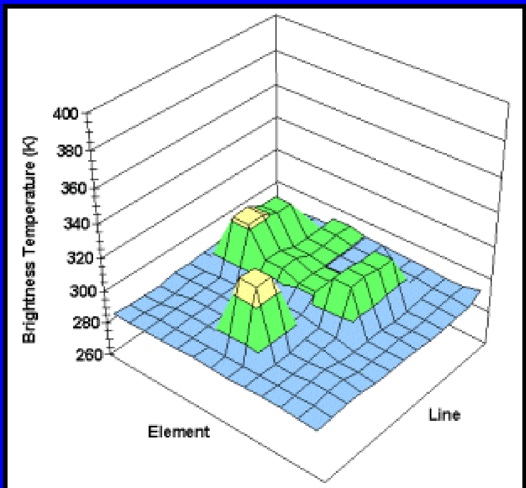
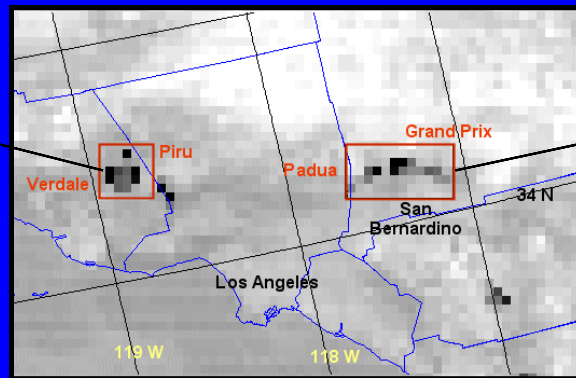


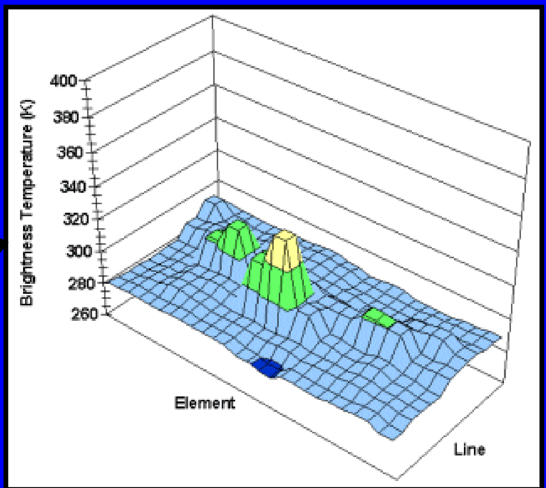
Figure courtesy of J. Li and P. Zhang

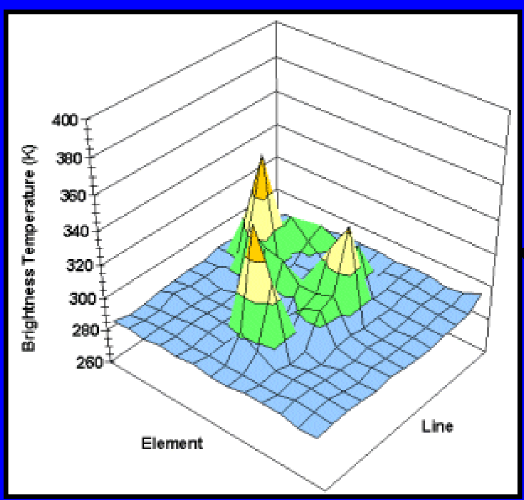
GOES-R and GOES-I/M Simulations of Southern California Fires



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







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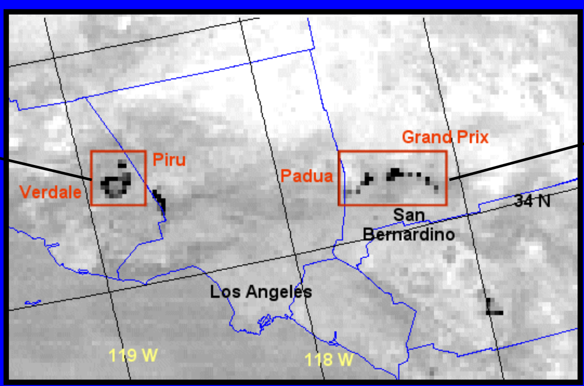
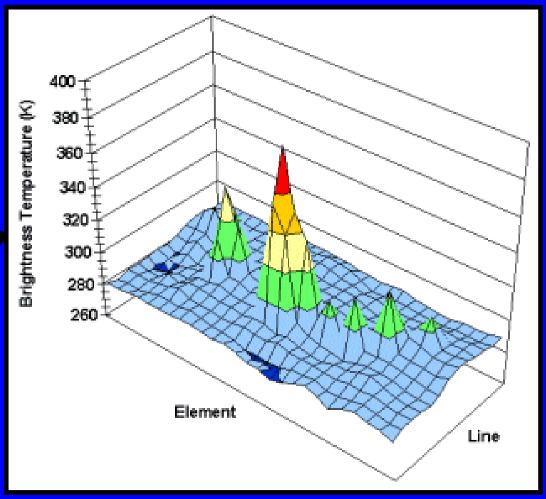




Brightness Temperature (K)

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

Figure courtesy of Elaine Prins

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

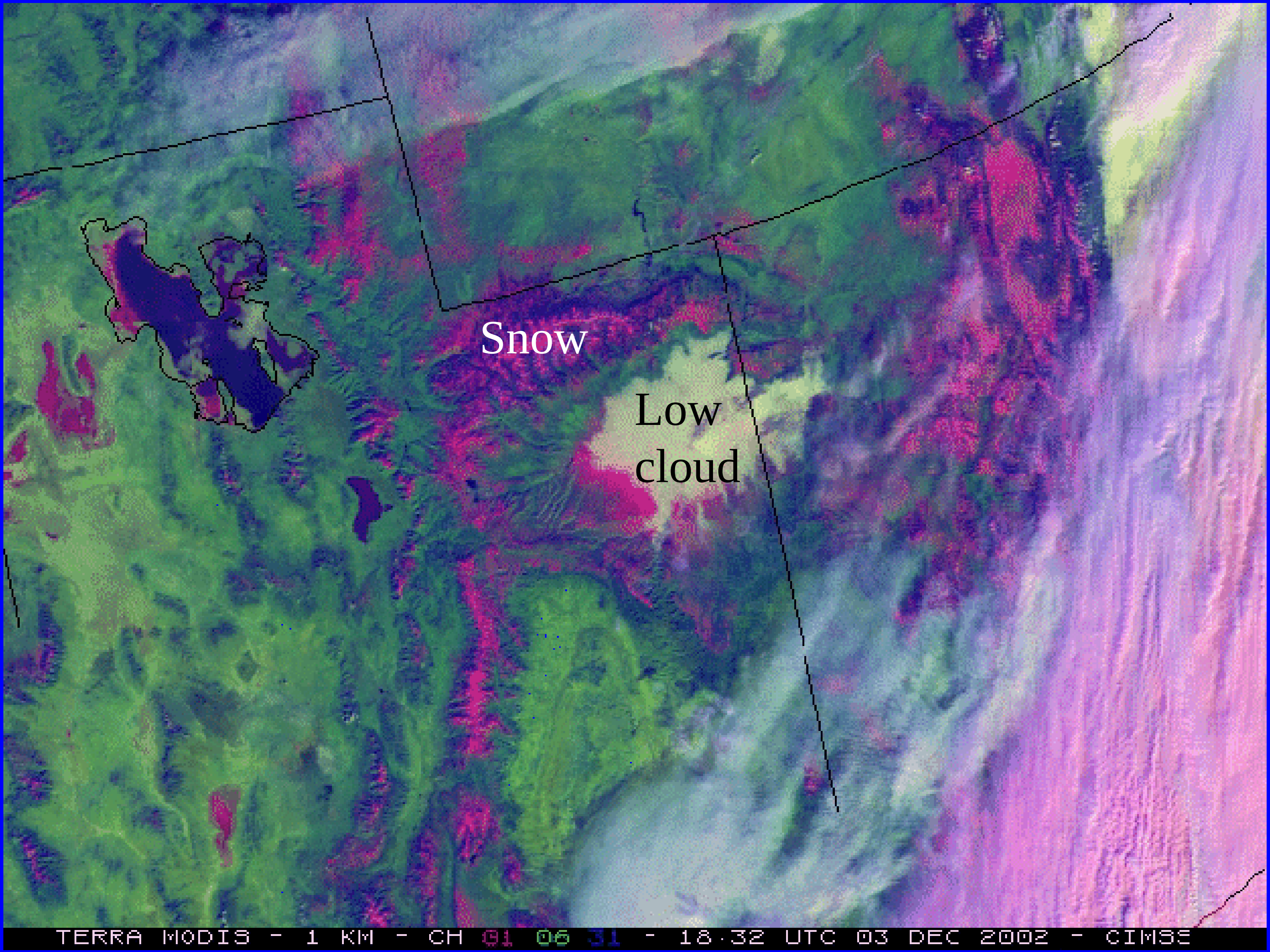
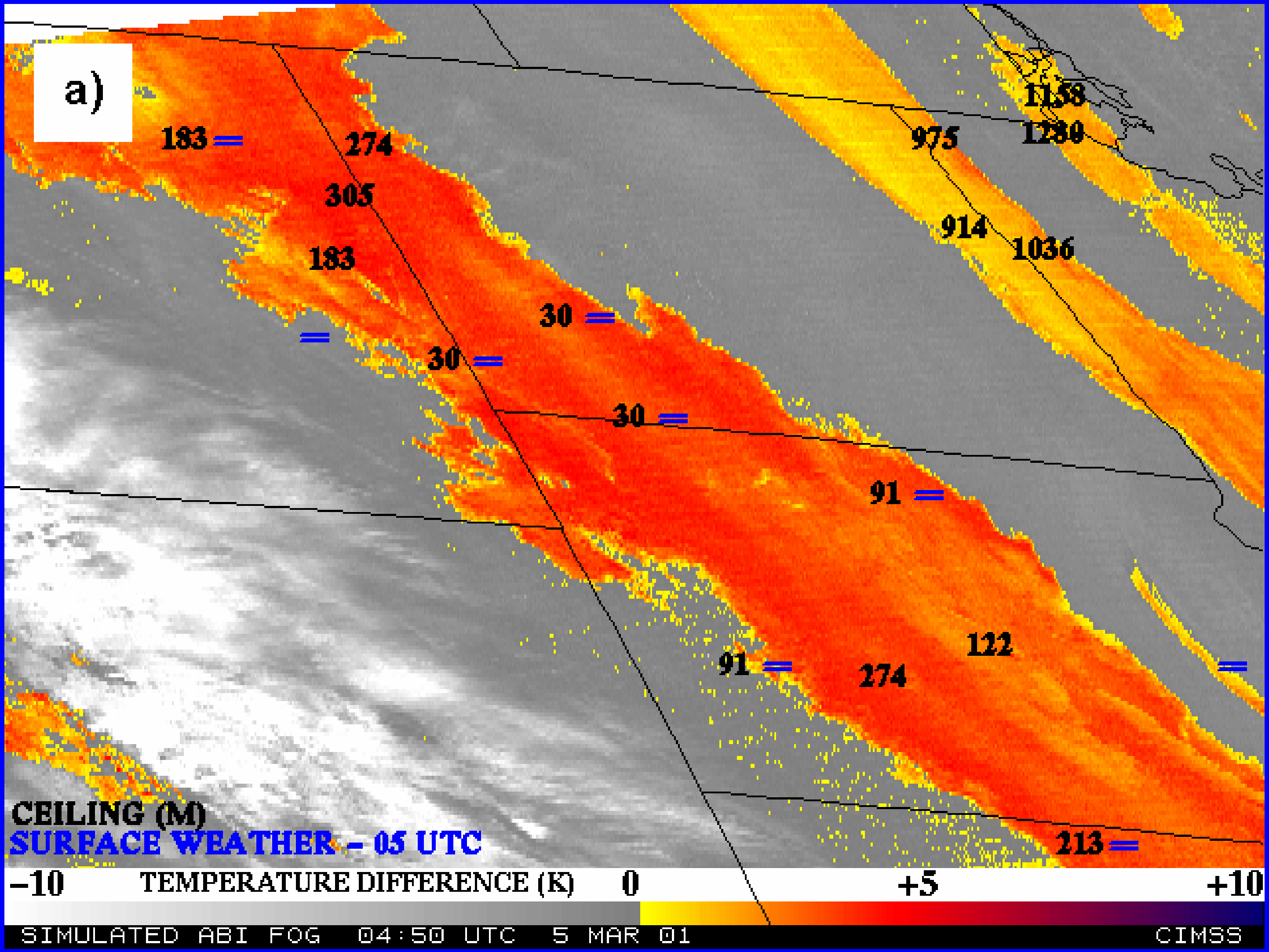


Figure courtesy of S. Bachmeier

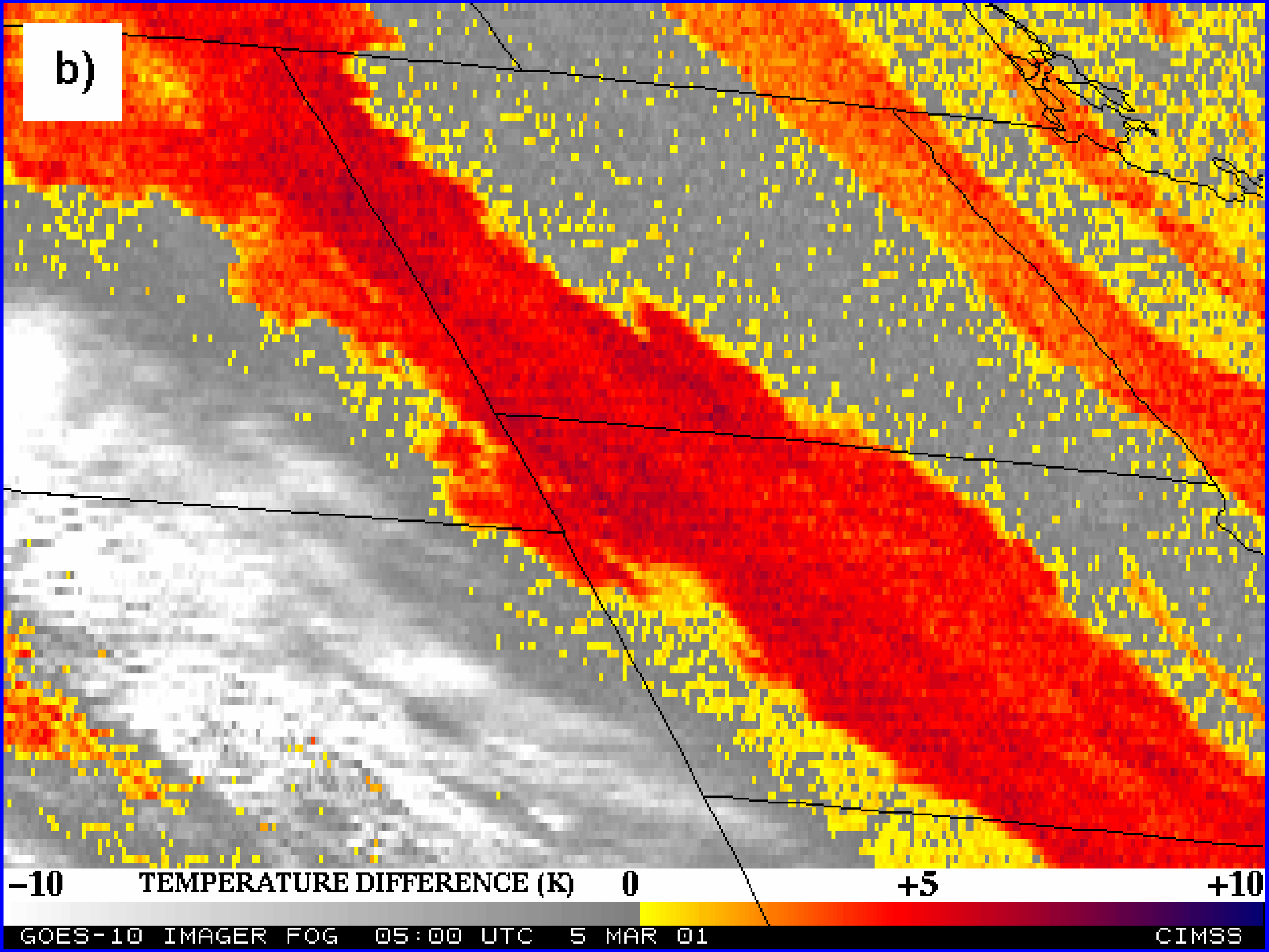
Nocturnal Fog/Stratus Over the Northern Plains



"ABI" 4 minus 11 µm Difference

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

Nocturnal Fog/Stratus Over the Northern Plains

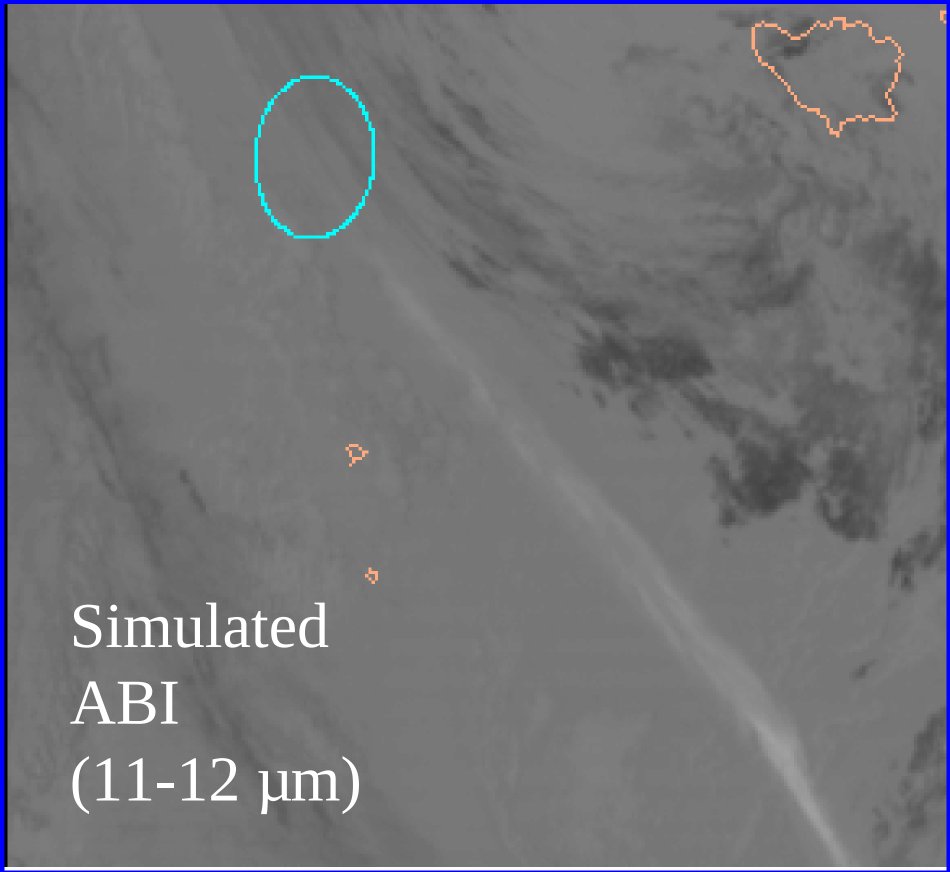


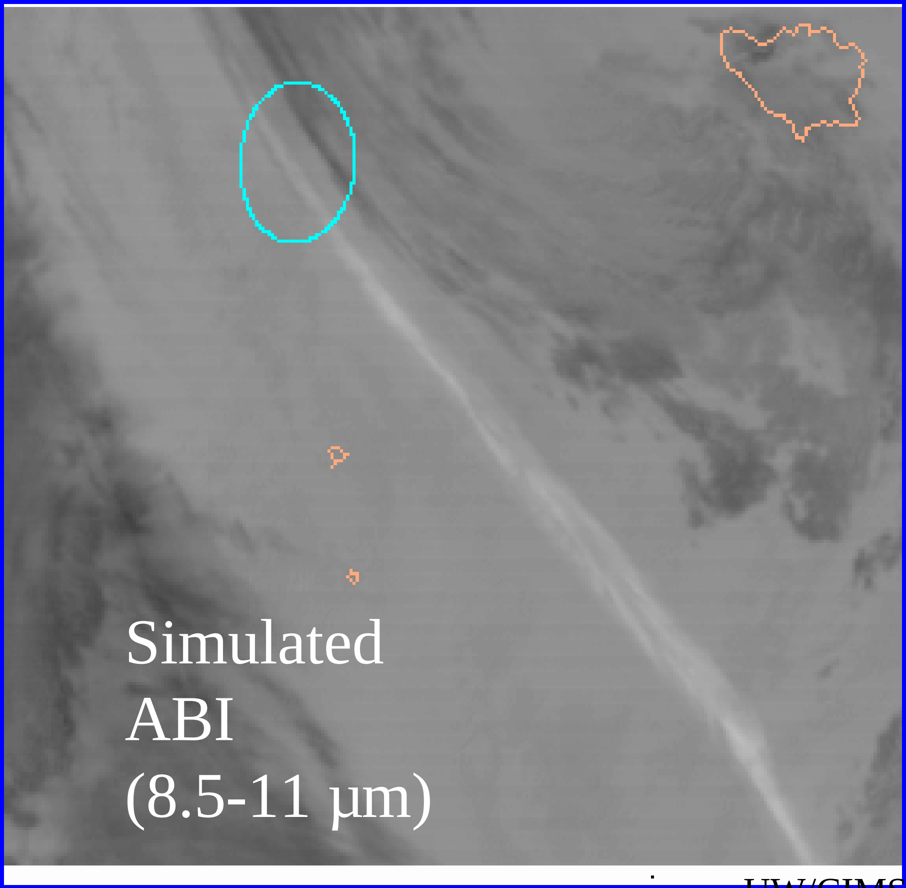
GOES-10 4 minus 11 µm Difference

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

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

One day after the Mt. Cleveland eruption
20 February 2001, 8:45 UTC





UW/CIMSS

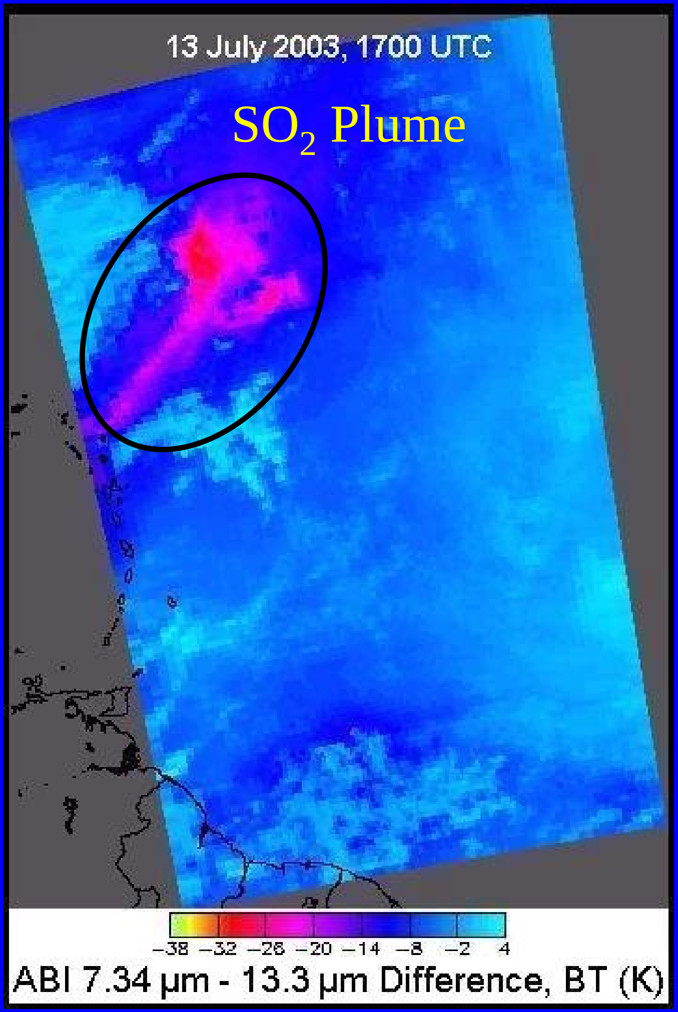
GOES-R ABI will detect SO2 plumes

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

Figure courtesy of Kris Karnauskas

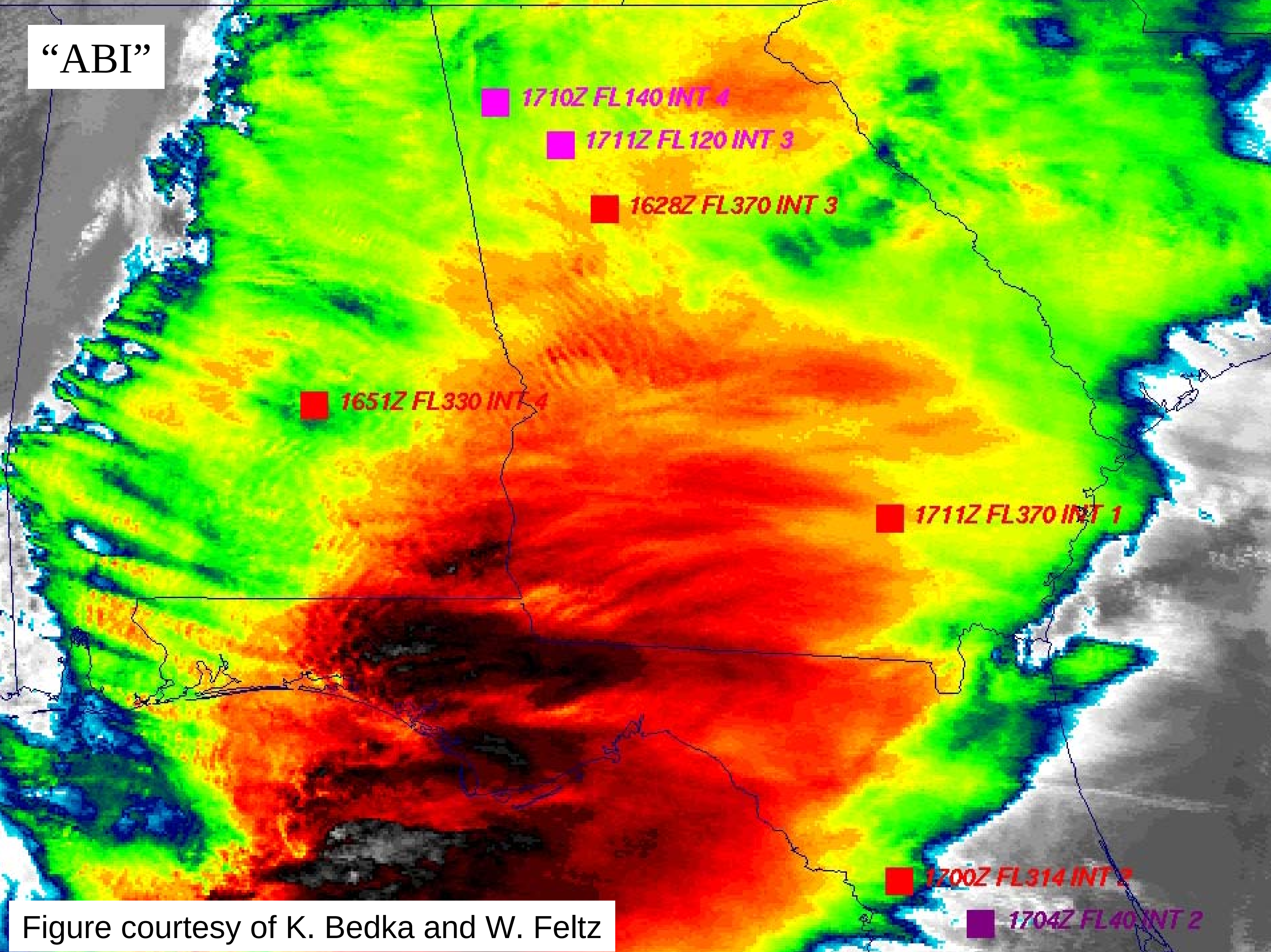


Figure courtesy of K. Bedka and W. Feltz

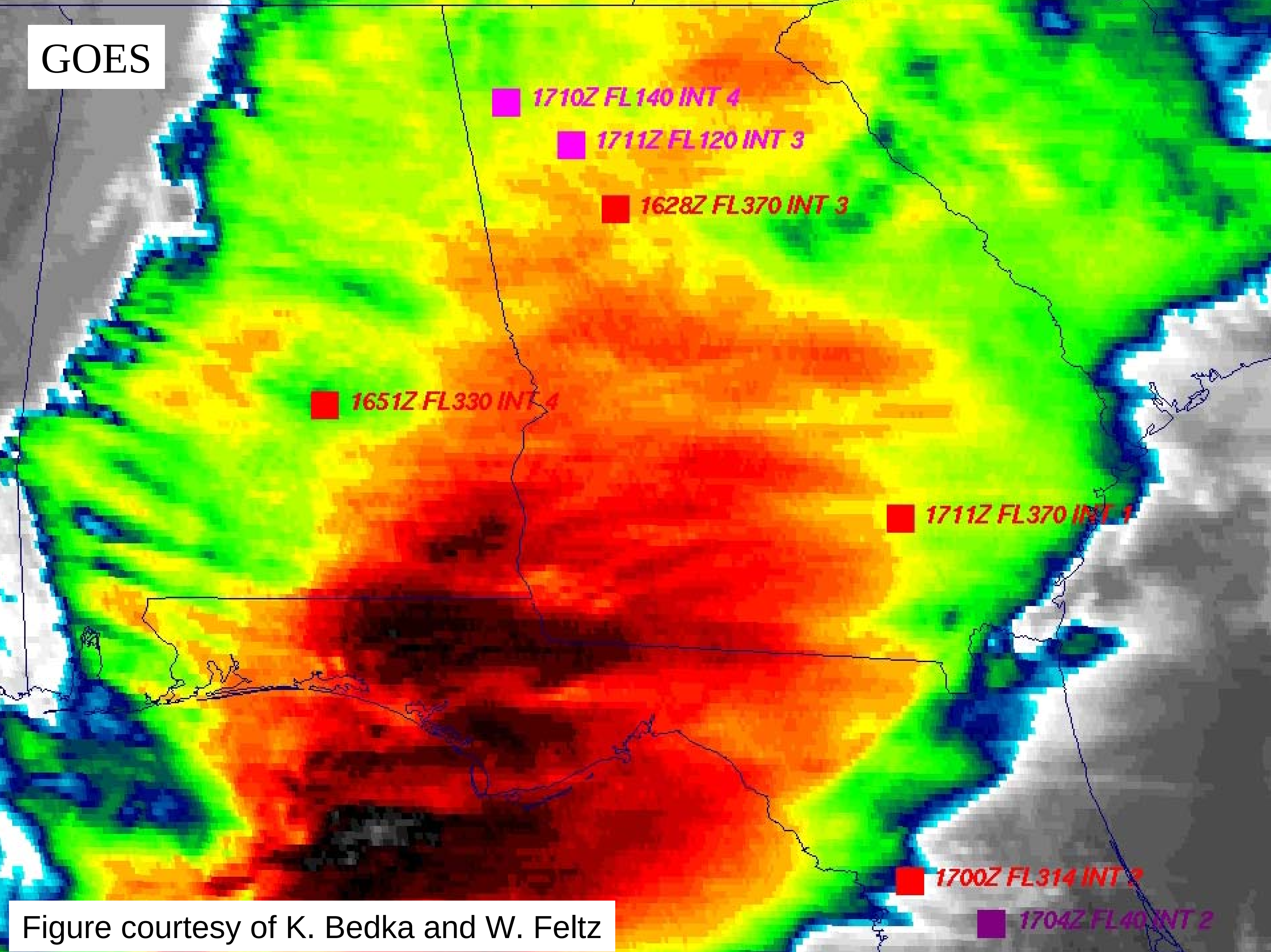
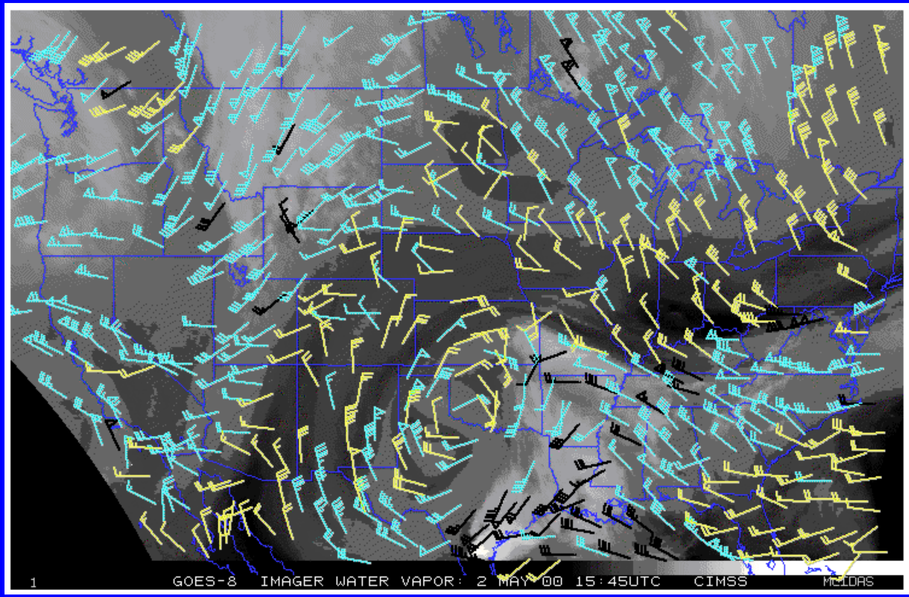


Figure courtesy of K. Bedka and W. Feltz

Satellite-derived winds



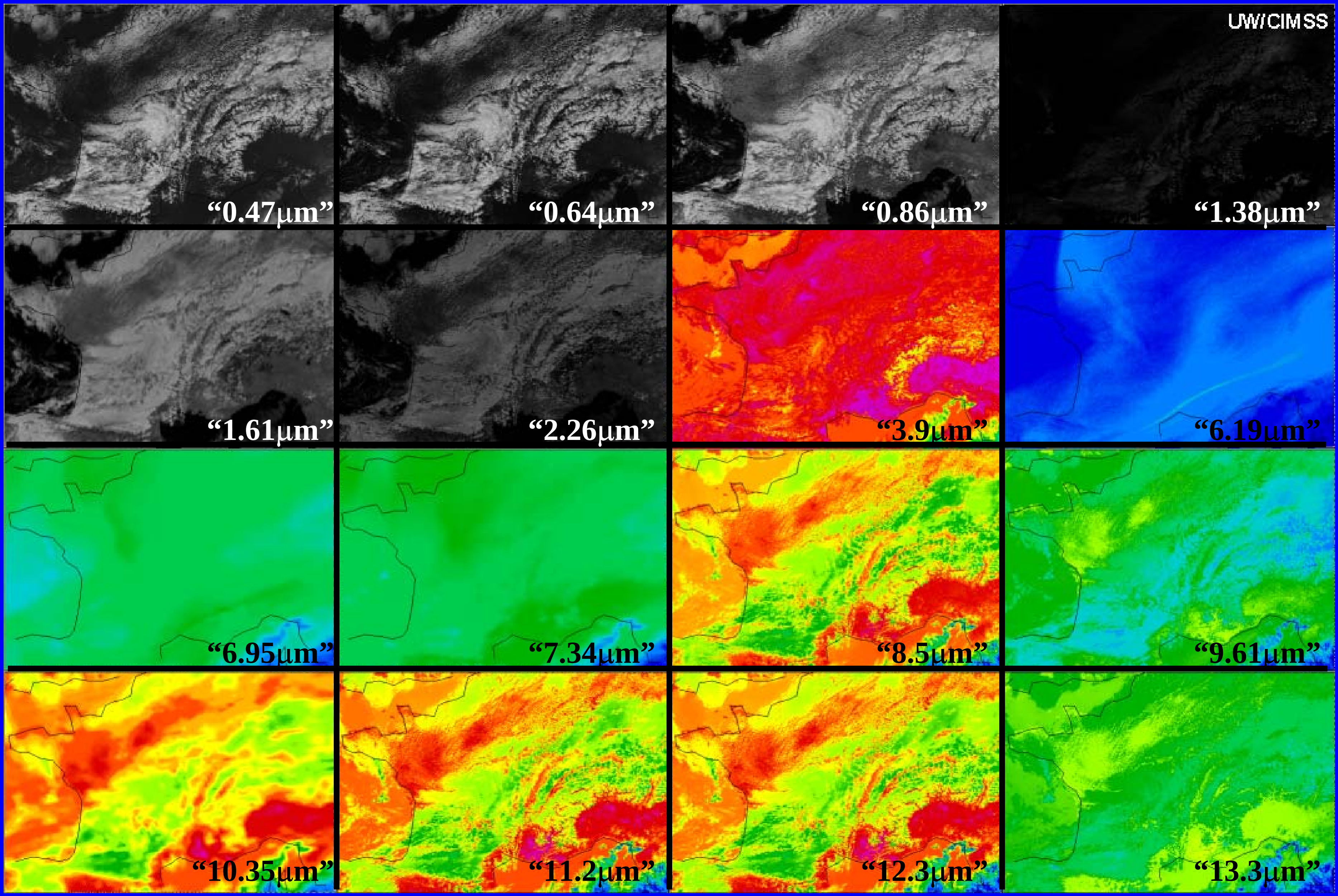
Satellite-derived winds will be improved with the ABI due to:

- **higher spatial resolution (better edge detection)**
- **more frequent images (offers different time intervals)**
- **better cloud height detection (with multiple bands)**
- **new bands may allow new wind products**
- **better NEdT's**
- **better navigation/registration**

Plus, improved winds from the HES.

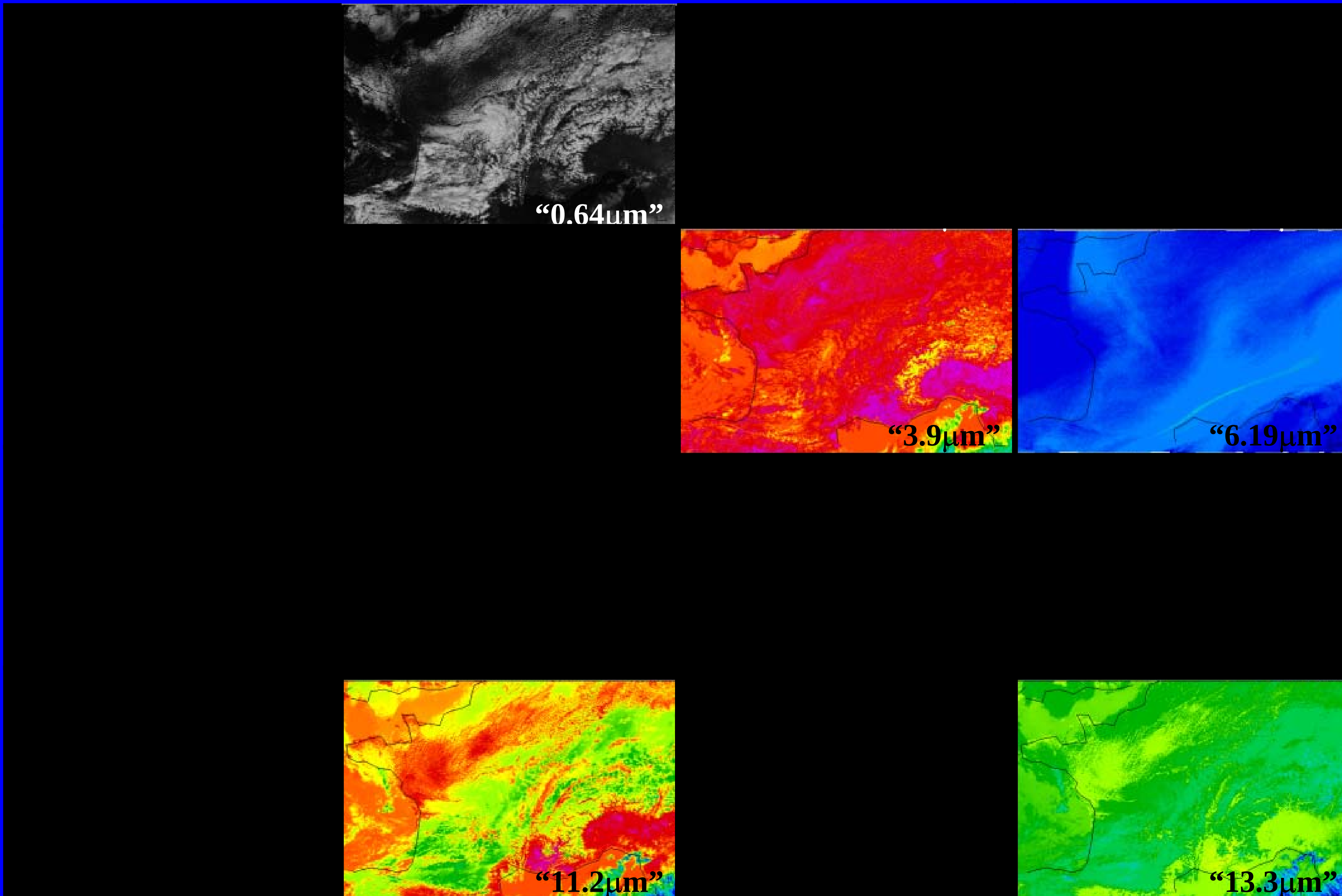
Using MODIS, MET-8 and AIRS to simulate the ABI

Figure courtesy of M. Gunshor, CIMSS

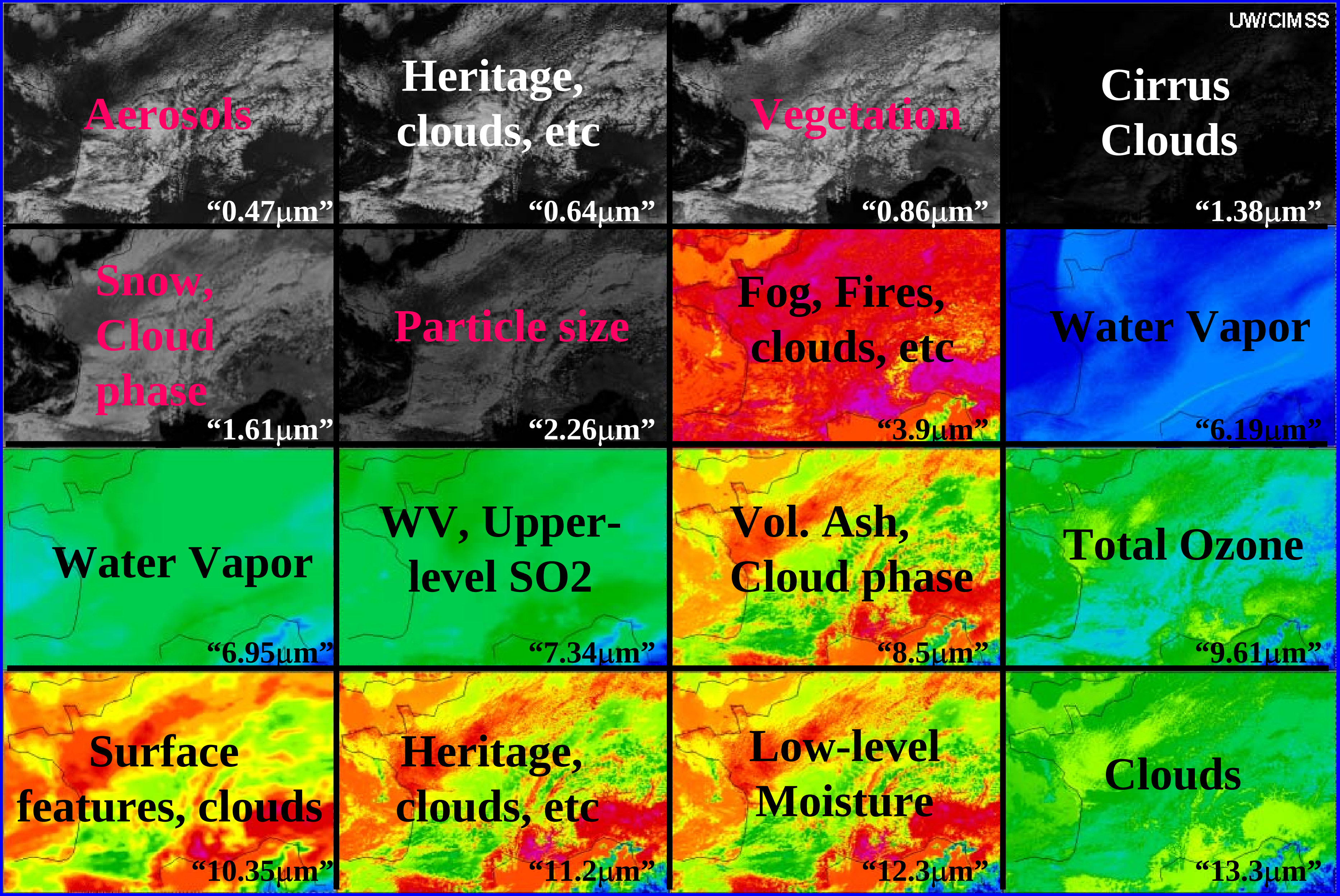


Similar bands on the GOES-12 Imager

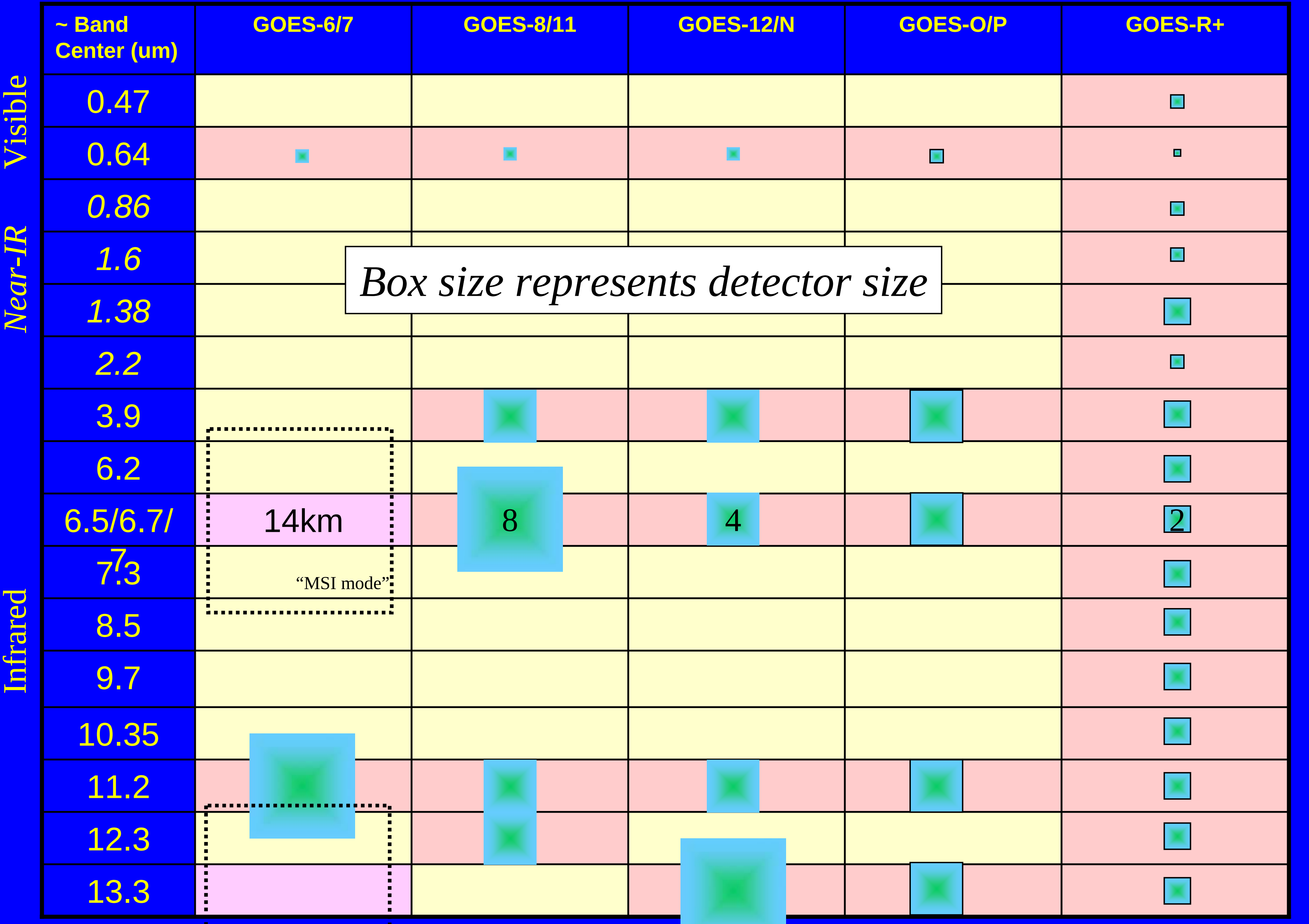
Figure courtesy of M. Gunshor, CIMSS



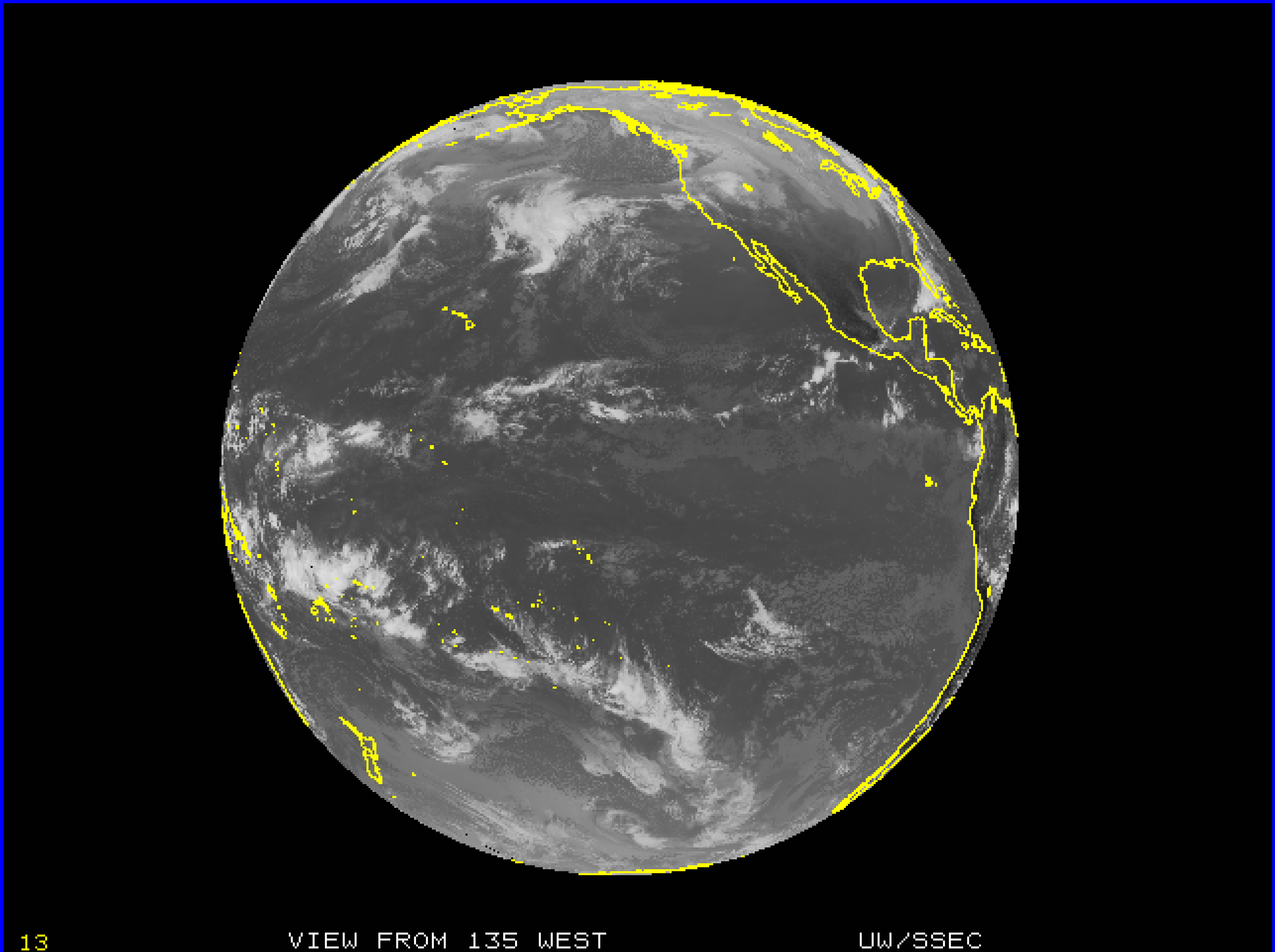
The additional bands on the Advanced Baseline Imager (ABI) allow new or improved products



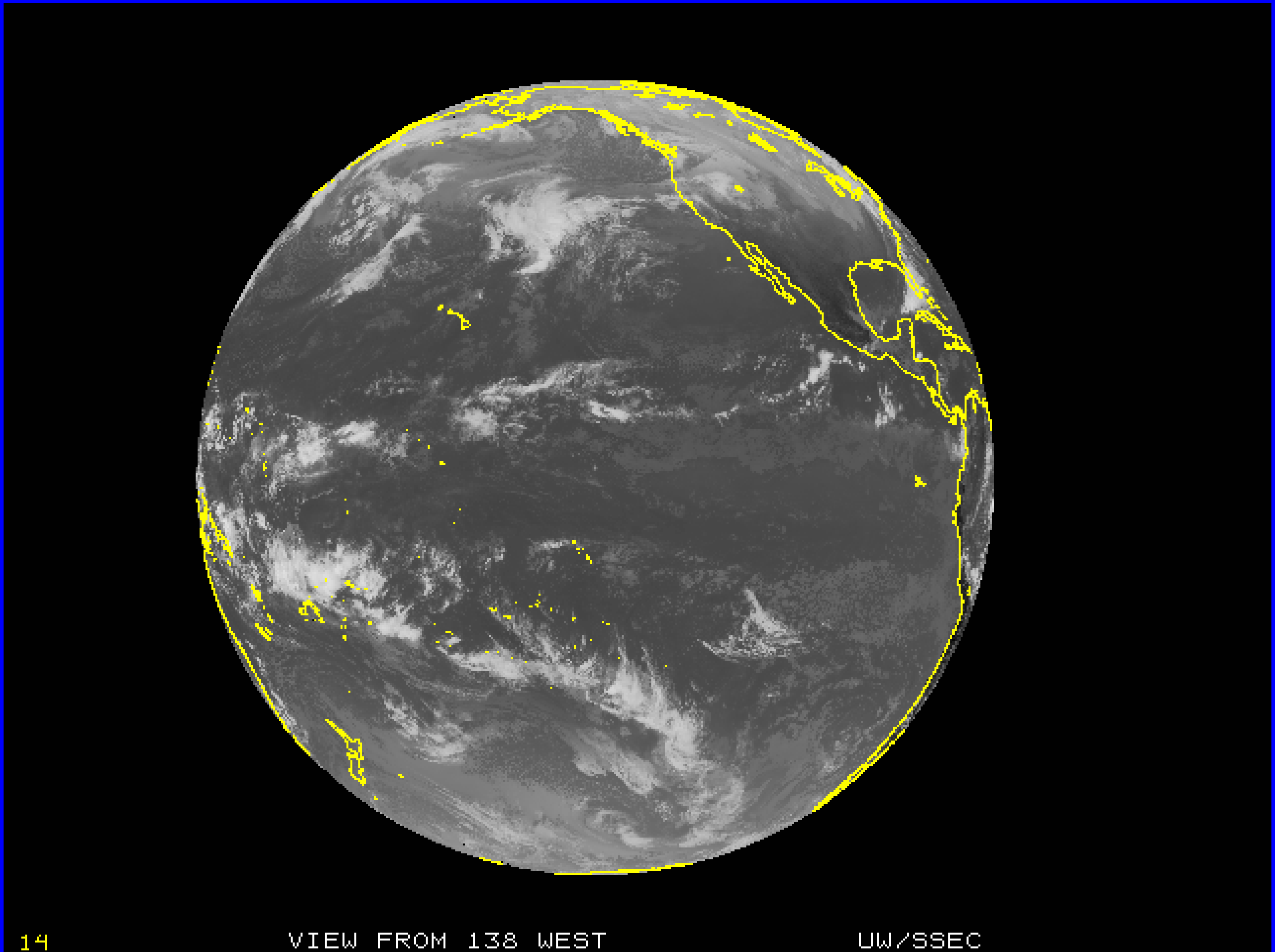
Approximate spectral and spatial resolutions of US GOES Imagers



GOES-West view from 135º



GOES-West view from 138º

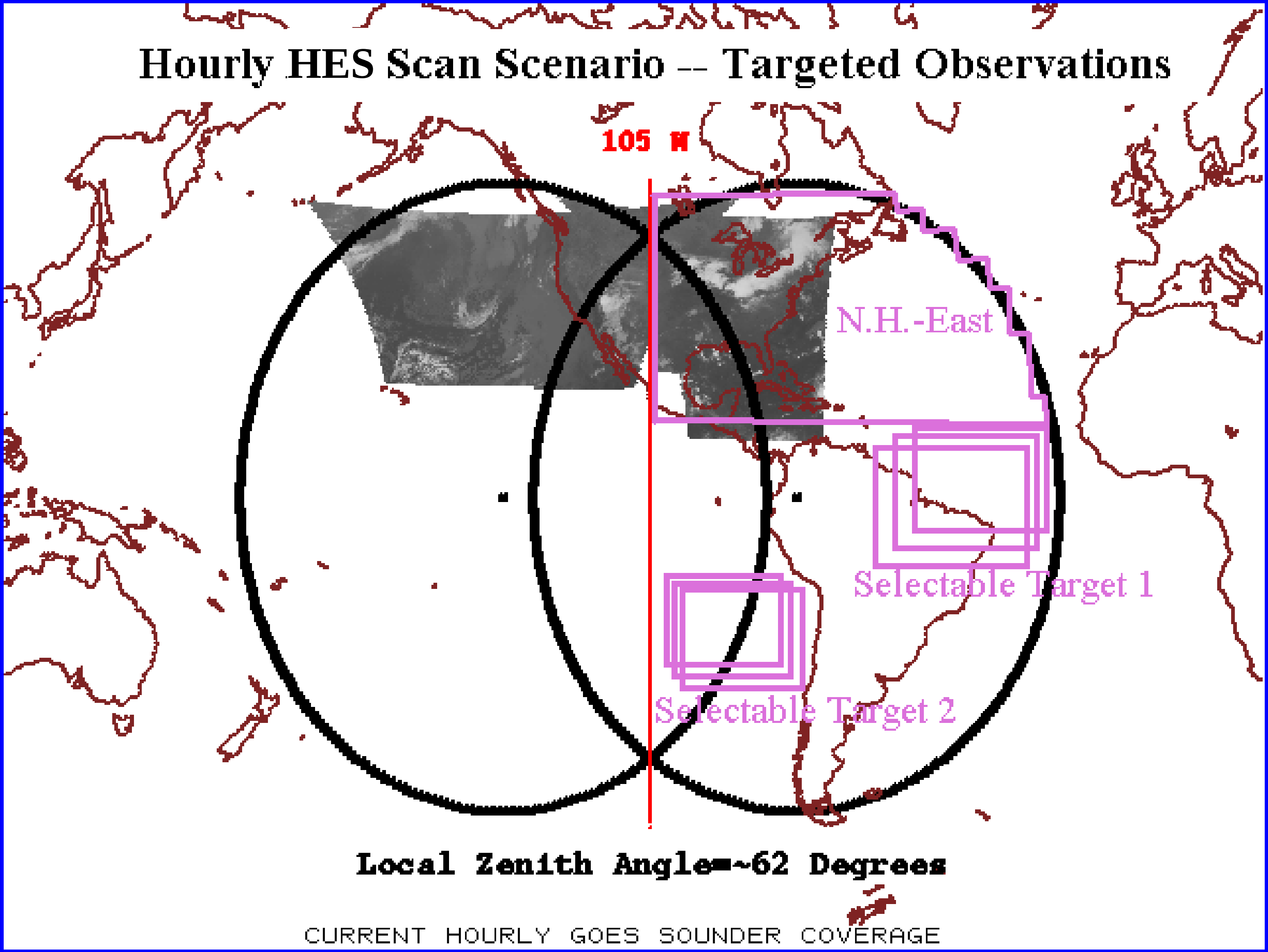


GOES-R Series Baseline Instruments

- Advanced Baseline Imager (ABI)
- **Hyperspectral Environmental Suite (HES)**
  - **Infrared Sounder**
  - **Coastal Water Imaging**
- Geostationary Lightning Mapper (GLM)
- Solar Instrument Suite
- Space Environment In Situ Suite

Sounder Comparison
(Current to HES-Requirement)

	Current	Requirement
Coverage Rate	CONUS/hr	Sounding Disk/hr
Horizontal Resolution		
Sampling Distance	10 km	4 - 10 km
Sounding FOR	30-50 km	10 km
Vertical Resolution	~3 km	1 km
Accuracy		
Temperature	2 deg. K	1 deg. K
Relative Humidity	20%	10%



Targeted observations -- look where information is needed

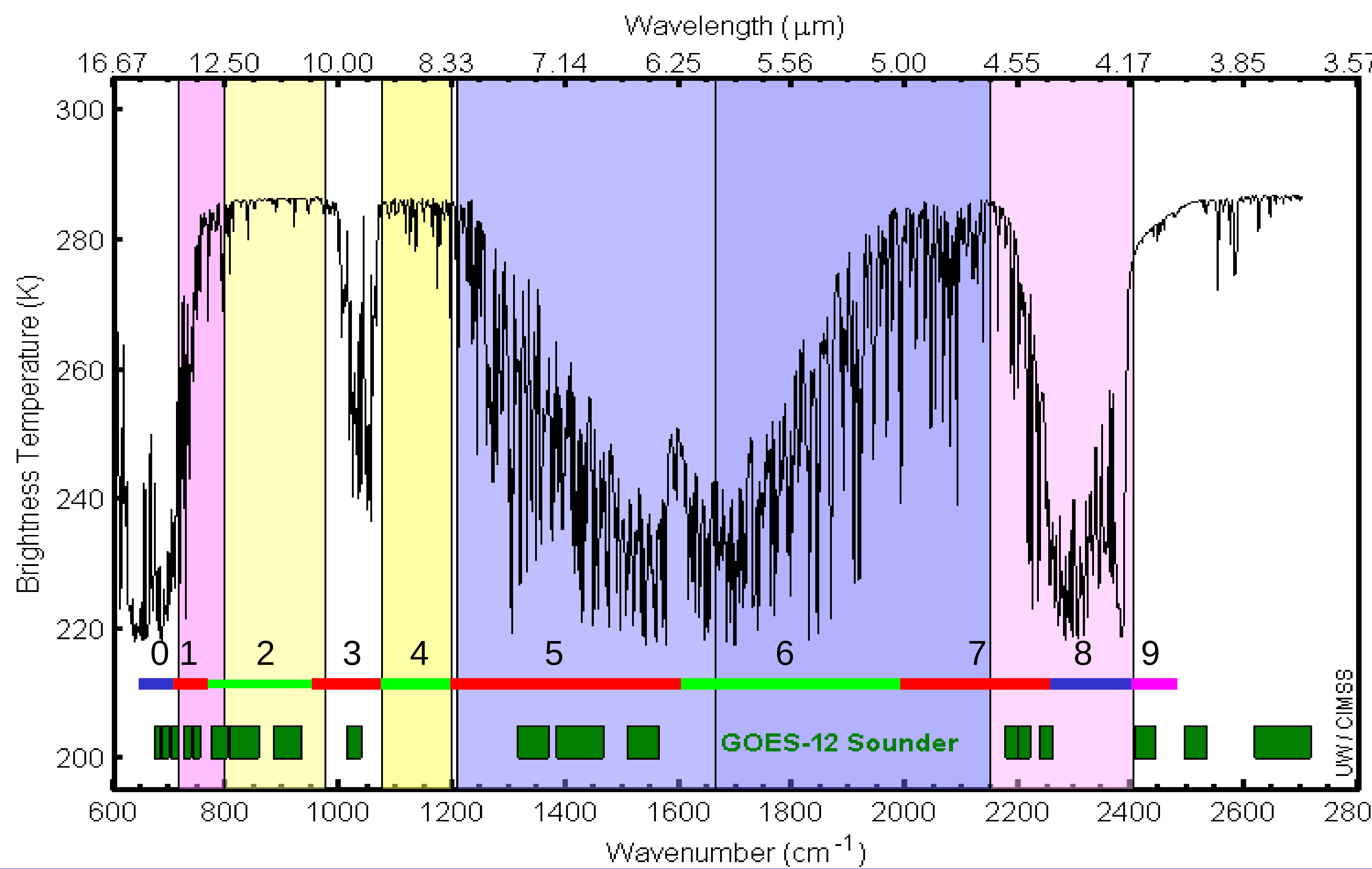
HES-IR Tasks

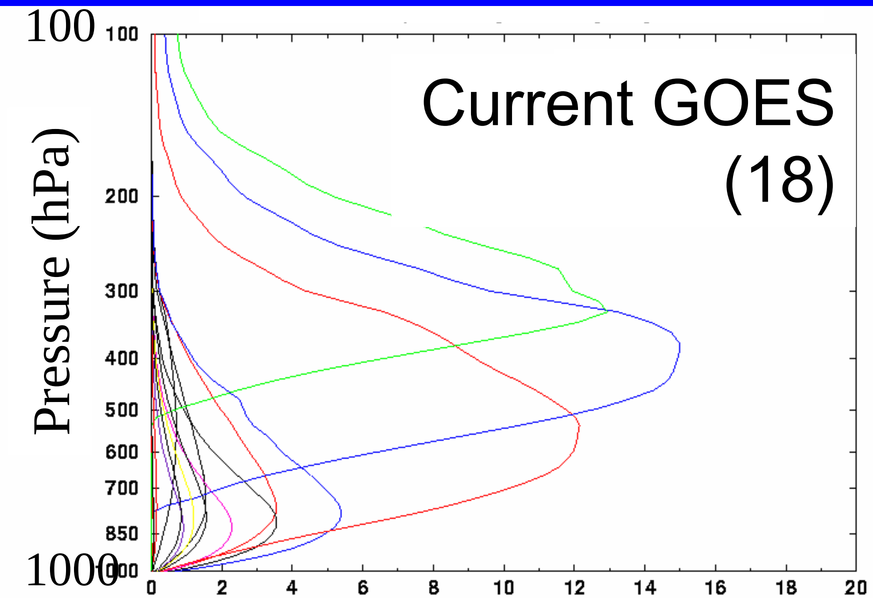
- HES - Disk Sounding (HES-DS)
  - Provide **vertical moisture and temperature information**, and **other environmental data** to be used by NOAA and other agencies in routine meteorological analyses and forecasts
  - Provide data to extend knowledge and understanding of atmospheric processes for **improved short/long-term weather forecasts**
  - Full “sounding’ disk within one hour possible

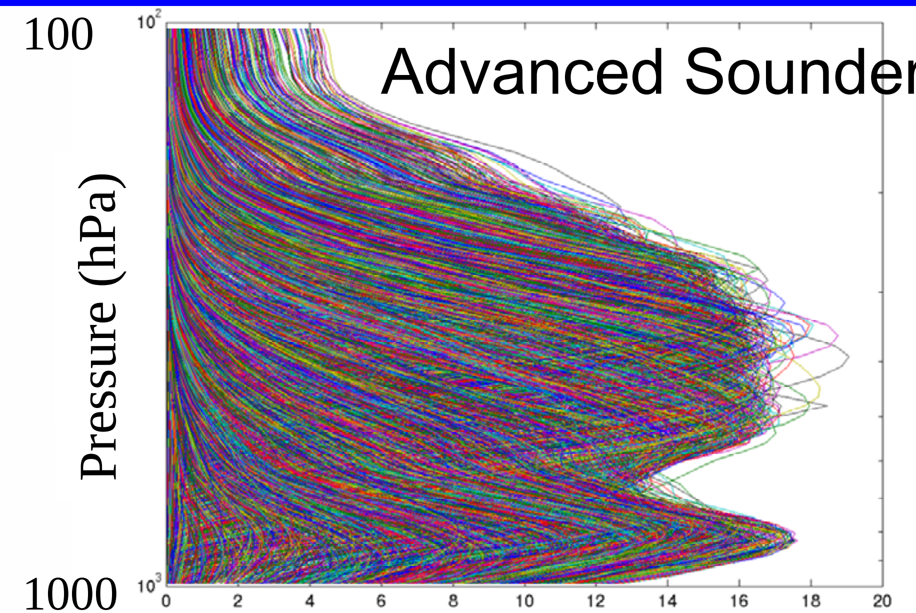
- HES - Severe Weather / Mesoscale (HES-SW/M)
  - Provide **environmental data** to expand knowledge of **mesoscale** and synoptic scale storm development and help in forecasting severe weather events
  - 1000 x 1000 km in less than 5 minutes

HES spectral coverage details are not yet fully defined.

GOES-R / MTG IR sounder spectral coverage considerations



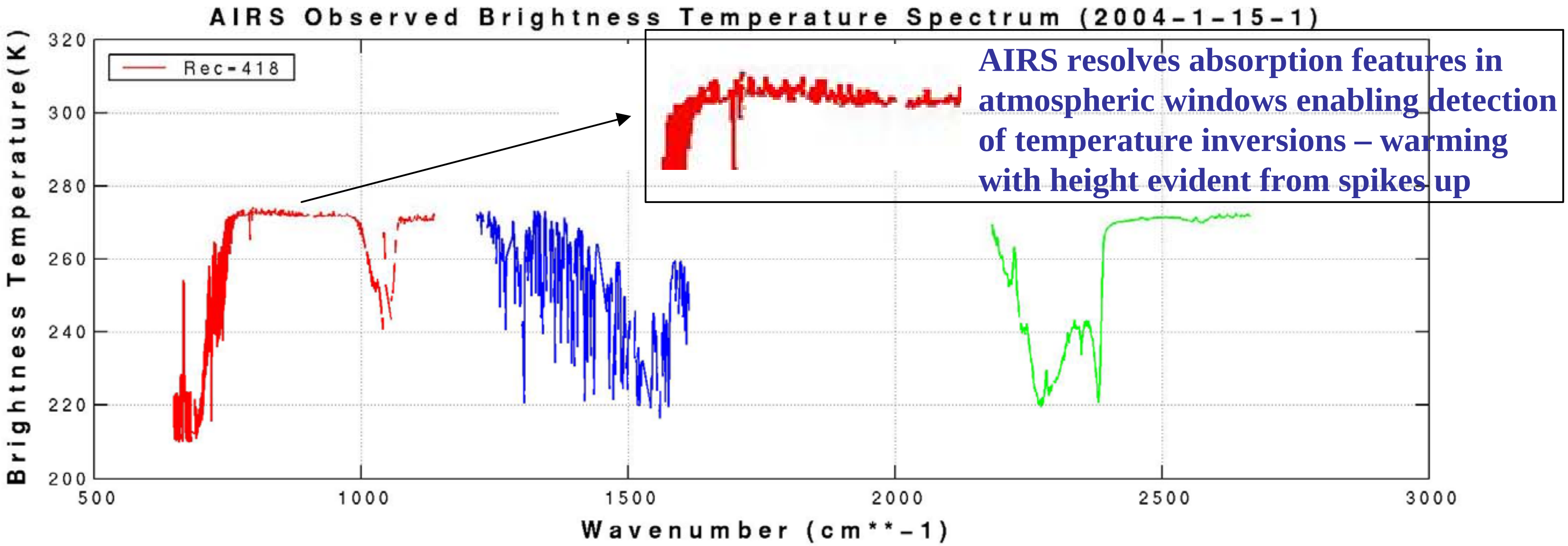


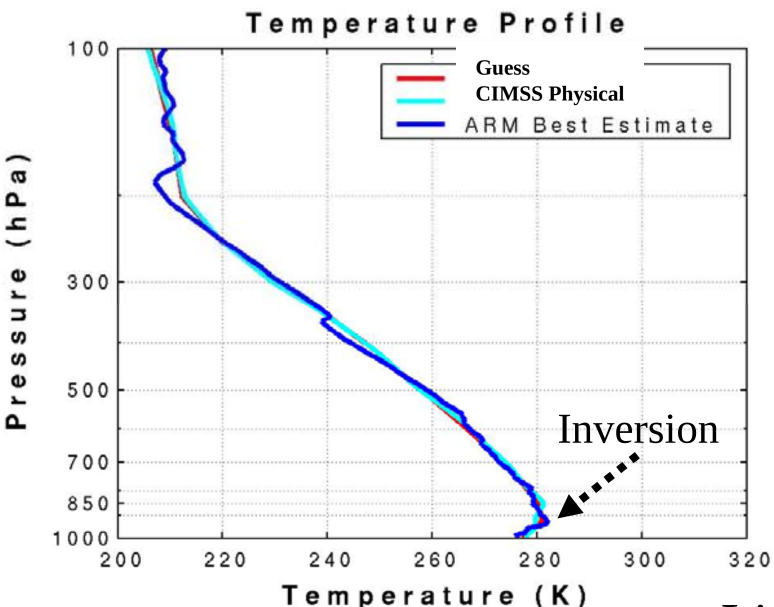


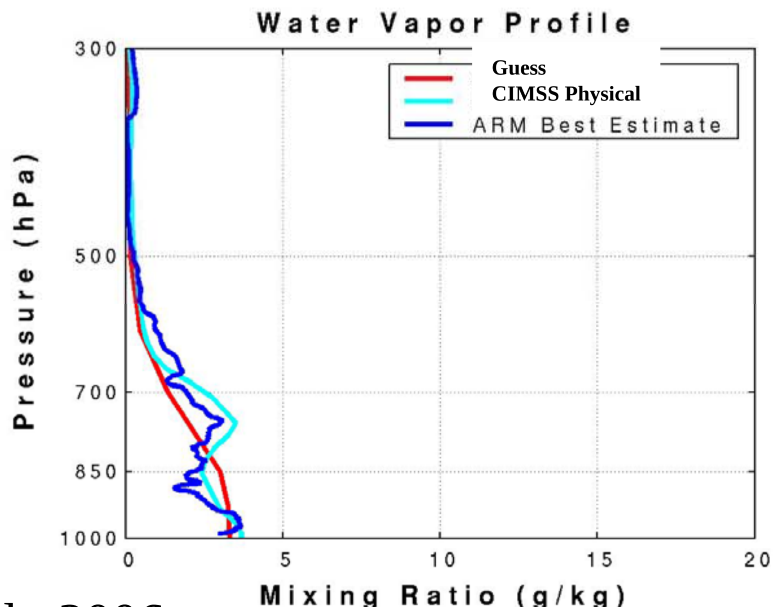
Moisture Weighting Functions

High spectral resolution advanced sounder will have more and sharper weighting functions compared to current GOES sounder. Retrievals will have better vertical resolution.

Validation of AIRS profile retrievals at CART site





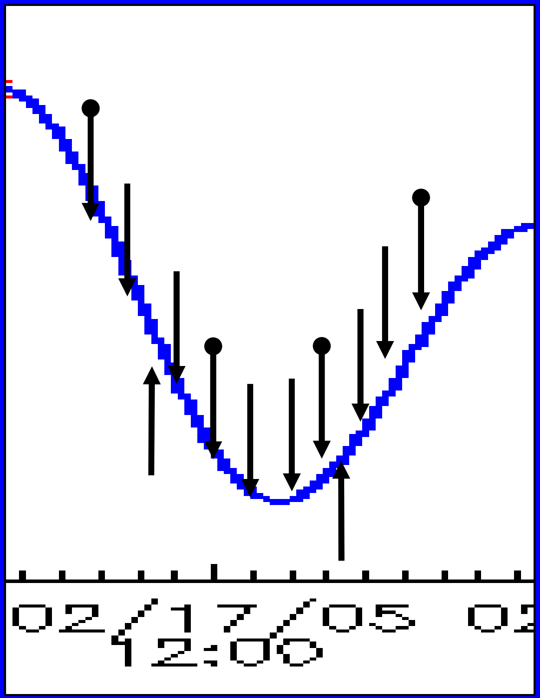


Li et al, 2006

Why HES-CW given VIIRS?

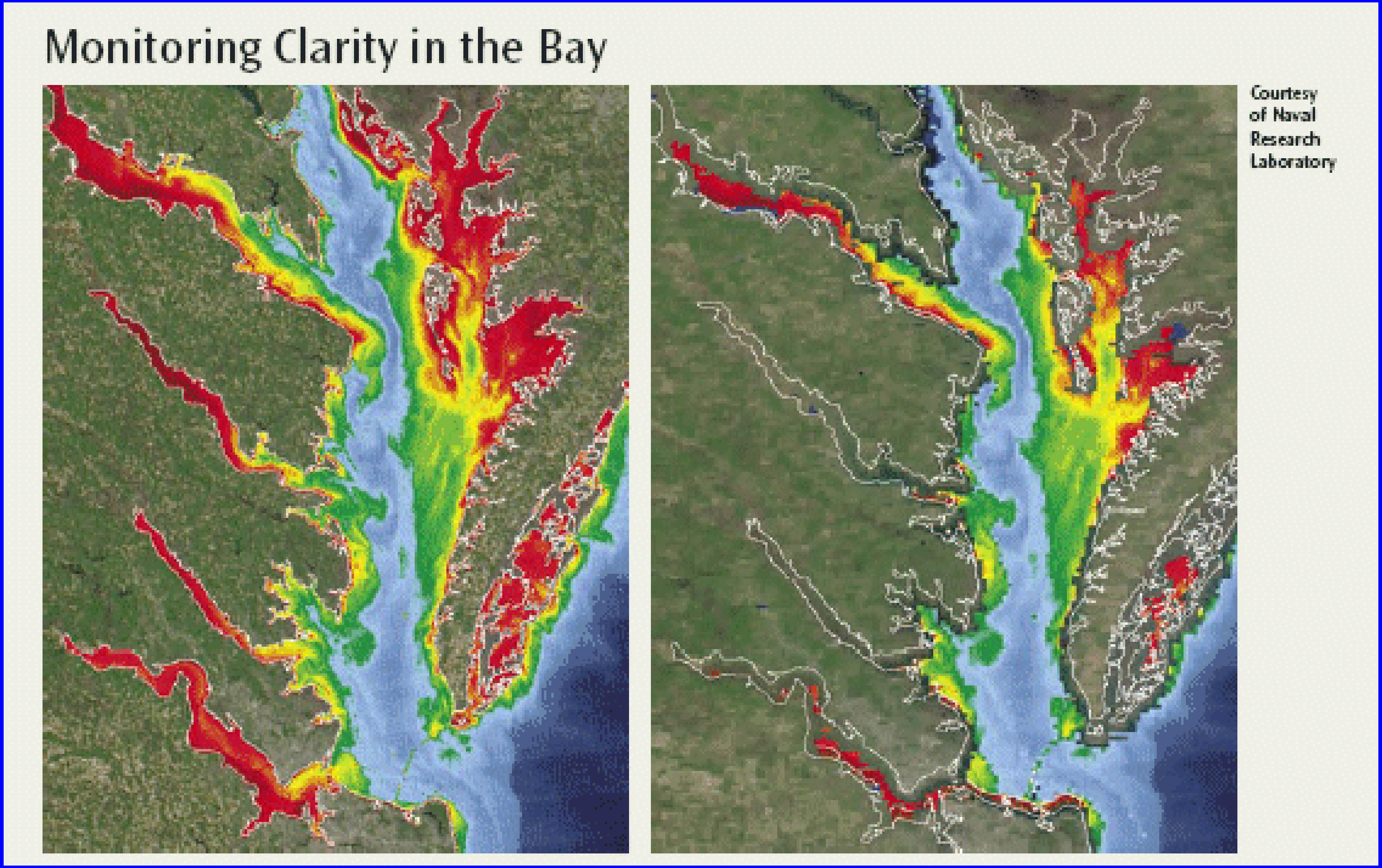
- Tides, diel winds (such as the land/sea breeze), river runoff, upwelling and storm winds drive coastal currents that can reach several knots. Furthermore, currents driven by diurnal and semi-diurnal tides reverse approximately every 6 hours.
- VIIRS daily sampling at the same time cannot resolve tides, diurnal winds, etc.
- HES-CW can resolve tides from a geostationary platform and will provide the management and science community with a unique capability to observe the dynamic coastal ocean environment.
- HES-CW will provide higher spatial resolution (375 m vs. 1000 m)
- HES-CW will provide additional channels to measure solar stimulated fluorescence, suspended sediments, CDOM and improved atmospheric correction.

These improvements are critical for the analyses of coastal waters.



Example tidal cycle from Charleston, OR. Black arrows VIIRS sampling, red arrows HES-CW sampling.

HES-CW higher spatial resolution critical to monitor complex coastal waters



MODIS 250 m

1000 m

HES-CW Products and Applications

Products:

- Spectral water leaving radiances
- Chlorophyll
- Chlorophyll fluorescence
- Turbidity
- Spectral absorption and scattering

Applications:

- Water quality monitoring
- Coastal hazard assessment
- Navigation safety
- Human and ecosystem health awareness (Harmful Algal Blooms)
- Natural resource management in coastal and estuarine areas
- Climate variability prediction (e.g., role of the coastal ocean in the carbon cycle)
- Nowcast and Forecast models of the coastal ocean

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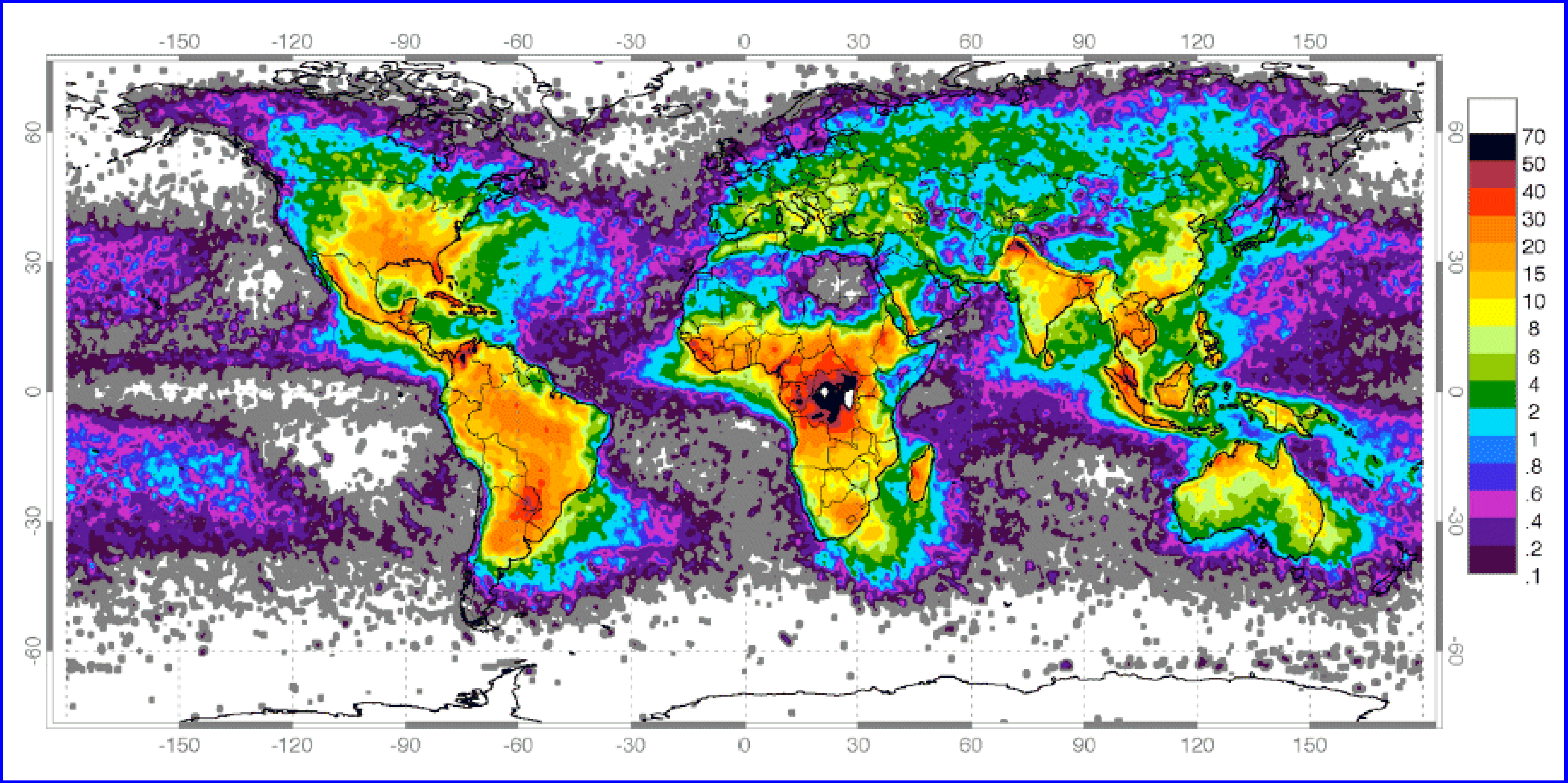
- Solar Instrument Suite (SIS)
- Space Environment In Situ Suite (SEISS)

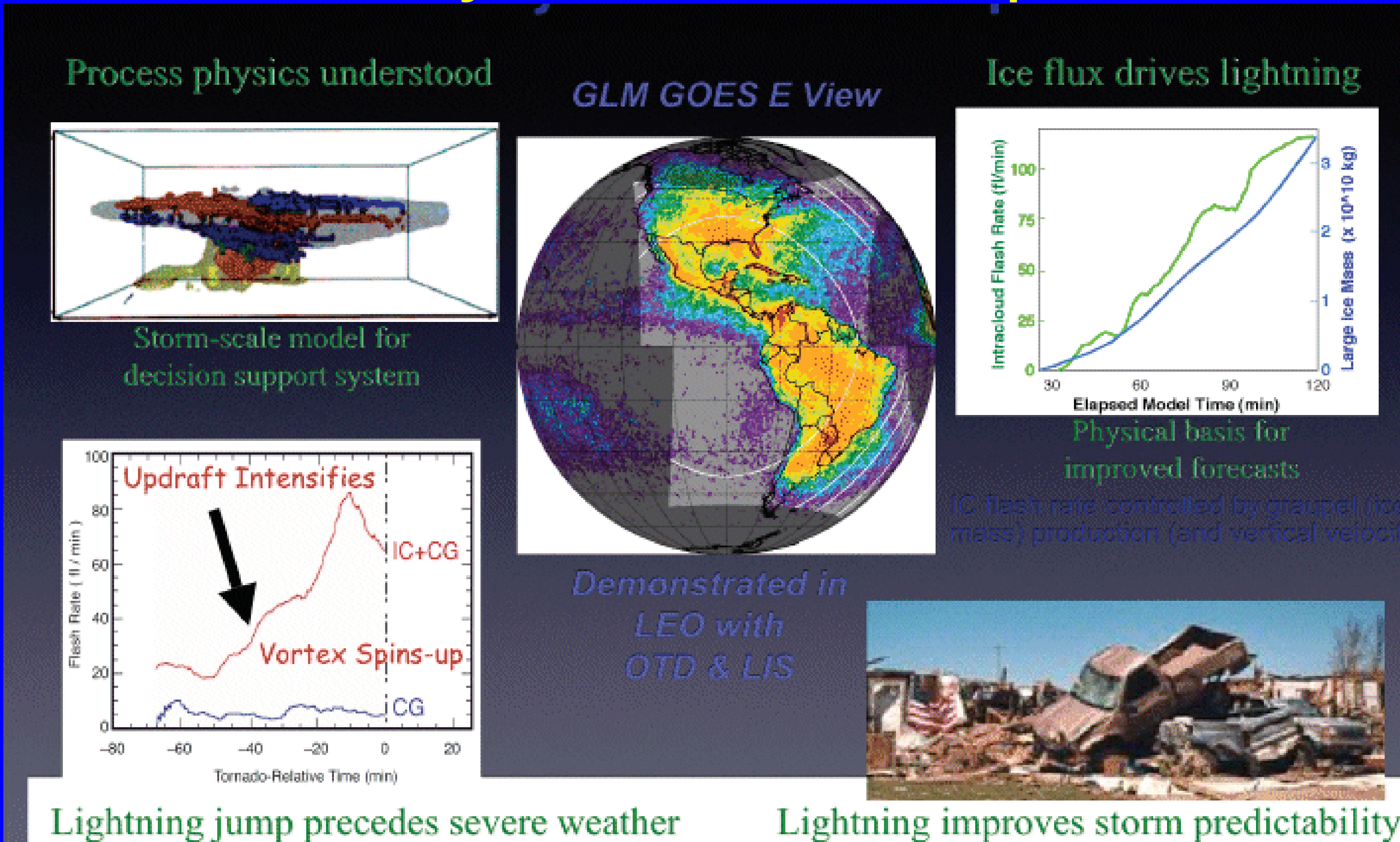
GLM Instrument Requirements *(going into Formulation Phase)*

- *Full-disk coverage*
- *Flash POD: 70% threshold at EOL (99% goal)*
- *Flash FAR: < 5%*
- *Ground Sample Distance:*
  10 km threshold; 0.5 km goal
- *Pointing knowledge: 4 km threshold; 2 km goal*
- *Flash intensity to within 10%.*
  Pulse detection of O(1 ms).
- *Reliability > 0.6 after 10 yr MMD 8.4 yr;*
  Design Life 10 yr.

NASA LEO Precursors
Climatology - *flashes / km^2 / year*



Continuous GEO Total Lightning will identity severe storm potential



GOES-R Series Baseline Instruments

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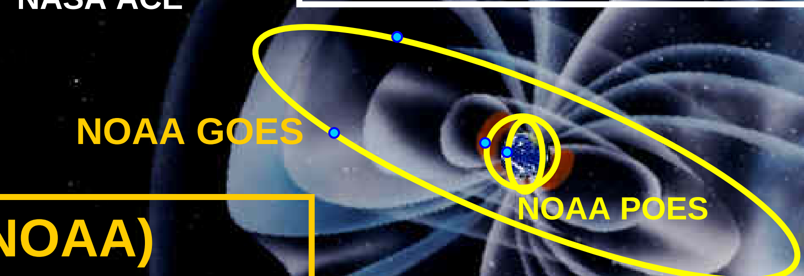
Monitor, Measure and Specify: Data for Today's Space Weather

- **SOHO (ESA/NASA)**
  - Solar EUV Images
  - Solar Corona (CMEs)

- **Ground Sites**
  - Magnetometers (NOAA/USGS)
  - Thule Riometer and Neutron monitor (USAF)
  - SOON Sites (USAF)
  - RSTN (USAF)
  - Telescopes and Magnetographs
  - Ionosondes (AF, ISES, …)
  - GPS (CORS)

- **ACE (NASA)**
  - Solar wind speed, density, temperature and energetic particles
  - Magnetic field strength and direction

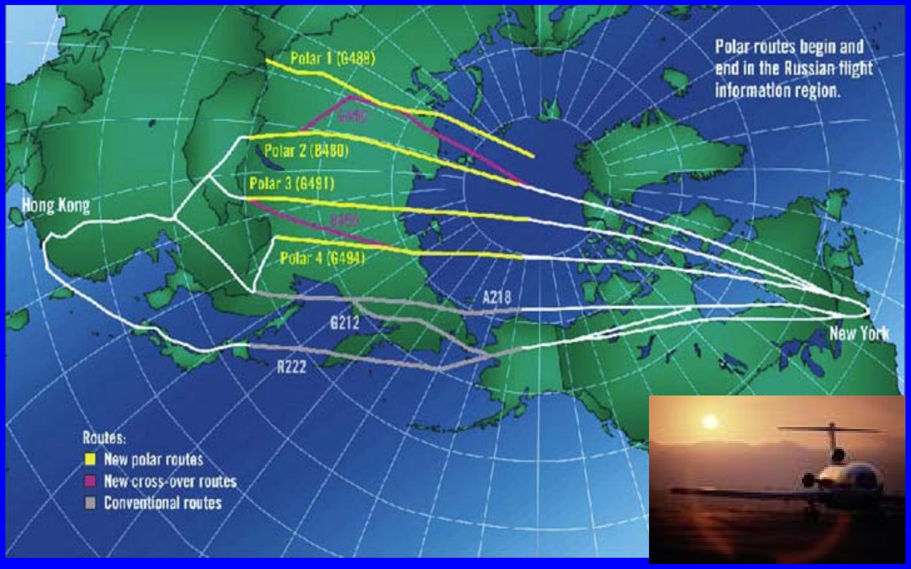


- **GOES (NOAA)**
  - Energetic Particles
  - Magnetic Field
  - Solar X-ray Flux
  - Solar EUV Flux
  - Solar X-Ray Images

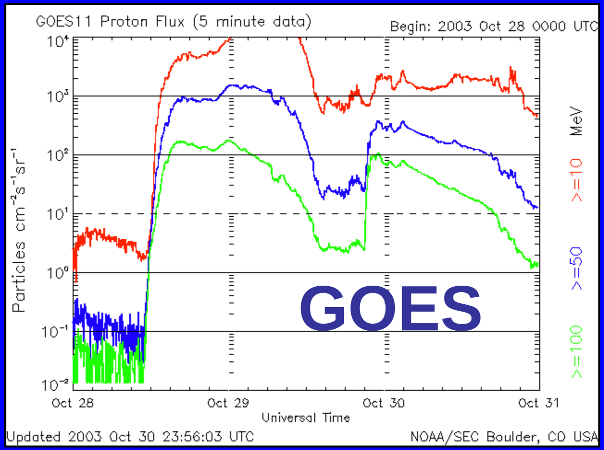
- **POES (NOAA)**
  - High Energy Particles
  - Total Energy Deposition
  - Solar UV Flux

GOES Measurements: Unique and Crucial

Aviation Growth...



Solar Energetic Particles Monitored by GOES affect Polar Route Communications



The advent of new long range aircraft such as the A340-500/600, B777-300ER and B777-200LR

Next 6 Years:

Airlines operating China-US routes go from 4 to 9

Number of weekly flights from 54 to 249

Next 12 Years:

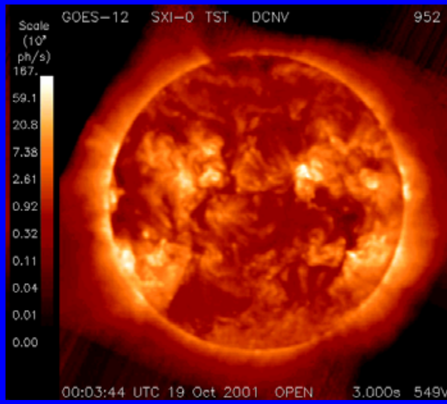
1.8 million polar route passengers by 2018

United Airlines identified space weather as the #1 concern for polar flights

GOES Space Environment Monitor (SEM) Instrumentation Status

Space Environment In-Situ Suite (SEISS)

- Energetic Particle Sensors monitor solar, galactic and in situ electron, proton, and alpha particle fluxes
- Medium energy electrons and protons begin on GOES N
- Low energy electrons and protons begin on GOES R
- Heavy Ions begin on GOES-R
- Completed formulation; implementation phase in source selection



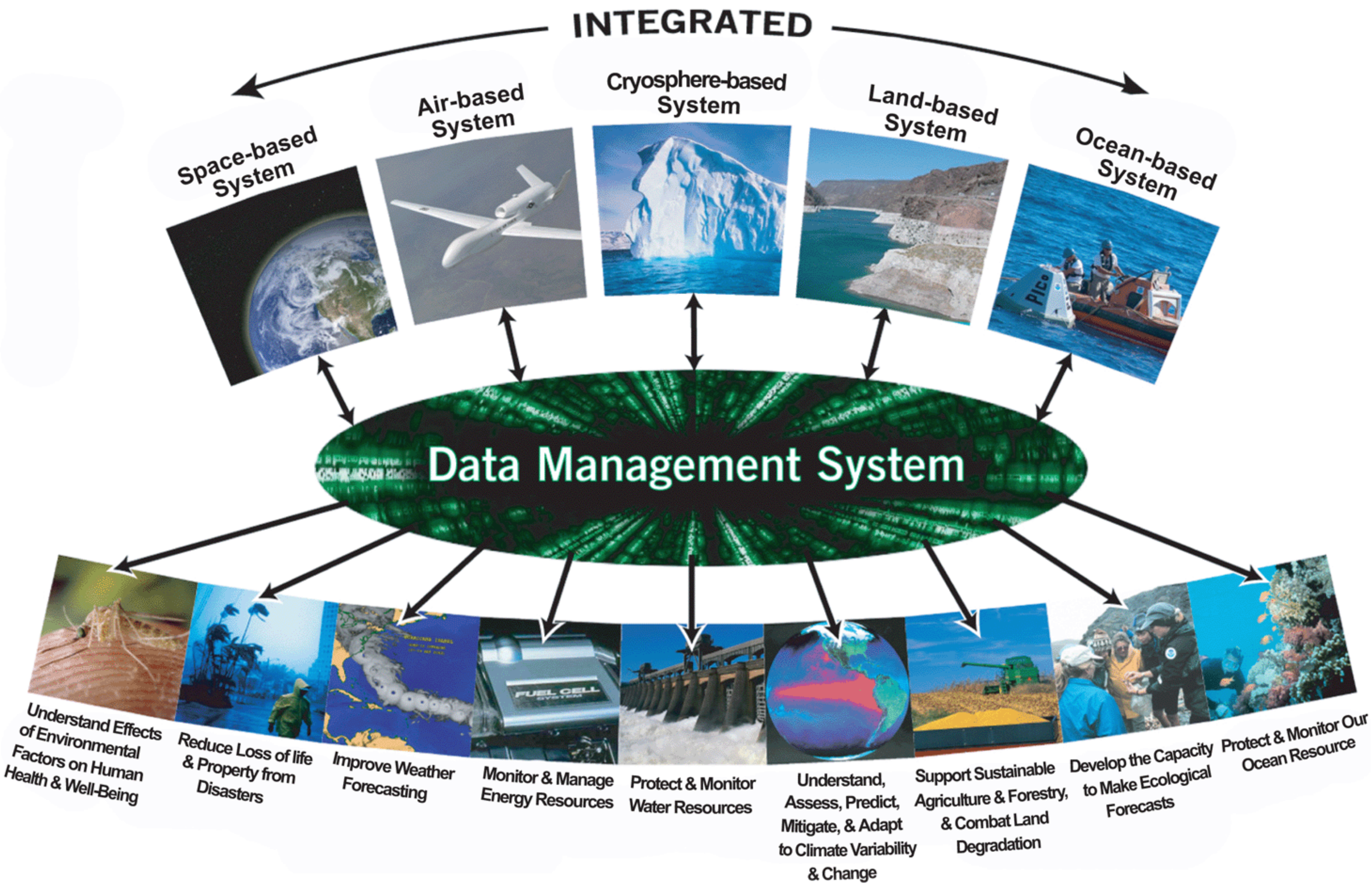
Magnetometer (MAG)

- Monitors Earth's time-varying vector magnetic field
- Included in spacecraft formulation

Solar Imaging Suite (SIS)

- X-Ray Sensor (XRS) monitors whole-Sun x-ray brightness in two bands
- Solar EUV Sensor (EUVS) to monitor whole-Sun EUV irradiance in five bands first on GOES N
- Solar X-ray Imager (SXI) monitors solar flares, coronal holes, active regions… first on GOES 12
- Formulation phase nearing completion
- Coronagraph (SCOR) –GOES-R Pre-Planned Product Improvement (not yet manifested)

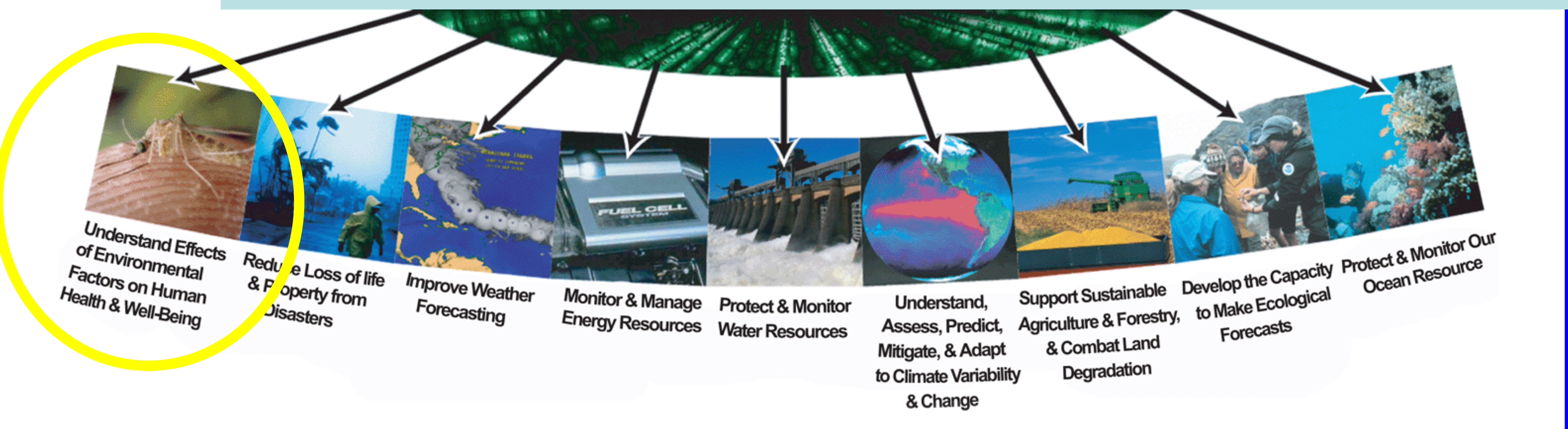
GOES-R supports each GEOSS societal benefit area



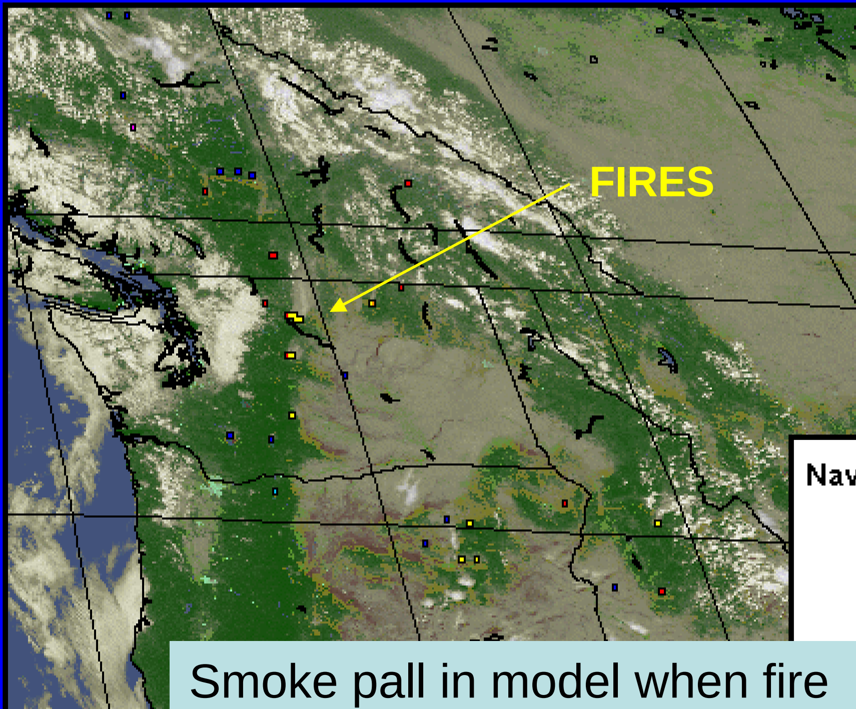
GOES-R and Societal Benefit areas

Health

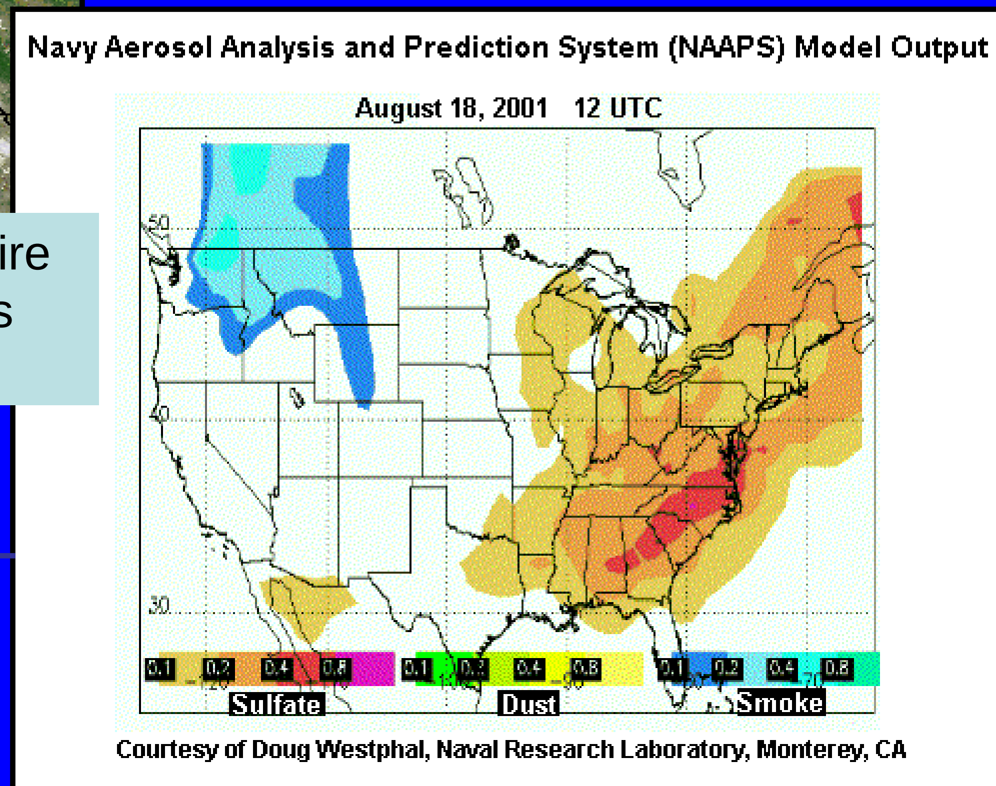
• Space Weather forecasts for aviation, especially in the polar regions
• Improved data for air quality forecasts (aerosol and ozone monitoring and better hot spot detection and characterization)
• HAB monitoring,
• etc.



Real-Time Aerosol Transport Model Assimilation of the Wildfire ABBA Fire Product (GOES-R will have improved fire monitoring)



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



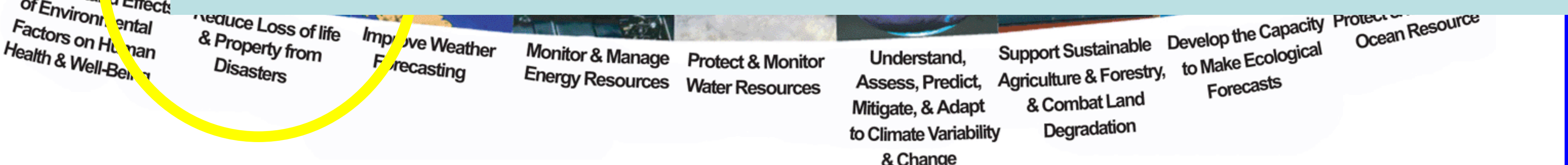
Smoke pall in model when fire locations and characteristics were included.

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

GOES-R and Societal Benefit areas

Loss of Life

- Search and Rescue and EMWIN
- Aircraft icing (cloud-top phase)
- Volcanic ash monitoring
- Lightning observations to locate turbulent areas
- Heavy precipitation monitoring
- Severe storm/hurricane monitoring
- Space weather and the health of satellites
- Solar/energetic particle observations leading to improved forecasts and specification of radiation and communication impacts for aviation interests
- etc.



Klyuchevskoy Volcano MODIS 08 March 2005

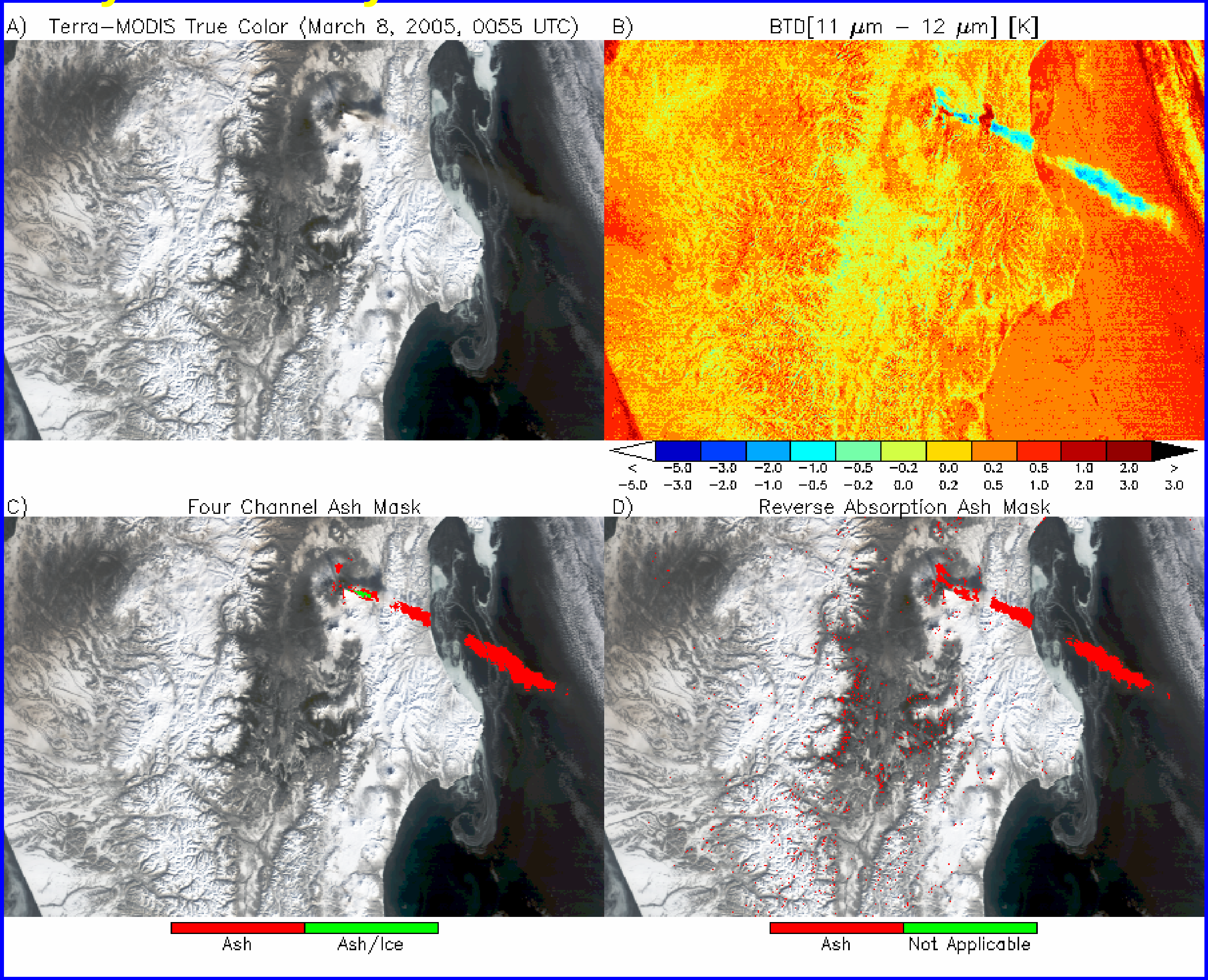


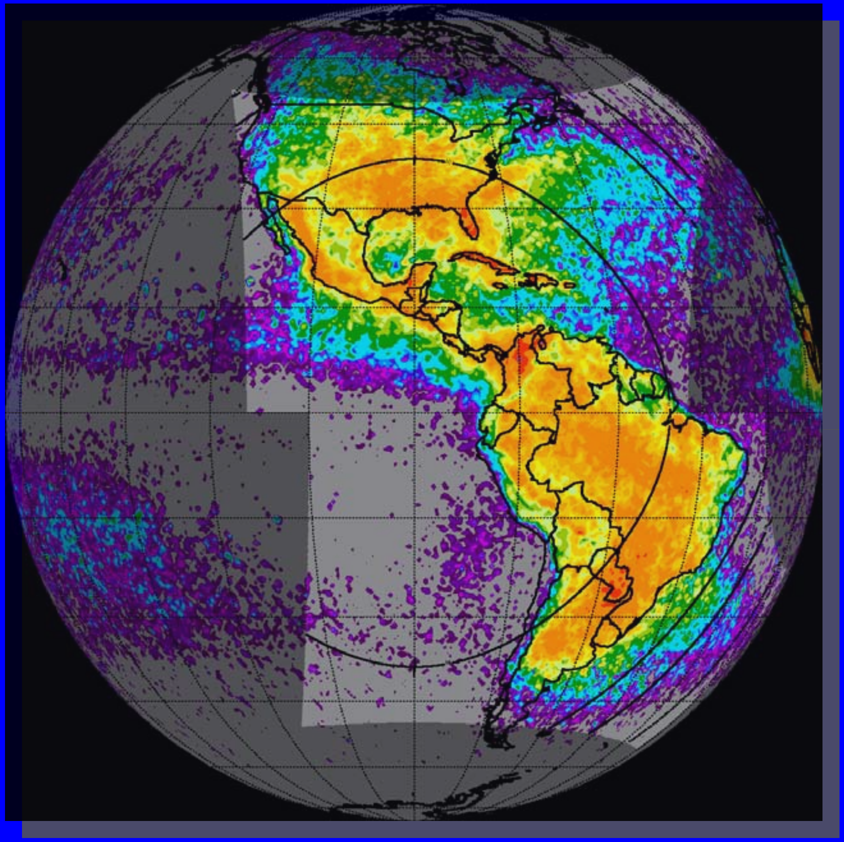
Figure courtesy of M. Pavolonis

GOES-R will allow improved volcanic ash detection.

GLM

- Diurnal signature of lightning (both cloud-to-ground and intra-cloud discharges) over both land and ocean in the western hemisphere

Annual lightning strikes



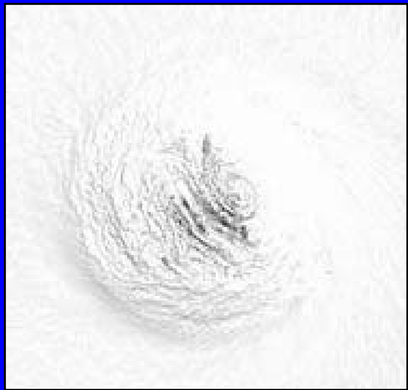
GOES-R and Societal Benefit areas

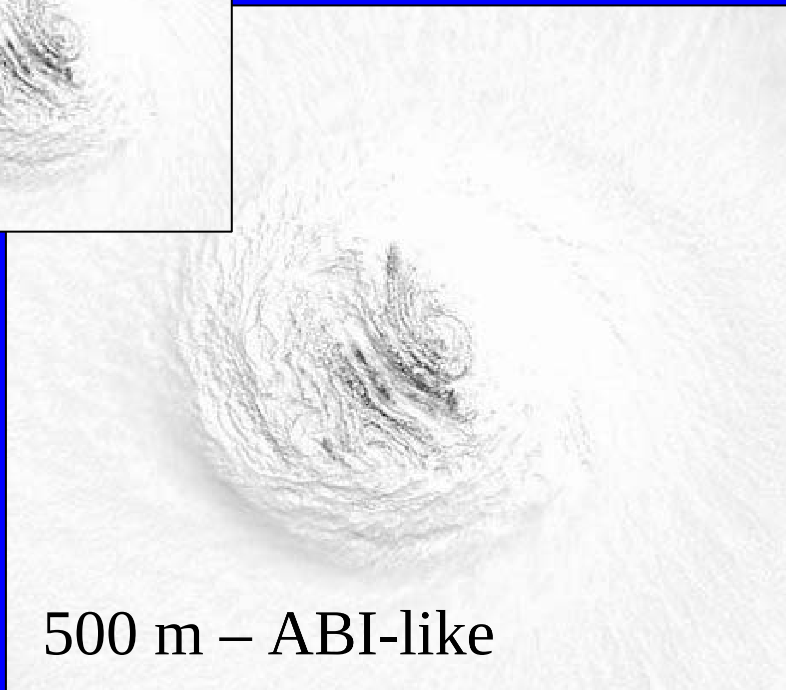
Weather forecasting

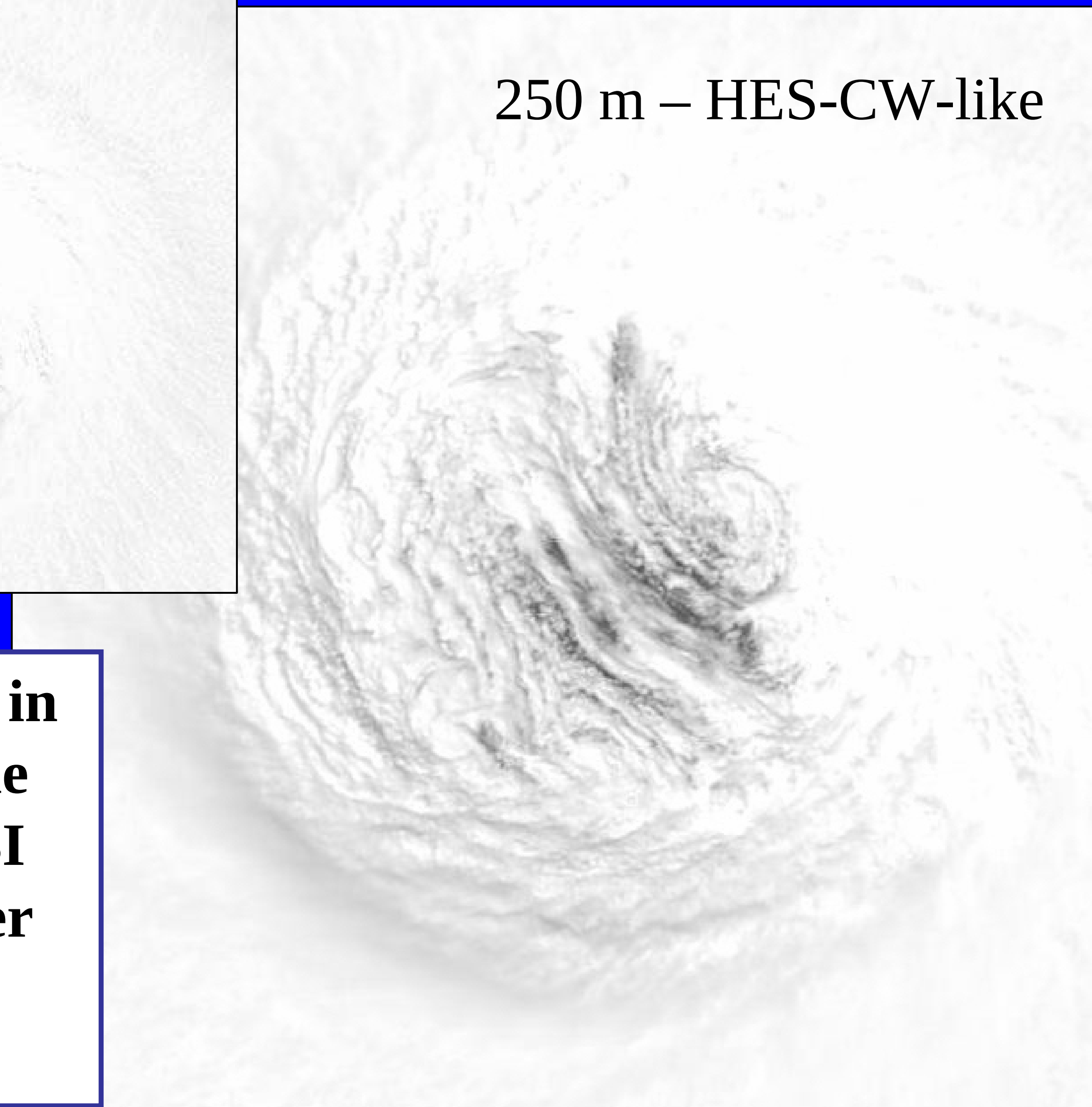
- Improved disaster mitigation for hurricane trajectory forecasts from better definition of mass and motion fields
- Better general weather announcements affecting public health from improved forecasting and monitoring of surface temperatures in urban and metropolitan areas during heat stress (and sub-zero conditions).
- Better monitoring of the sun and near-Earth space environment
- Better fog detection
- Better thunderstorm monitoring
- Better cloud monitoring
- Better hurricane monitoring
- Better observations of snow
- Better NWP, etc.

September 14th at 17 :55 UTC
Hurricane Isabel

1000 m – current GOES-like







Meso-vortices may help in understanding hurricane intensifications. The ABI will have also have better temporal observations (routine 5 minute data).

GOES-R and Societal Benefit areas

Energy

• Better information regarding conditions leading to fog, icing, head or tail winds, and development of severe weather including microbursts en route makes air traffic more economical and safer.

• Power consumption can be regulated more effectively with real-time assessment of regional and local insolation/clouds and temperatures.

• Monitoring SST eddies in the Gulf of Mexico can be useful for oil and gas operations.

• Better monitoring of solar disturbances that can interfere with GPS use, interrupt communications, and cause disruptions of electric power grids.

• etc.

Space Weather Scales

Three Categories: data they are based on and example users

- **Geomagnetic Storms**
  (Ground-based magnetic field)
  Power Utilities, GPS Users, Spacecraft operations

- **Solar Radiation Storms**
  (GOES > 10 MeV particles)
  Astronaut Safety
  Airline Communication

- **Radio Blackouts**
  (GOES Solar X-rays)
  Airline and Maritime HF Comm.

Two of the three Space Weather Scales depend on GOES

NOAA Space Weather Scales

Category: Scale	Category: Descriptor	Effect (Duration of event will influence severity of effects)	Physical measure	Average Frequency (1 cycle = 11 years)
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.)**.	Kp=9	4 per cycle (4 days per cycle)
G 4	Severe	Power systems: possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. Spacecraft operations: may experience surface charging and tracking problems, corrections may be needed for orientation problems. Other systems: induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.)**.	Kp=8, including a 9-	100 per cycle (60 days per cycle)
G 3	Strong	Power systems: voltage corrections may be required, false alarms triggered on some protection devices. Spacecraft operations: surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. Other systems: intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.)**.	Kp=7	200 per cycle (130 days per cycle)
G 2	Moderate	Power systems: high-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. Spacecraft operations: corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. Other systems: HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.)**.	Kp=6	600 per cycle (360 days per cycle)
G 1	Minor	Power systems: weak power grid fluctuations can occur. Spacecraft operations: minor impact on satellite operations possible. Other systems: migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine)**.	Kp=5	1700 per cycle (900 days per cycle)

* Based on this measure, but other physical measures are also considered.
** For specific locations around the globe, use geomagnetic latitude to determine likely sightings (see www.sec.noaa.gov/Aurora)

Scale	Descriptor	Effect	Physical measure	Average Frequency
Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
S 4	Severe	Biological: unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: may experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.	10^4	3 per cycle
S 3	Strong	Biological: radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk.*** Satellite operations: single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: degraded HF radio propagation through the polar regions and navigation position errors likely.	10^3	10 per cycle
S 2	Moderate	Biological: passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk.*** Satellite operations: infrequent single-event upsets possible. Other systems: effects on HF propagation through the polar regions, and navigation at polar cap locations possibly affected.	10^2	25 per cycle
S 1	Minor	Biological: none. Satellite operations: none. Other systems: minor impacts on HF radio in the polar regions.	10	50 per cycle

* Flux levels are 5 minute averages. Flux in particles·s^{-1}·$ster^{-1}$·cm^{-2} Based on this measure, but other physical measures are also considered.
** These events can last more than one day.
*** High energy particle measurements (>100 MeV) are a better indicator of radiation risk to passenger and crews. Pregnant women are particularly susceptible.

Scale	Descriptor	Effect	Physical measure	Average Frequency
Radio Blackouts			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extreme	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle
R 4	Severe	HF Radio: HF radio communication blackout on most of the sunlit side of Earth for one to two hours. HF radio contact lost during this time. Navigation: Outages of low-frequency navigation signals cause increased error in positioning for one to two hours. Minor disruptions of satellite navigation possible on the sunlit side of Earth.	X10 (10^{-3})	8 per cycle (8 days per cycle)
R 3	Strong	HF Radio: Wide area blackout of HF radio communication, loss of radio contact for about an hour on sunlit side of Earth. Navigation: Low-frequency navigation signals degraded for about an hour.	X1 (10^{-4})	175 per cycle (140 days per cycle)
R 2	Moderate	HF Radio: Limited blackout of HF radio communication on sunlit side, loss of radio contact for tens of minutes. Navigation: Degradation of low-frequency navigation signals for tens of minutes.	M5 ($5x10^{-5}$)	350 per cycle (300 days per cycle)
R 1	Minor	HF Radio: Weak or minor degradation of HF radio communication on sunlit side, occasional loss of radio contact. Navigation: Low-frequency navigation signals degraded for brief intervals.	M1 (10^{-5})	2000 per cycle (950 days per cycle)

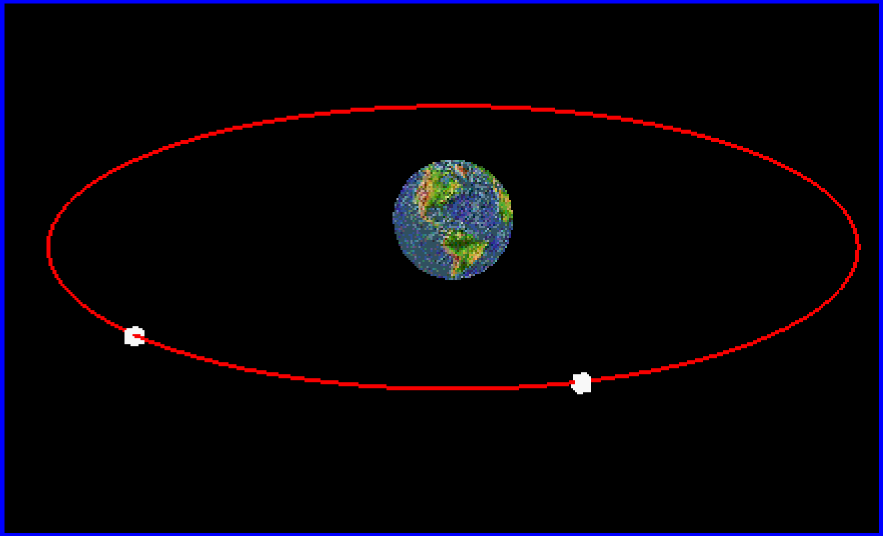
* Flux, measured in the 0.1-0.8 nm range, in W·m^{-2}. Based on this measure, but other physical measures are also considered.
** Other frequencies may also be affected by these conditions.

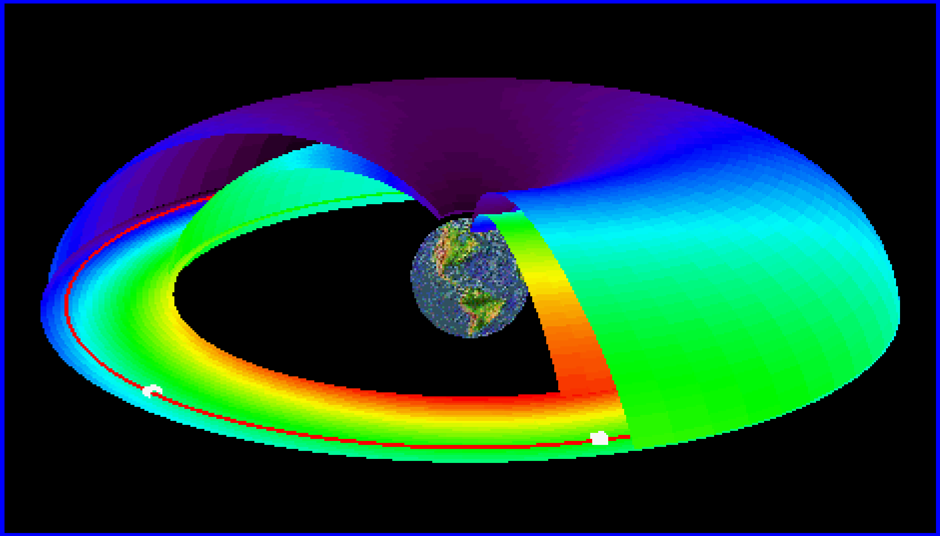
URL: www.sec.noaa.gov/NOAAScales

March 1, 2005

http://sec.noaa.gov

Relativistic Electron Specification Throughout Inner Magnetosphere: >2 MeV Electron Flux





Current Product

One value at GOES-East
One value at GOES-West
5 minute cadence

New Product

Utilize data and models to specify radial band at all longitudes
3-D grid to low altitudes
5 minute cadence

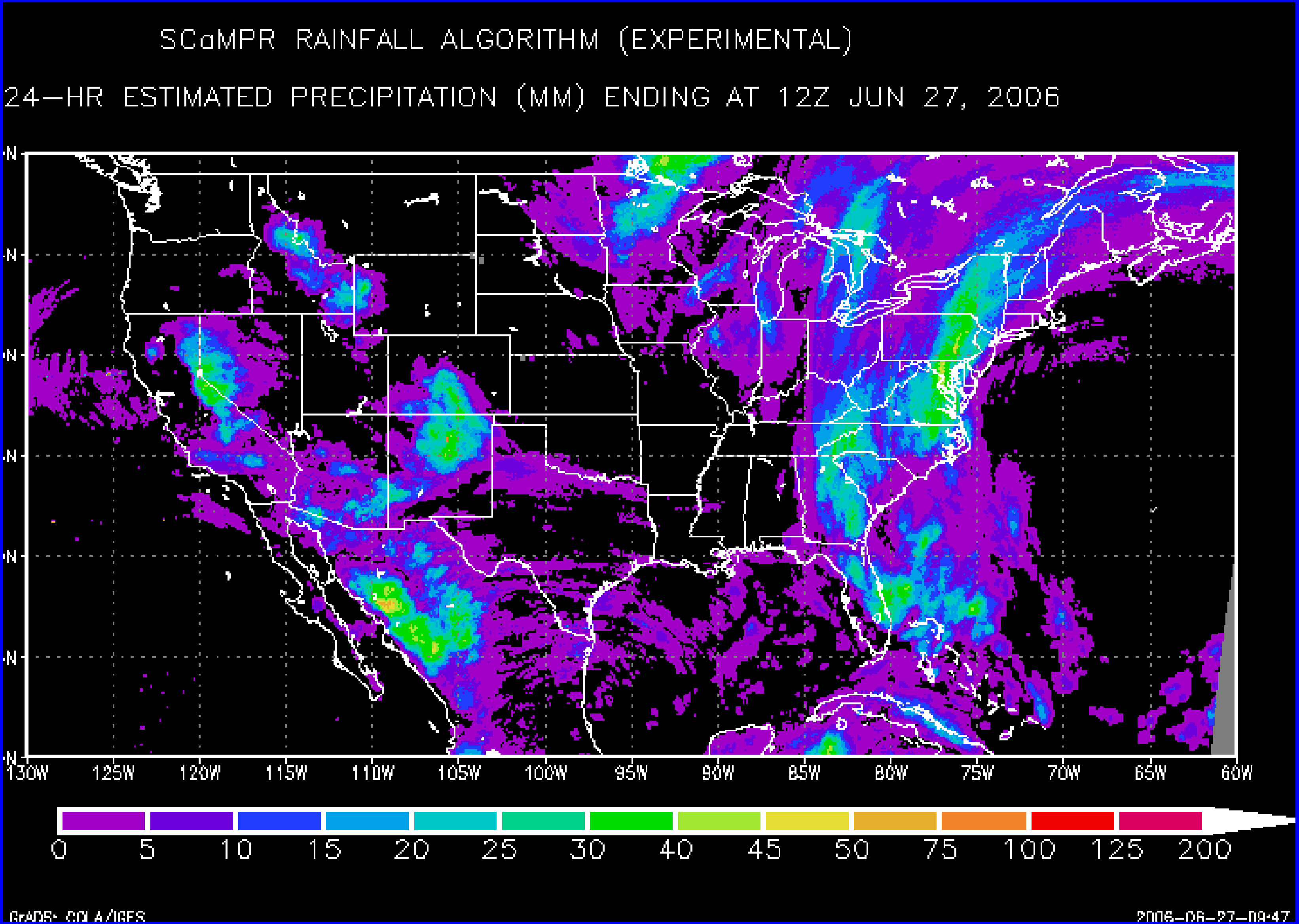
Benefit: Improved specification of the satellite-charging environment at all longitudes (GEO) and in MEO and LEO, and improved specification of human radiation hazard at International Space Station.

GOES-R and Societal Benefit areas

Water Resources

- Monitoring coastal environment
- Auxiliary services data collection (river monitoring, etc).
- Monitoring of chlorophyll, turbidity and sediment transport
- Auxiliary services used for Reservoir Management, water quality, etc.
- Rainfall
- Drought
- etc.

Rainfall (from Bob Kuligowski)



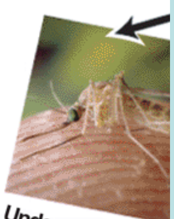

TERRA MODIS 2006-06-18 1615-1627 UTC Bands 010403: Washington DC hi-res
SSEC UW-MADISON DIRECT BROADCAST
June 18, 2006 – “Before”


TERRA MODIS 2006-06-29 1556-1608 UTC Bands 010403: Washington DC hi-res
SSEC UW-MADISON DIRECT BROADCAST
June 29, 2006 – “After”

GOES-R and Societal Benefit areas

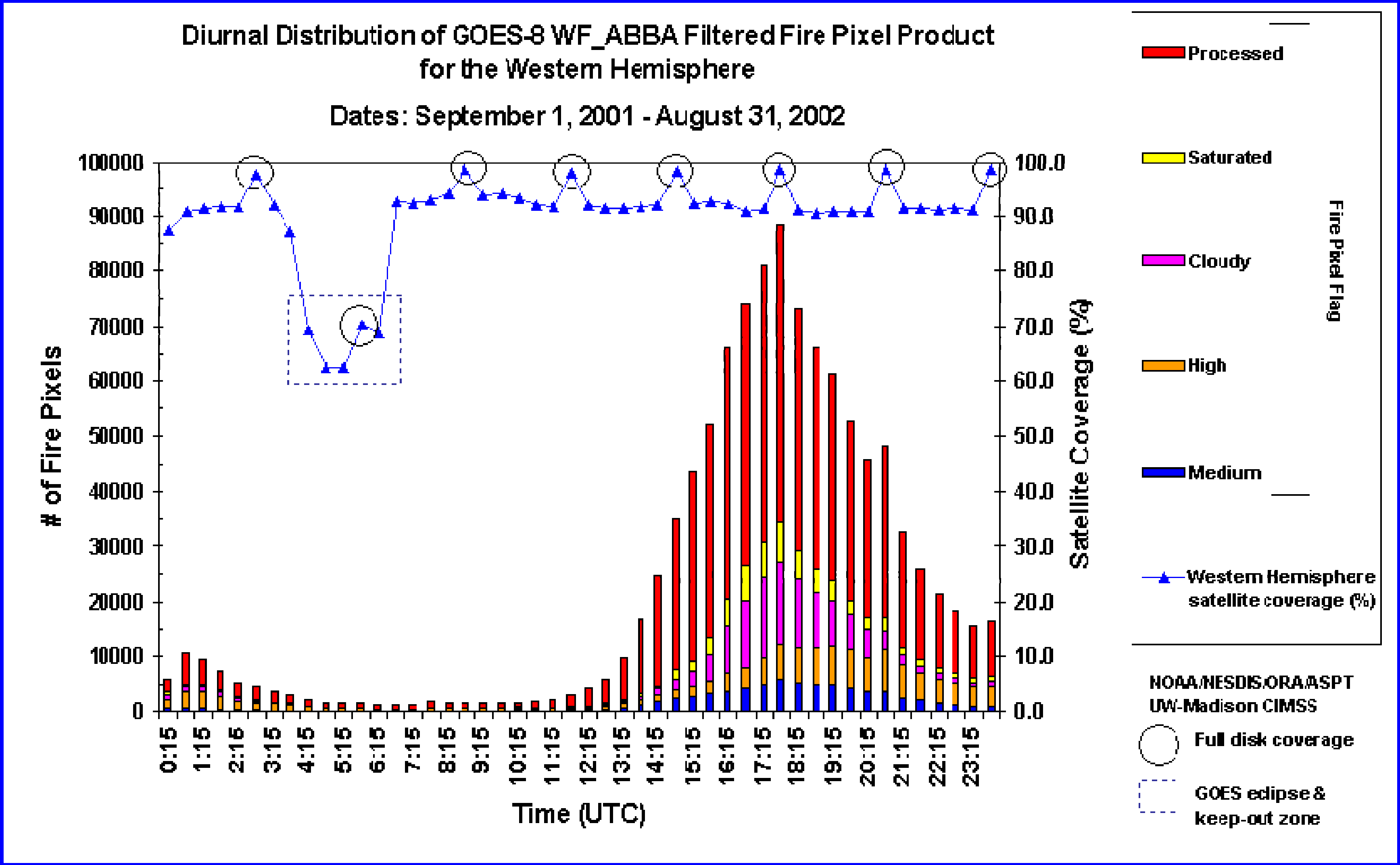
Climate

- Hourly high spectral resolution infrared radiances facilitate radiance calibration, calibration-monitoring
- Provide measurements that resolve climate-relevant changes in atmosphere, ocean, land and cryosphere.
- Solar irradiance inputs
- Diurnal signature for fires
- Diurnal signature of clouds
- Diurnal signature for clear-sky Land/Sea temperatures
- Diurnal signature of lightning over both land and ocean
- Improved measurements of Outgoing Longwave Radiation (OLR) and some trace gases
- Continuing the geostationary radiance database
- etc.



& Change

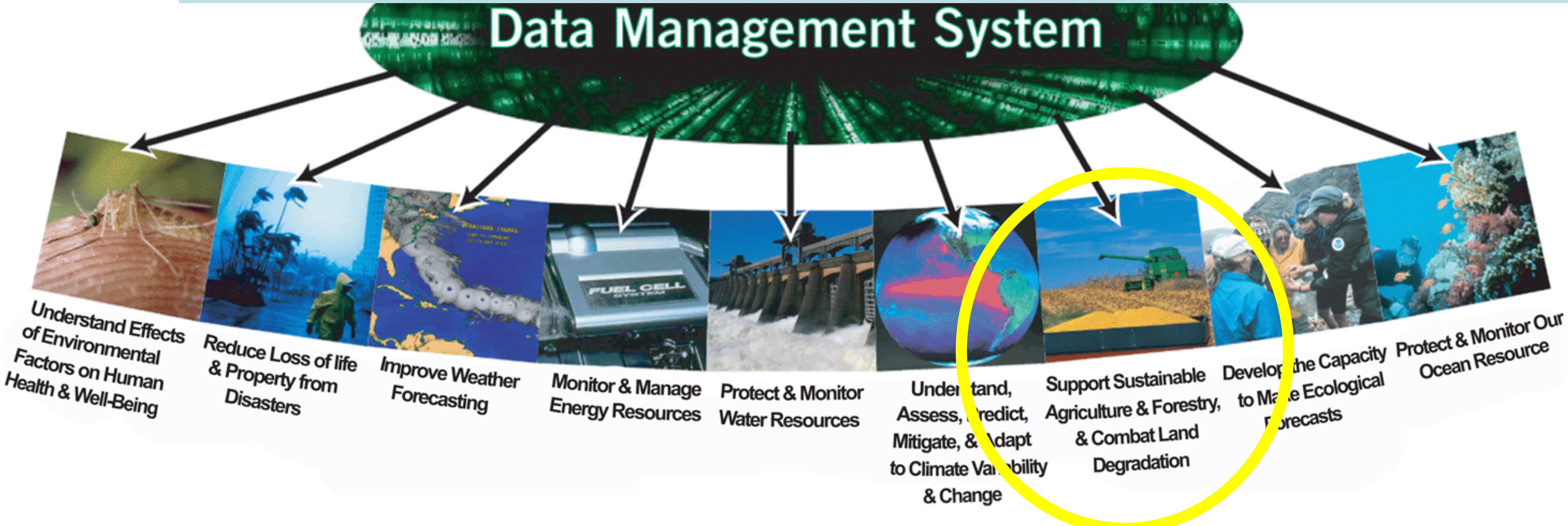
GOES can monitor diurnal changes



GOES-R and Societal Benefit areas

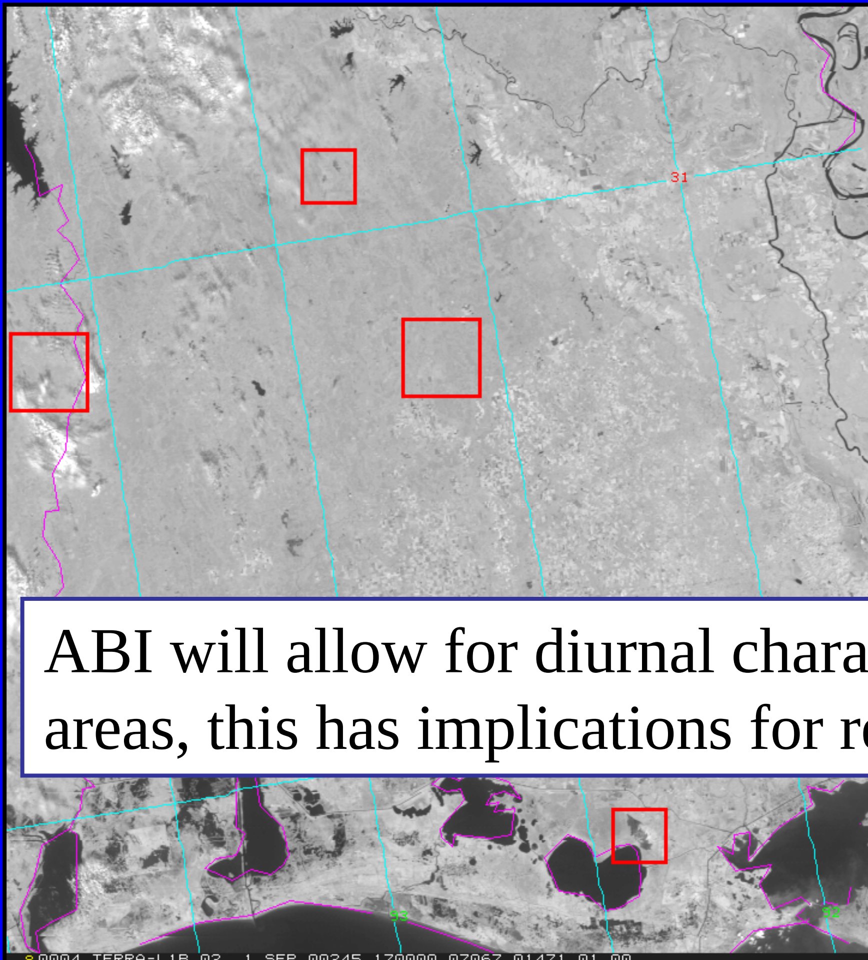
Agriculture

- Monitoring of the surface vegetation
- Monitoring of burn scars
- Improved knowledge of moisture/thermal fields provide better data for agricultural forecasting.
- NWP
- etc.

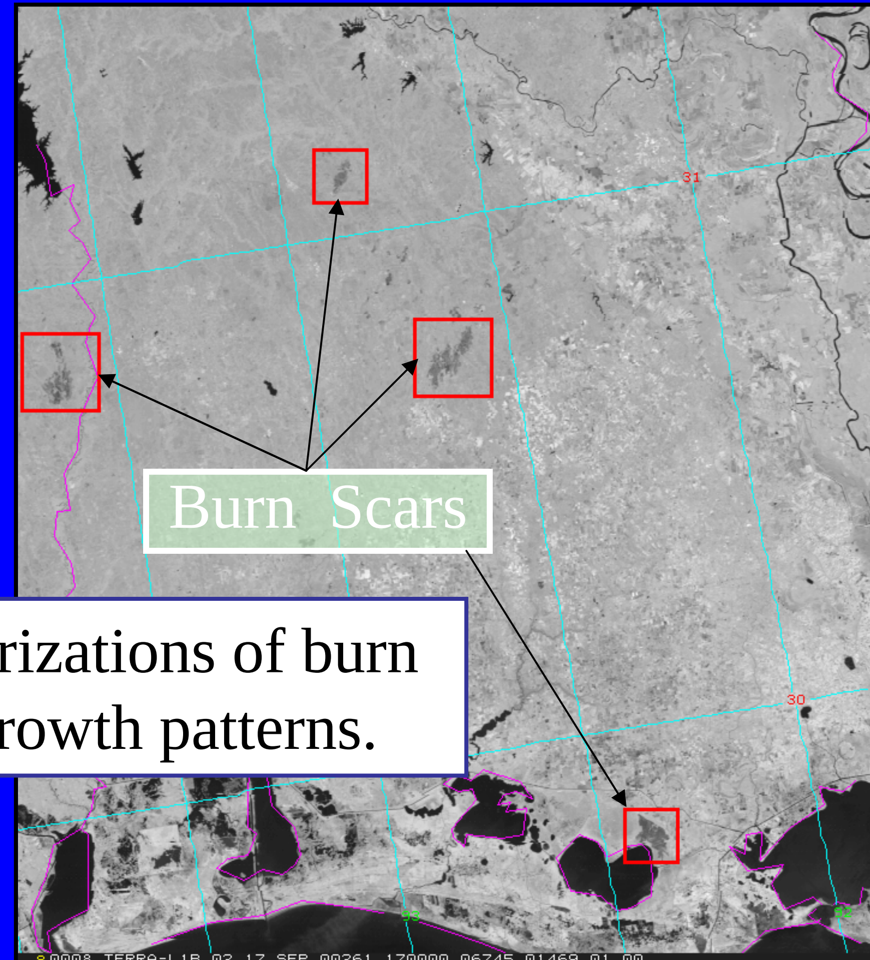


MODIS Detects Burn Scars in Louisiana

01 September 2000-- Pre-burning



17 September 2000-- Post-burning



ABI will allow for diurnal characterizations of burn areas, this has implications for re-growth patterns.

Scars (dark regions) caused by biomass burning in early September are evident in MODIS 250 m NIR channel 2 (0.85 μm) imagery on the 17th.

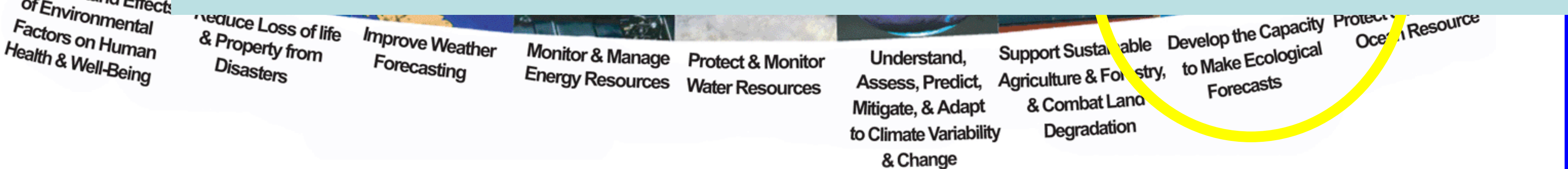
CIMSS, UW

MODIS Data from GSFC DAAC

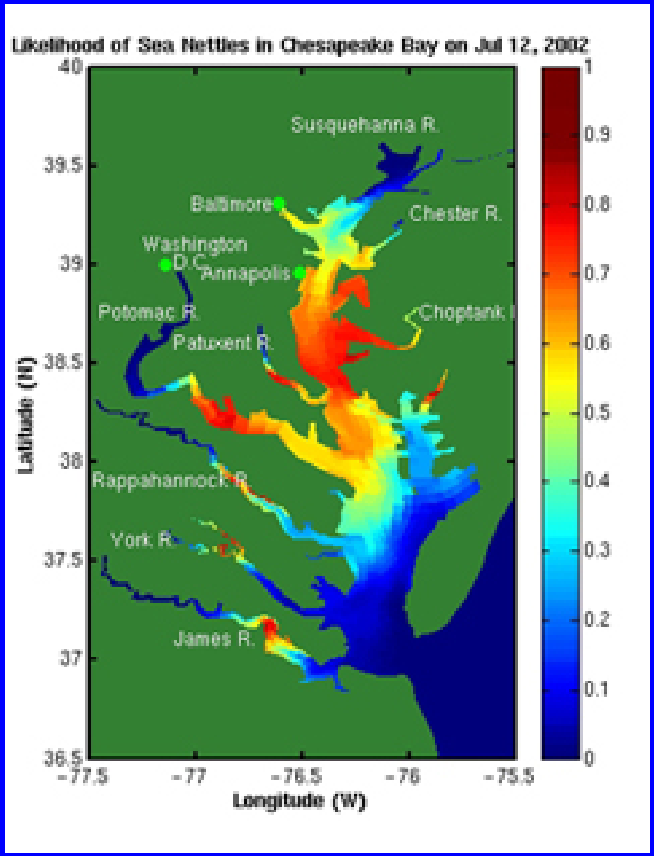
GOES-R and Societal Benefit areas

Ecological forecasts

- Huge increase in measurements beneficial to ecosystem management and coastal & ocean resource utilization.
- First time ever, characterization of diurnal ocean color as a function of tidal conditions and observation of phytoplankton blooms (e.g. red tides) as they occur.
- Improved coastal environment monitoring of the response of marine ecosystems to short-term physical events, and location of hazardous materials, such as some oil spills, and noxious algal blooms
- etc.



Local Short-term Ecological Forecasting

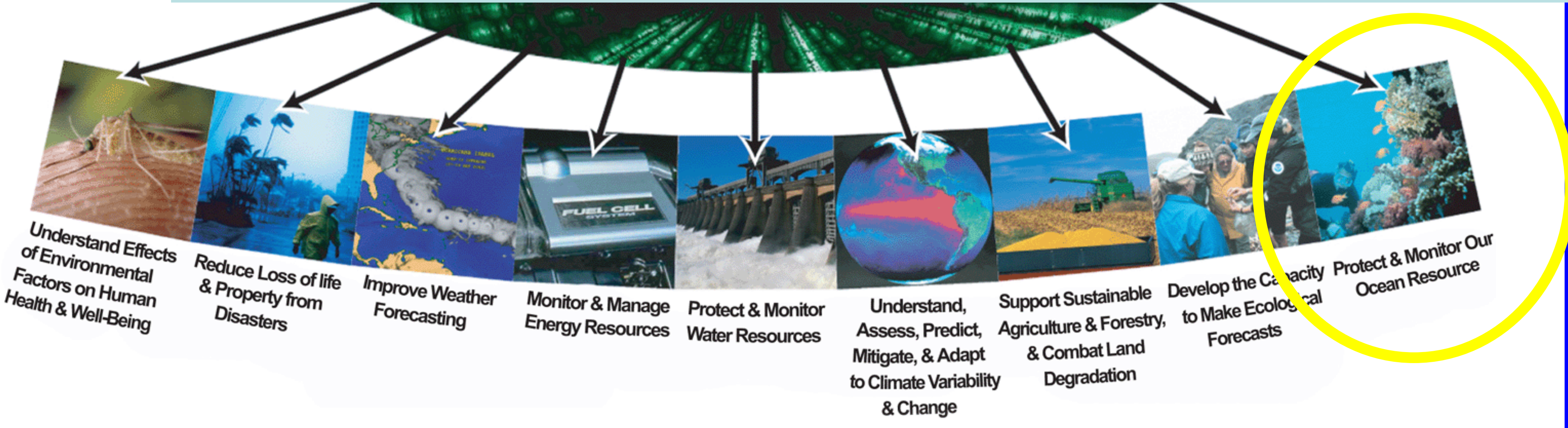


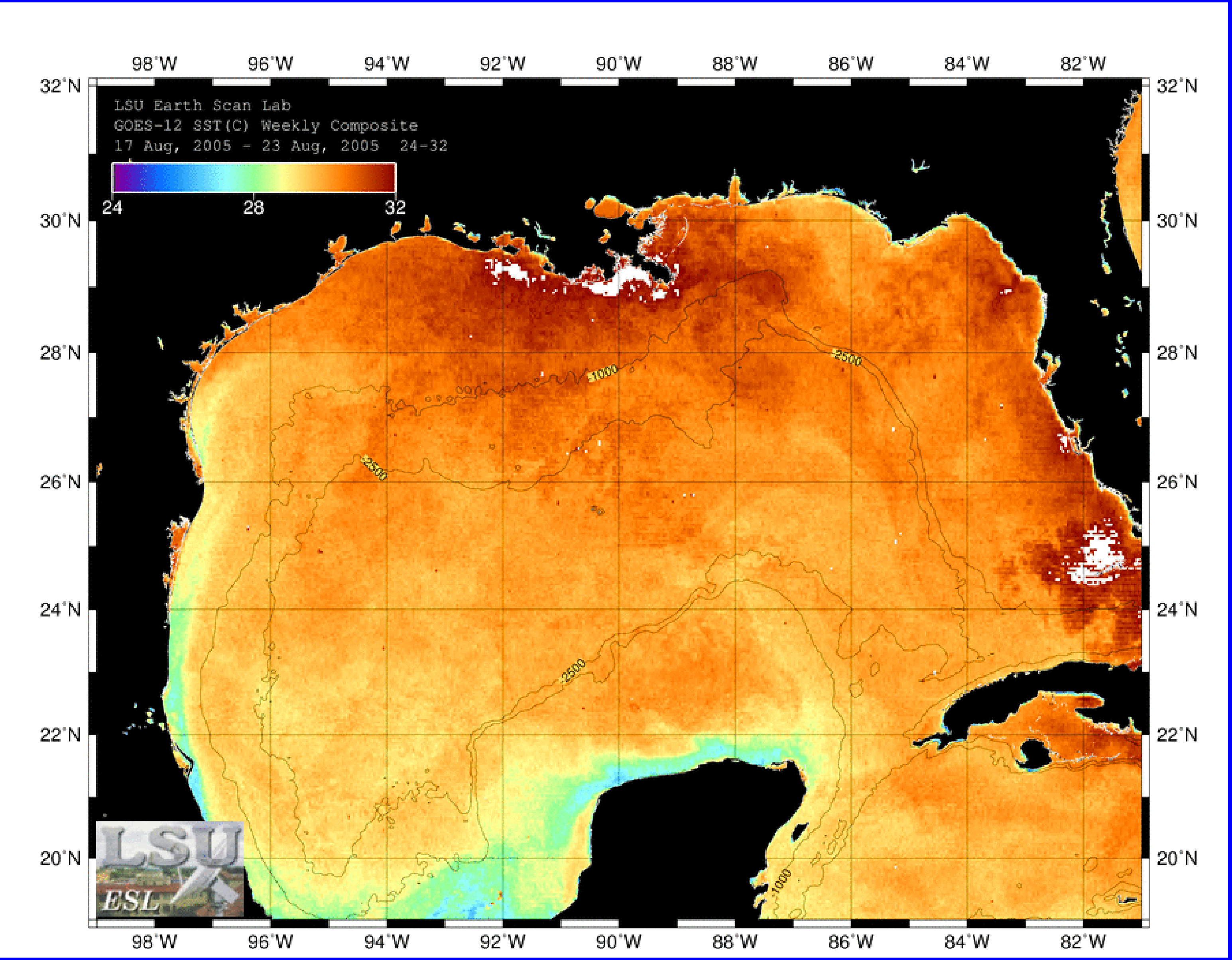
- **Sea Nettles in the Chesapeake Bay:** Sea nettles, *Chrysaora quinquecirrha*, seasonally infest the Chesapeake Bay and affect many activities along its shores, including recreational activities.

GOES-R and Societal Benefit areas

Ocean Resources

• Monitoring of sea surface temperature near corals in the Western hemisphere
• Better depiction of ocean currents, low level winds and calm areas, major storms, and hurricanes (locations, intensities, and motions) benefits ocean transportation.
• etc.





GOES SST can capture diurnal SST trends

Summary

The great amount of information from the GOES-R will offer a continuation of current products (precipitation, atmospheric motion vectors, SST, radiances, hurricane intensity, atmospheric retrievals, solar/space monitoring, etc) and new products.

The GOES-R products, based on validated requirements, will cover a wide range of phenomena. This includes applications relating to: weather, ocean, coasts, land, climate, solar, space and hazards.

The Advanced Baseline Imager (ABI), along with the HES, and the GLM on GOES-R series will enable much improved monitoring of Earth compared to current capabilities. The SIS and SEISS will improve monitoring of the near-Earth and Solar environments.

Aviation -- Summary

Aviation interests with be much better served with GOES-R

ABI: visibility (dust, fog, smoke, fires), fog, waves, SO_2, winds, rainfall, clouds, etc

HES: ozone, temperature/moisture profiles, inversions, winds, clouds, etc.

GLM: lightning, indirectly updrafts, etc.

SIS/SEISS: comm, polar flights, etc.

Also, these products can be used together to give an even more complete view of the earth/atmosphere.

More information

NOAA GOES-R page:

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

Documentation from NASA:

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

NOAA Space Weather Scales:

- http://sec.noaa.gov

COAST Home page:

- http://cioss.coas.oregonstate.edu/CIOSS/coast.html/

Total lightning data used operationally by forecasters:

- http://weather.msfc.nasa.gov/sport

ABI/HES Research Home pages:

- http://cimss.ssec.wisc.edu/goes/abi/
- http://cimss.ssec.wisc.edu/goes/hes/
- AMS BAMS Article on the ABI (August 2005)