GOES-R Algorithm Working Group (AWG) Level-2 Product Validation Readiness Activities

Jaime Daniels

Center for Satellite Applications and Research

National Environmental Satellite Data and Information Surface

National Oceanic and Atmospheric Administration

Contributions from AWG Team Leads and members of the GOES-R AWG teams

Outline

- GOES-R Instruments
- The Algorithm Working Group (AWG): A Brief Introduction
- AWG Pre-launch Product Validation Strategies and Activities
- Planning for Post-Launch

GOES-R Instruments

Terrestrial Weather

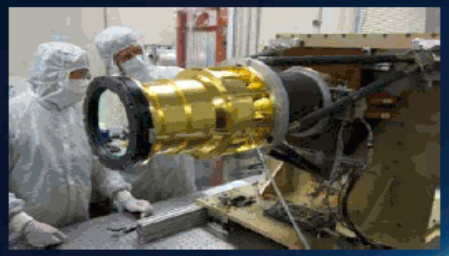
Visual & IR Imagery

Advanced Baseline Imager (ABI)

Exelis
Ft. Wayne, IN

Lightning Mapping

Geostationary Lightning Mapper (GLM)



Lockheed Martin Advanced Technology Center
Palo Alto, CA

New and improved capabilities for:

- Increased lead times for severe weather warnings
- Improved forecasts; Better storm tracking capabilities
- Solar, space weather, and climate analyses
- Advanced products for aviation, transportation, commerce

Space Weather

Space Weather Monitoring

Space Environment In Situ Suite (SEISS)

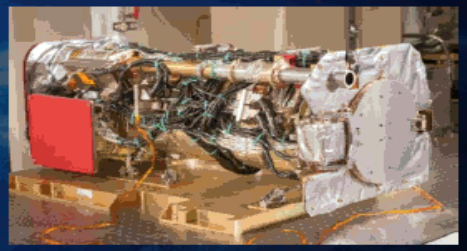
Assurance Technology Corp.
Carlisle, MA

Magnetometer

Lockheed Martin Space Systems Co.
Newtown, PA

Solar Imaging

Solar Ultra-Violet Imager (SUVI)

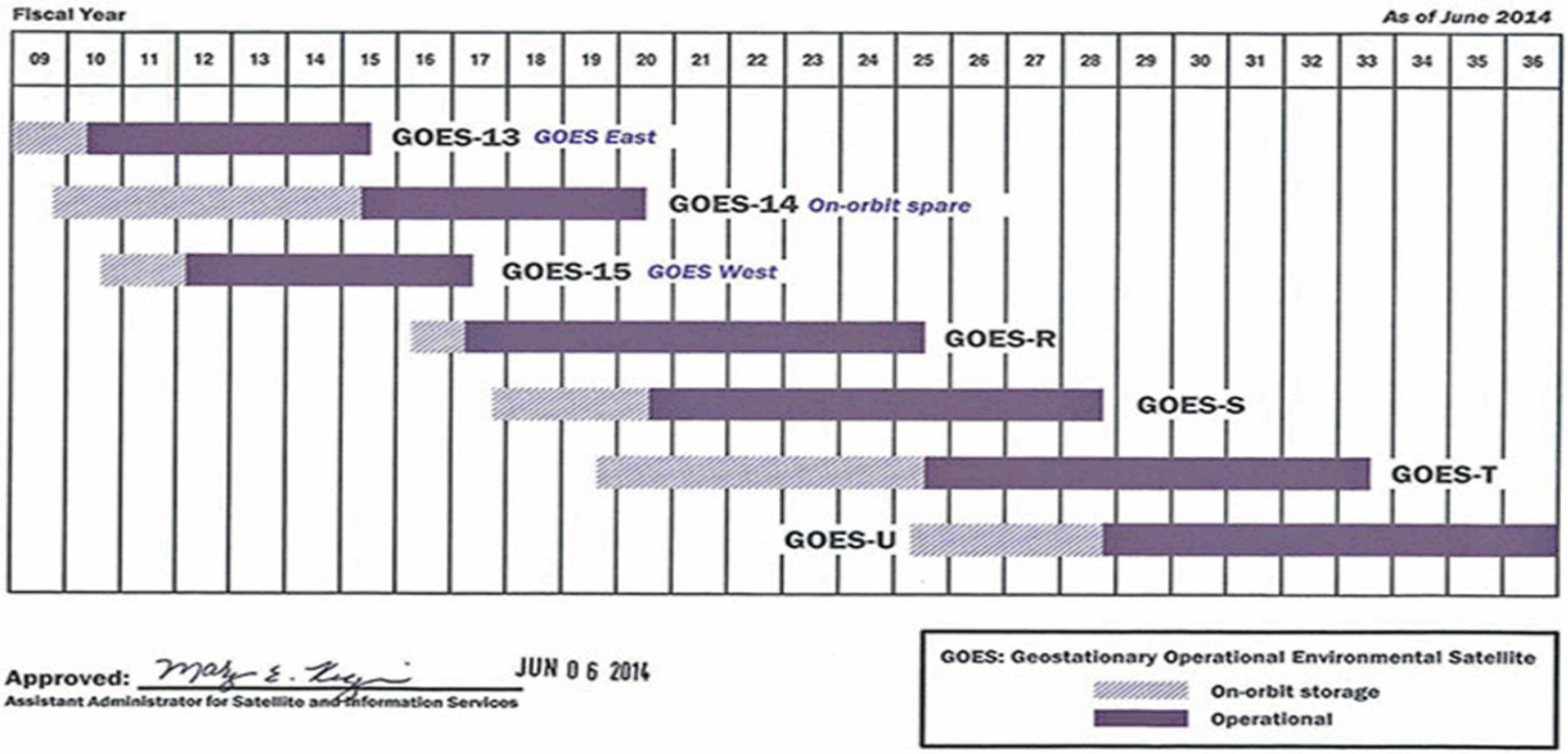


Lockheed Martin Advanced Technology Center

Extreme UV/X-Ray Irradiance Sensors (EXIS)

Laboratory for Atmospheric and Space Physics
Boulder, CO

GOES Fly-Out Chart



GOES-R Launch: *No earlier than March 2016*

GOES-R ABI

	ABI	Current GOES Imager
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

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)

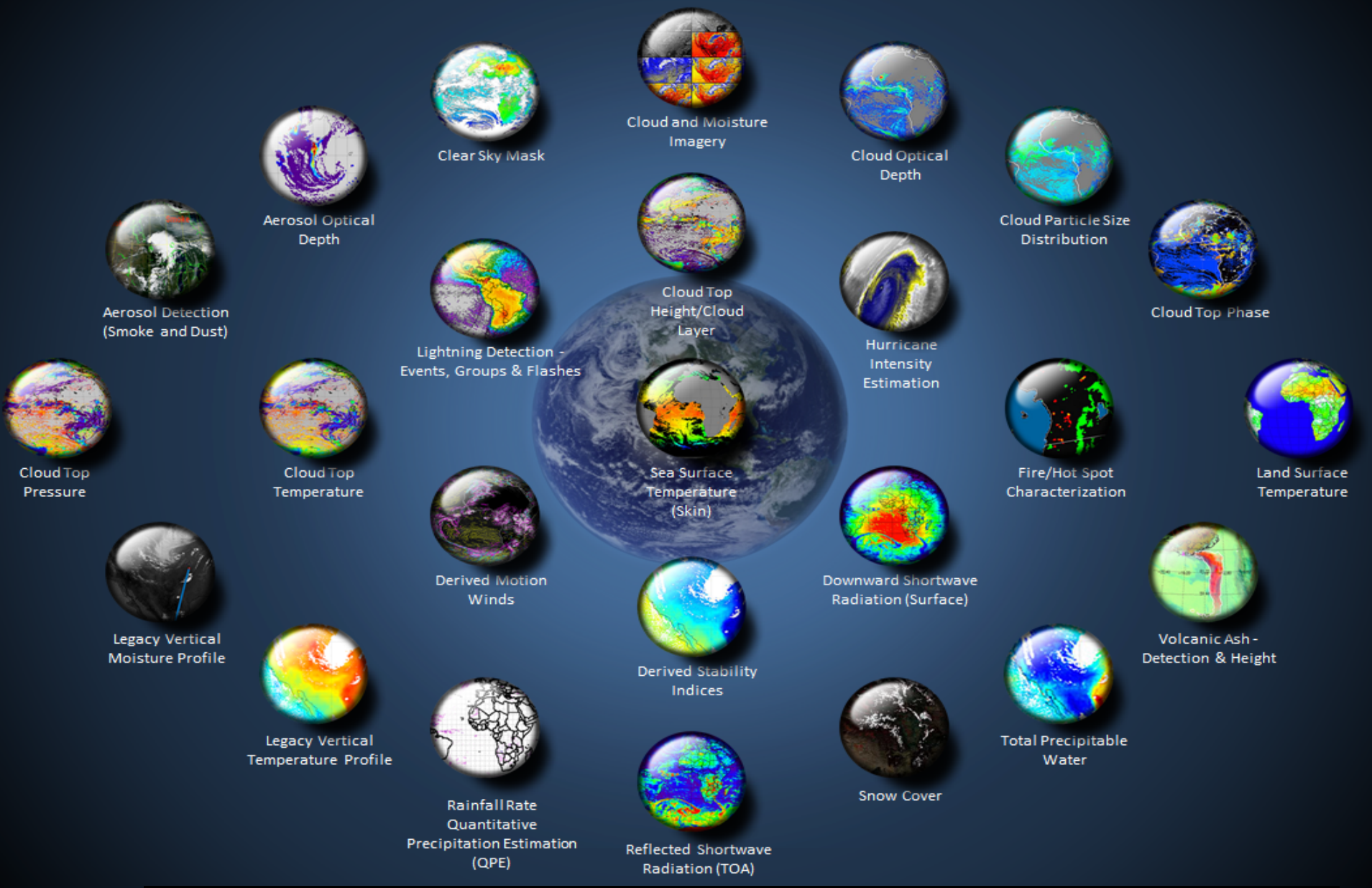
- Solar Flux: EUV
- Solar Flux: X-ray Irradiance

Solar Ultraviolet Imager (SUVI)

- Solar EUV Imagery

Level-2 products outlined in red

GOES-R Baseline Products



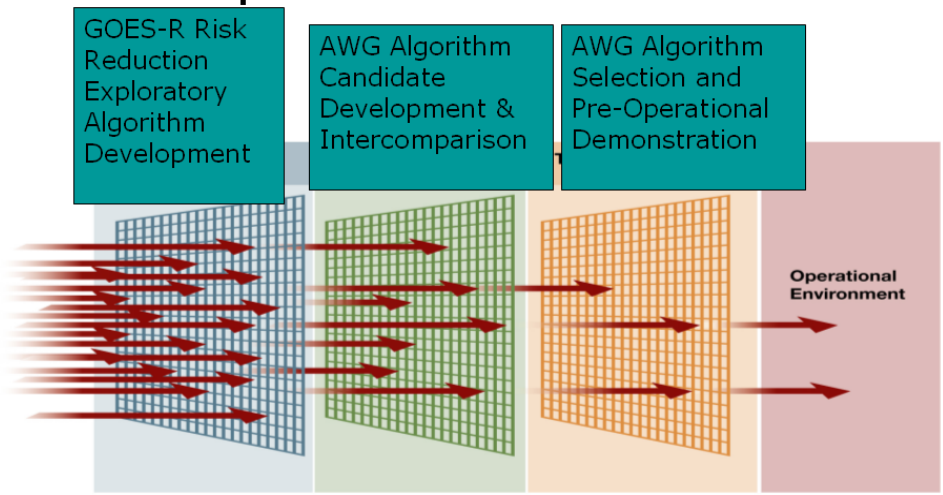
http://www.goes-r.gov/products/baseline.html

GOES-R Algorithm Working Group

- **Mission:**
  - To select, develop, test, validate, and demonstrate Level-2+ algorithms that meet the GOES-R F&PS requirements and provide them to the GOES-R Ground Segment.
  - Provide sustained life cycle validation and Level-2 product enhancements

- **End-to-End Capabilities**
  - Instrument Trade Studies
  - **Proxy Dataset Development**
  - **Algorithm Development and Testing**
  - **Product Demonstration Systems**
  - **Development of Cal/Val Tools**
  - Integrated Cal/Val Enterprise System
  - Radiance and **Product Validation**
  - Algorithm and application improvements
  - **User Readiness** and Education

Algorithm Research to Operation Process



Algorithm Working Group

STAR GOES-R AWG PM
Jaime Daniels

Management Support
Tess Valenzuela (Budget/Schedule)

Imagery
Tim Schmit

Soundings
Tim Schmit

Winds
Jaime Daniels

Clouds
Andy Heidinger

Aviation
Ken Pryor
Mike Pavolonis

Aerosols
Shobha Kondragunta

Land
Bob Yu

Cryosphere
Jeff Key

Radiation Budget
Istvan Laszlo

Lightning
Steve Goodman

SST
Alexander Ignatov

Hydrology
Bob Kuligowski

Ocean Dynamics
Eileen Maturi

Algorithm Integration
Walter Wolf

Proxy
Fuhzong Weng

Cal/Val (Sensor)
Fred Wu

Team leads are STAR Scientists

Product Calibration/Validation Objectives

- Characterize the performance of GOES-R Level-2 products and demonstrate that they meet their respective specification requirements as described in the GOES-R Requirement Documents

- Provide the GOES-R user community with operationally viable, validated, and useful data products for their applications and missions

- Provide investigations into any product issues that impact a customer's ability to fulfill their missions and provide effective solutions

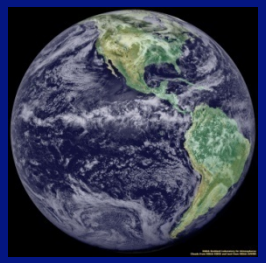
AWG Pre-launch Product Validation Strategies and Activities

- Verification of L2 product software being implemented in the GOES-R core ground system
- Extensive use of proxy data
- Continued validation and characterization of product performance
  - Through pre-launch Level-2 product demonstrations and validation studies
  - Using available ABI proxy data and reference/"ground truth" measurements
- Development of Level-2 product validation tools needed post-launch for:
  - Routine monitoring of L2 product performance (accuracy, precision)
  - "Deep-dive" assessments and analysis of products (problem resolution)

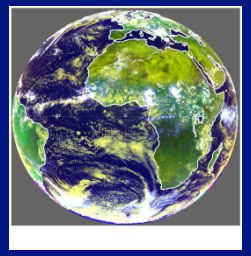
GOES-R Proxy Data Sources

"Real" PROXY Data Sources

Current GOES



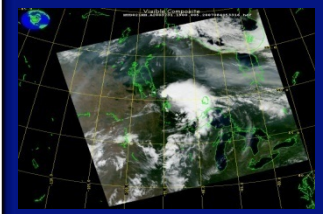
Meteosat/
SEVIRI



Future

Himawari-8

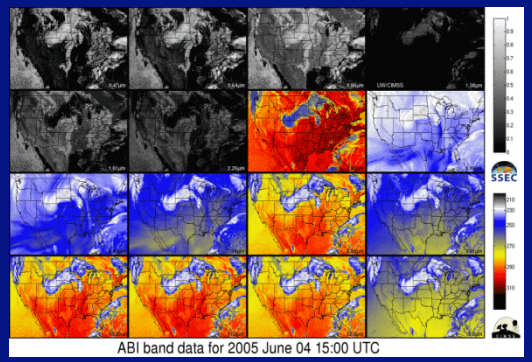
MODIS



TRMM/LIS

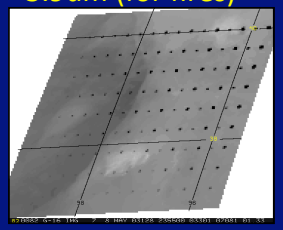
"Simulated" Proxy Data Sources

(FD, CONUS, Meso)

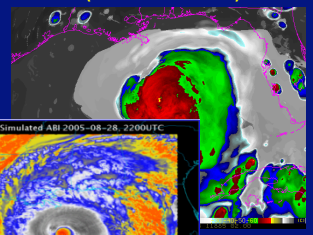


Case Studies

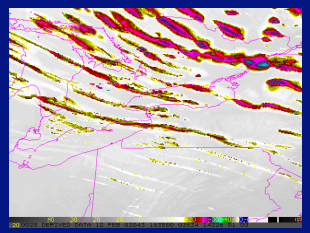
3.9um (for fires)

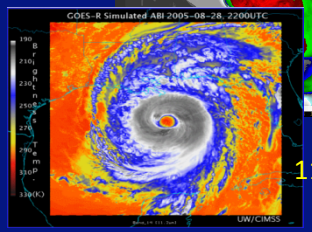


10.35um (Hurricane Lili)



10.35um (Lake Effect Snow)

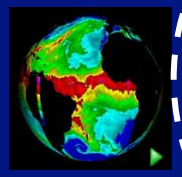
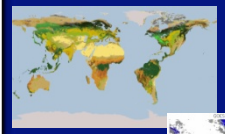
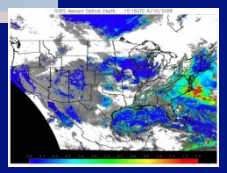


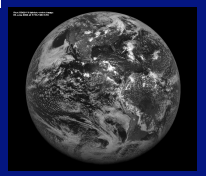


11.2 um (HurricaneKatrina)

The AWG teams continue to use available proxy data for their algorithm refinement, case study analyses, and product validation efforts…

Assessing and Characterizing Algorithm Performance



Seasonal conditions represented

Wide variety of atmospheric and surface conditions are represented

Algorithm Iterations

Level 2 Product Generation

Validate with Ground Truth

Validation Tools

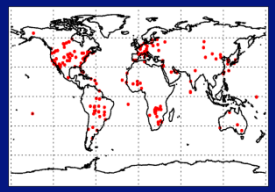
As algorithms mature…

- ✓ Better estimates of product performance
- ✓ Increased confidence that on-orbit product performance will meet specs
- ✓ Increased confidence that user needs are met

AWG approach for validating (estimating) performance (accuracy and precision) of L2 algorithms using ABI proxy data and correlative data sources…

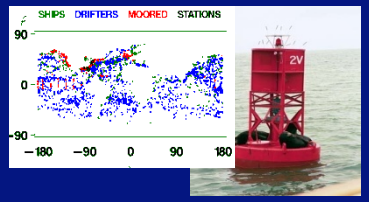
Reference/"Ground Truth" Data Sources

Aeronet Stations Aerosol Optical Depth

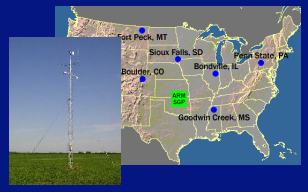


CALIPSO, CLOUDSAT
Clouds, Icing

Bouys, Ships SST



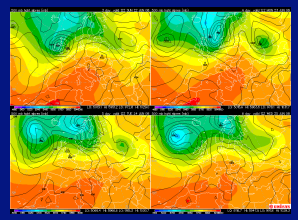
SURFRAD, ARM
LST, Radiation



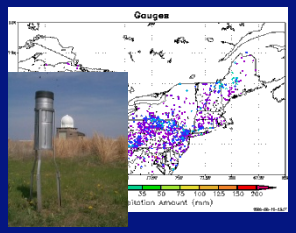
Radiosondes

Winds,Temperature, Moisture, Stability

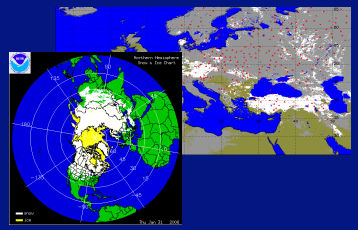
NWP Analyses Winds, Temperature, Moisture



Rain Guages
Precipitation



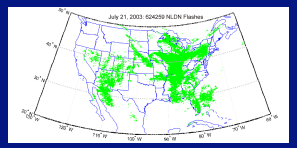
Sfc Snow Reports, NESDIS IMS
Snow



Ground-based Ozone
Ozone

Pilot Reports
Icing,Turbulence

National Lightning Detection Network (NLDN)
Lightning

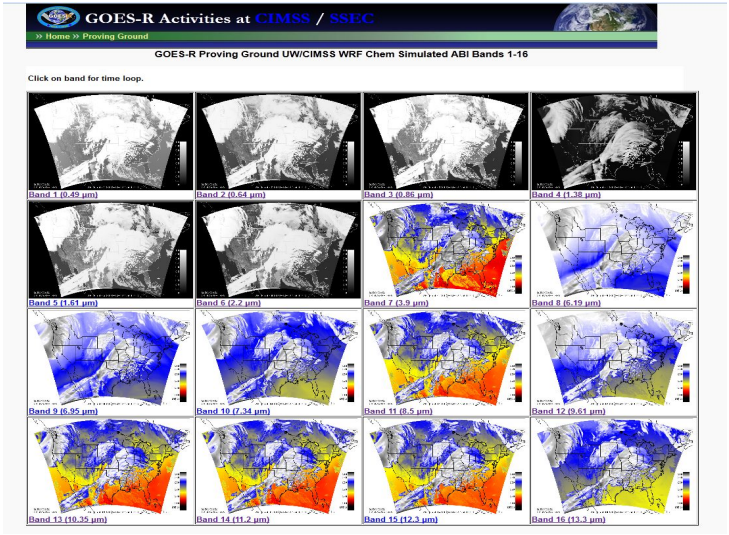


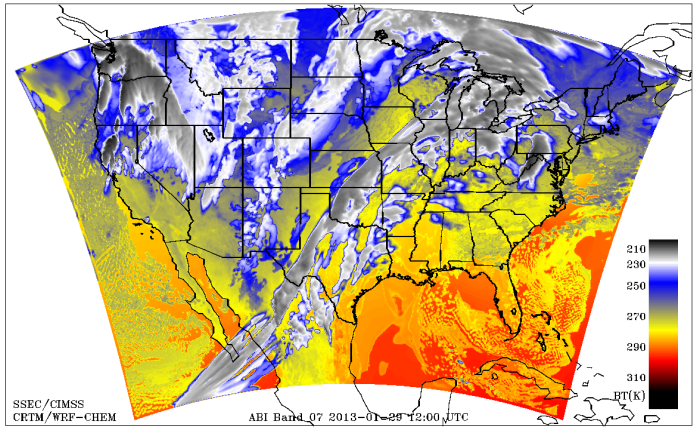
AWG Teams use a wide variety of Reference/"Ground Truth" datasets to assess and estimate Level-2 product algorithm performance.

GOES-R ABI High Fidelity Simulated Datasets

From the AWP Proxy Team at CIMSS…

- Generated via combination of high spatial resolution numerical model runs and advanced 'forward' radiative transfer models
- Some or all bands, various coverage (FD, CONUS, Meso), spatial resolutions, and formats (GOES-R Fixed Grid Format, NetCDF)
- Used by AWG product teams and in a number of GOES-R Proving Ground demonstrations
- Used to support ABI waiver analyses
- Planned use in GOES-R Ground System verification testing activities





These high fidelity simulated datasets are important for algorithm development, testing, verification, and user readiness activities

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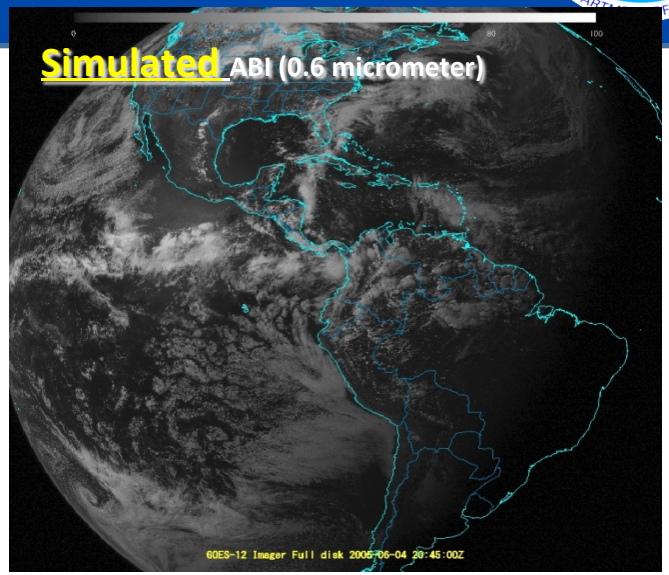

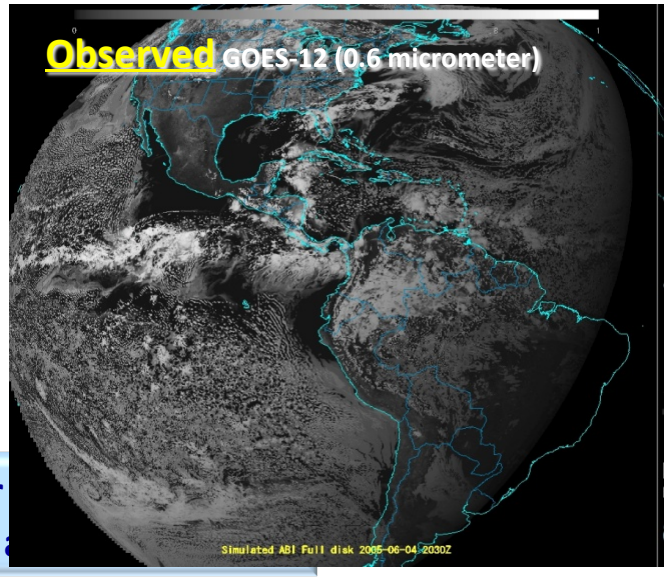

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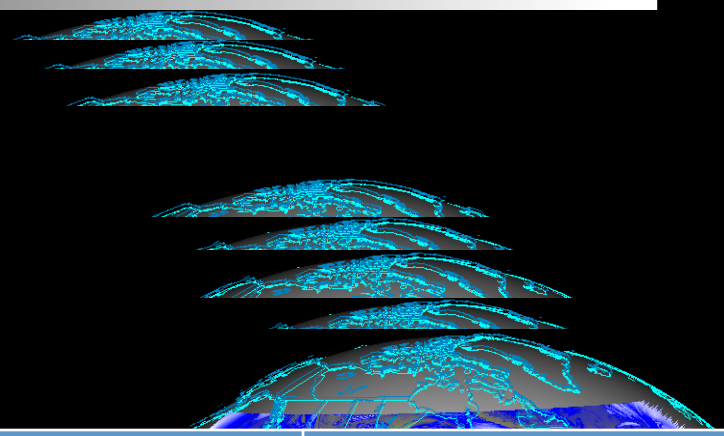
ABI Image Triplet Test Data @ 89.5W Delivered to the GOES-R Program



ABI Image Triplet	75W	89.5W	137W
Model	WRF	WRF	WRF
Number of times	7	7	7
Time range	20:00-20:30UTC	20:00-20:30UTC	20:00-20:30UTC
Day	04-Jun-2005	04-Jun-2005	04-Jun-2005
Sectors	FD, CONUS, MESO	FD, CONUS, MESO	FD, CONUS, MESO
Types	GRB, VAL	GRB, VAL	GRB, VAL
Navigation	FGF	FGF	FGF

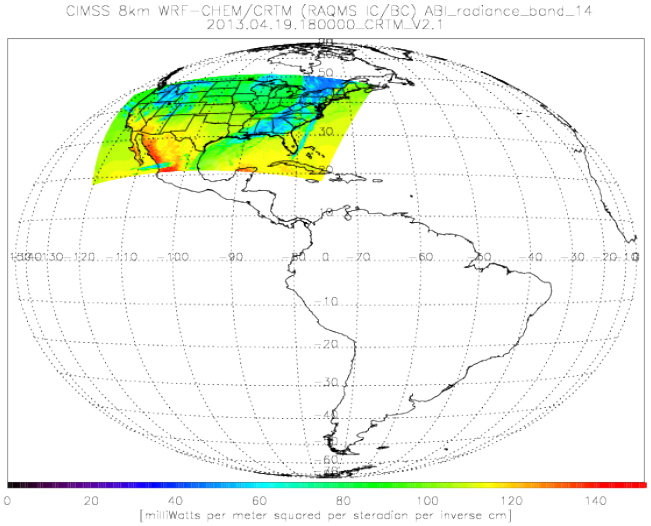
Simulated ABI Datasets for Ground System Testing

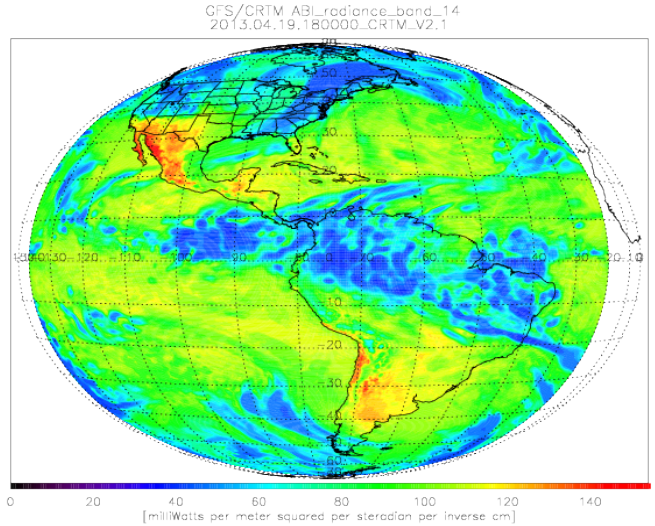
- Provide the ground system with "atmospherically realistic data" that can be used for system verification and system validation by injecting these data into the ground system *(Formal testing in 2015)*

- Capability exists now to provide routine, near real-time simulated ABI imagery
  - WRF-Chem model met/aerosol forecasts (8km) over CONUS using the Community Radiative Transfer Model (CRTM) to simulate all 16 ABI bands.
  - NCEP/GFS model 3 hr forecast (T574L64, an effective grid point spacing of ~27 km) outputs used, together with CRTM (v2.1), to produce ABI simulated radiances (all bands) at 3hr intervals
  - Generate simulated ABI radiances at 1hr intervals via interpolation of 3hr GFS forecast output and running CRTM every hour

- Simulated data (all bands) are remapped from WRF-chem & GFS grids to the GOES-R ABI fixed grid at their expected resolutions and converted to GRB

- Simulated imagery sent to and displayed in NOAA's National Weather Service's (NWS) AWIPS-2 System





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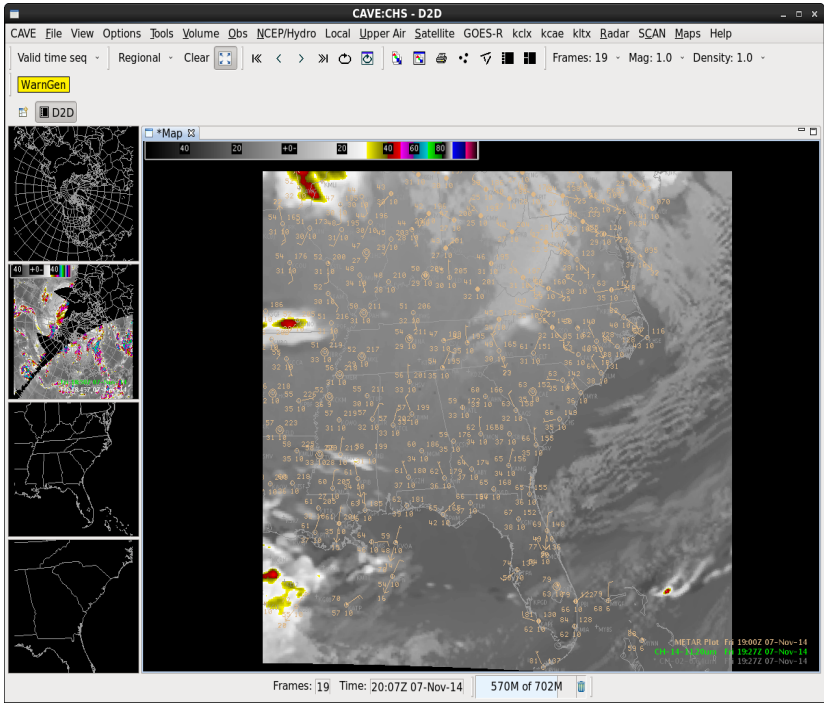
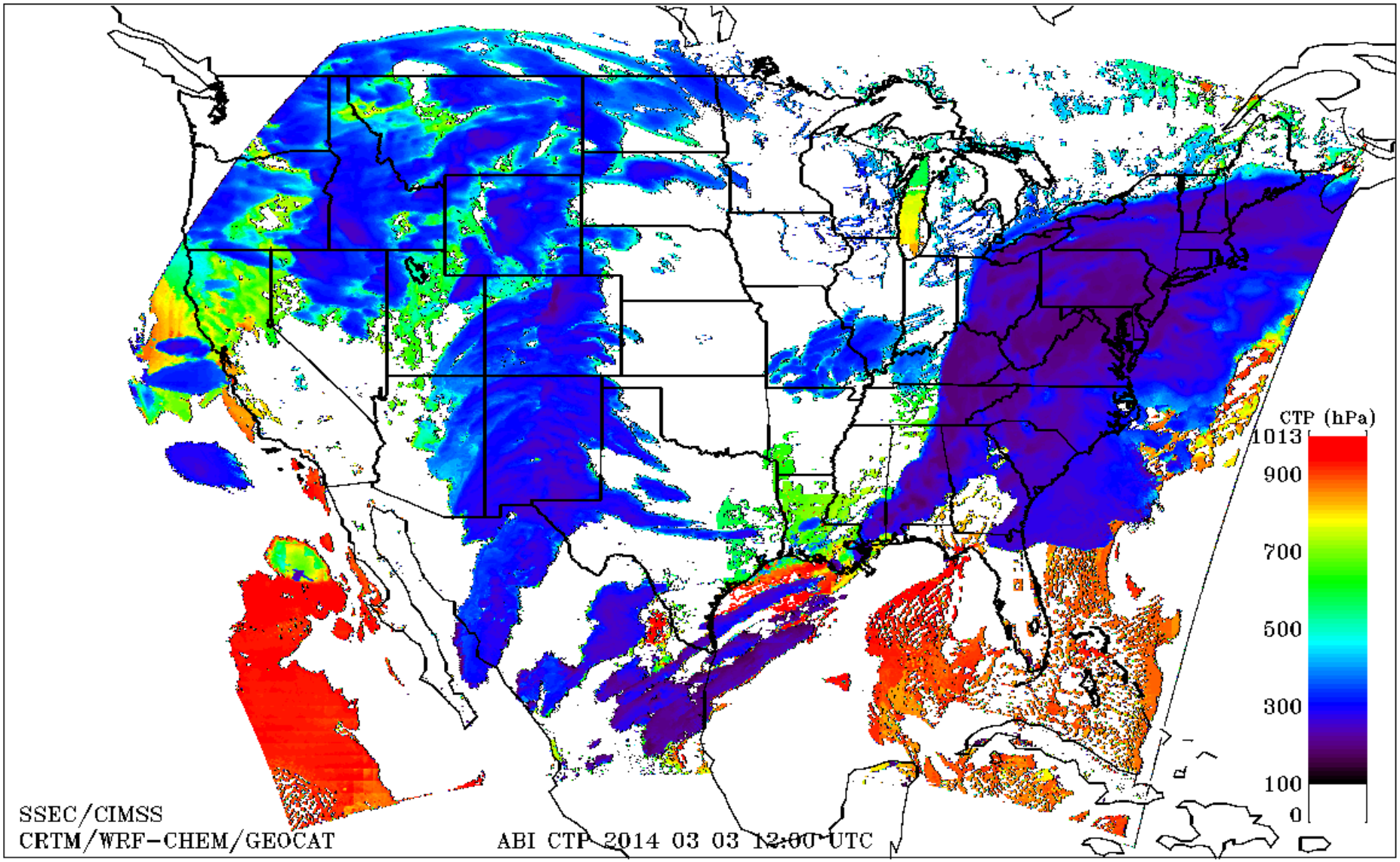
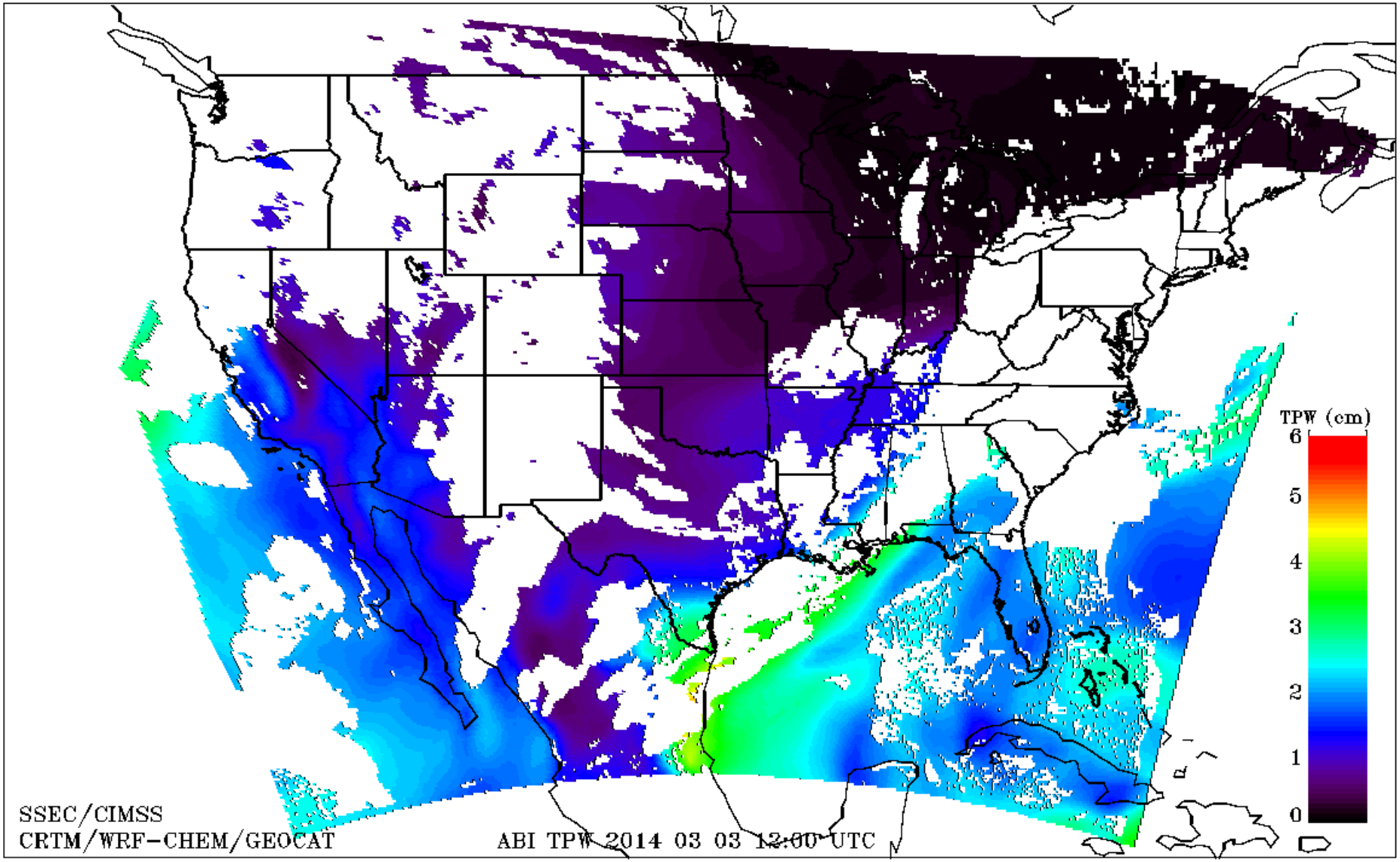
Simulated ABI 11.2um Imagery Displayed in NWS AWIPS-2 System



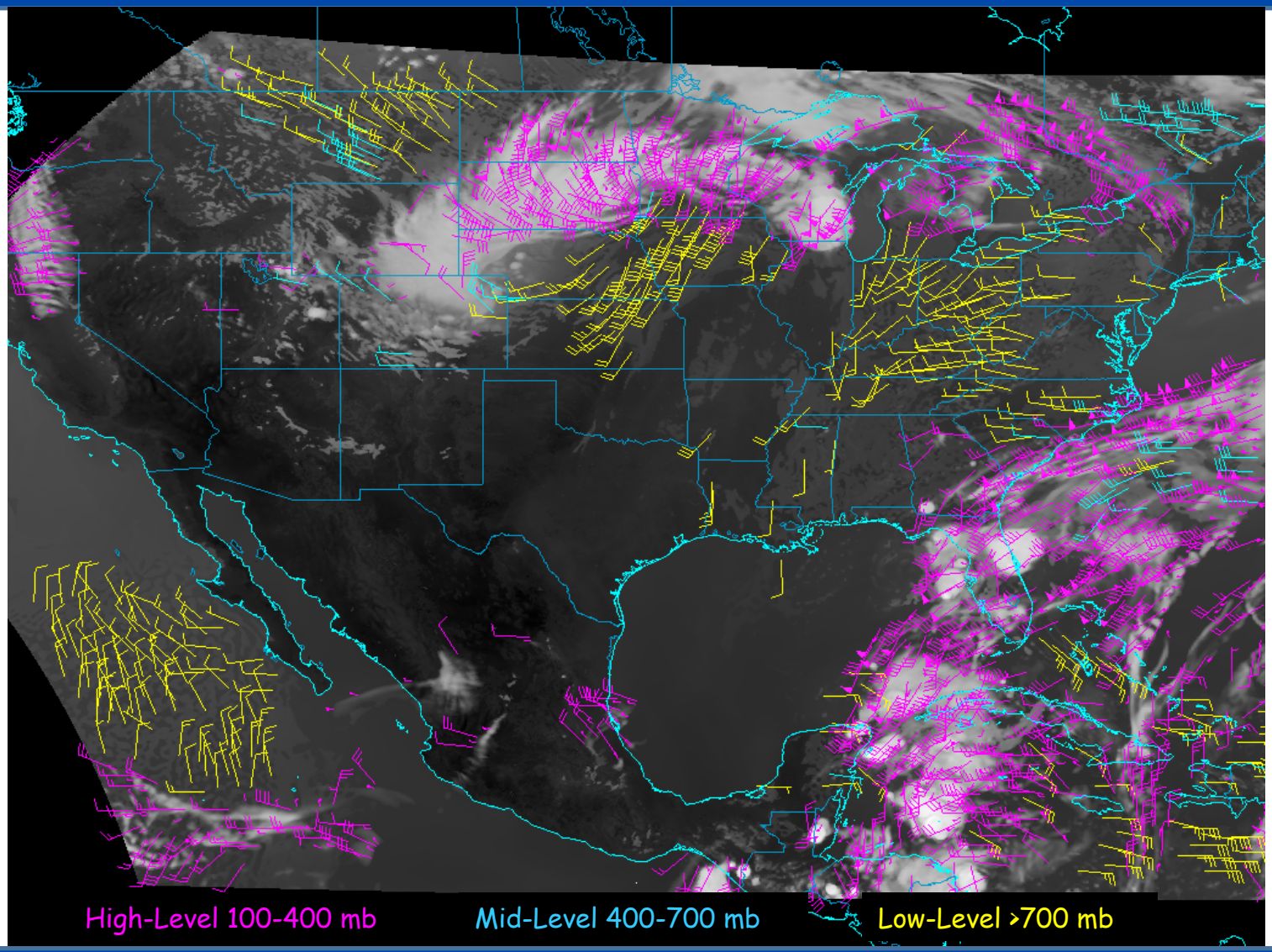
Cloud-Top Pressure Derived from Simulated ABI Imagery



Total Precipitable Water (TPW) Derived from Simulated ABI Imagery



Atmospheric Motion Vectors Derived from Simulated ABI Imagery



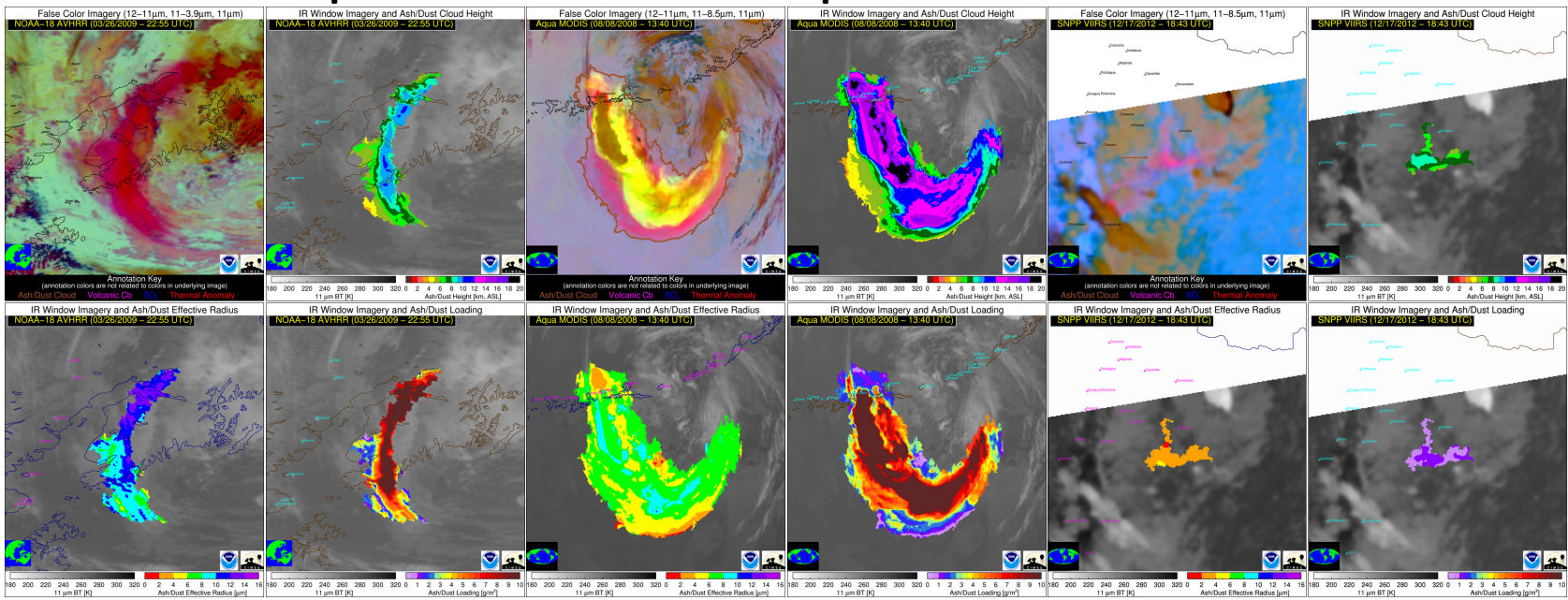
Making Full Use of the Space-based Observing System for Volcanic Cloud Monitoring

NOAA and MetOp AVHRR

Terra and Aqua MODIS

SNPP-VIIRS

LEO

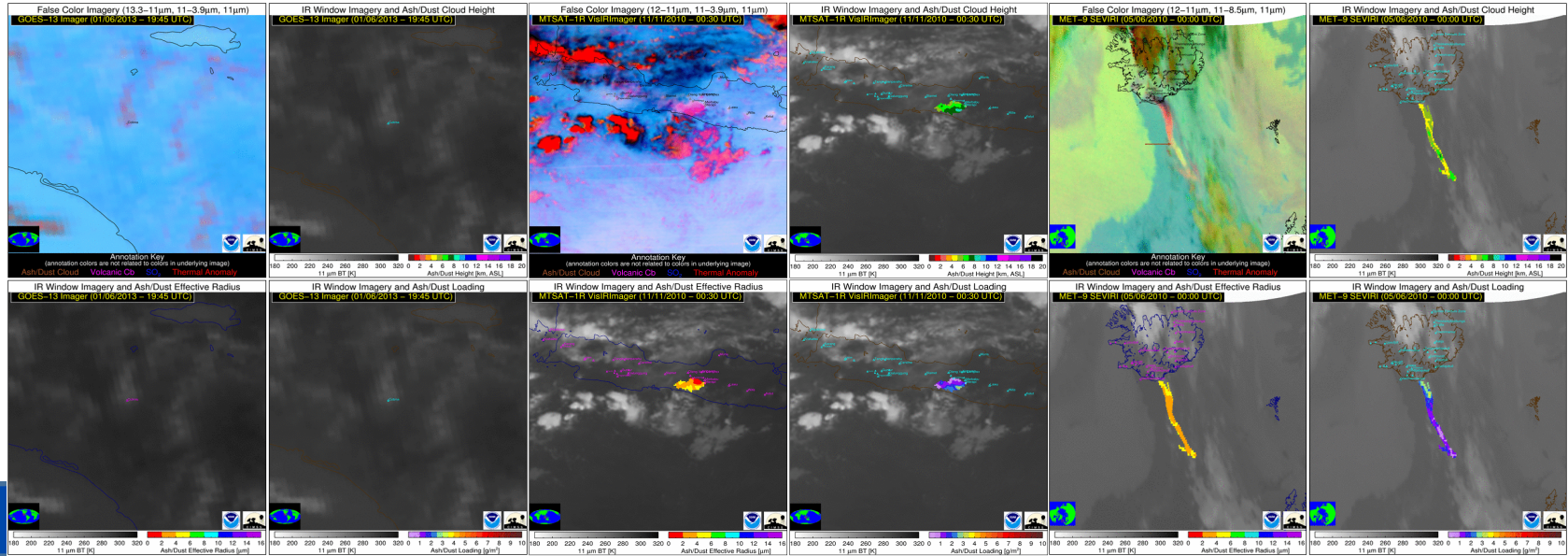


GOES-13-15

MTSAT-(1r and 2)

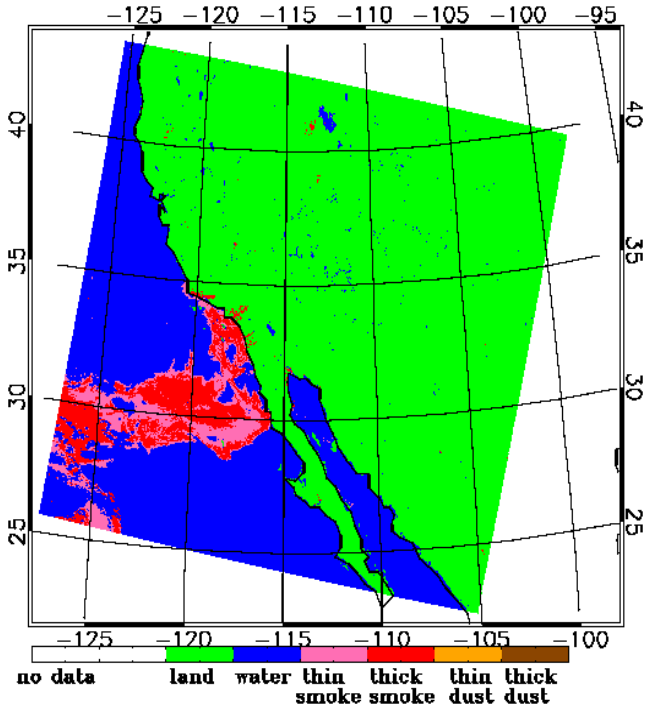
Met-(8,9,10) SEVIRI

GEO



Aerosol Detection Product

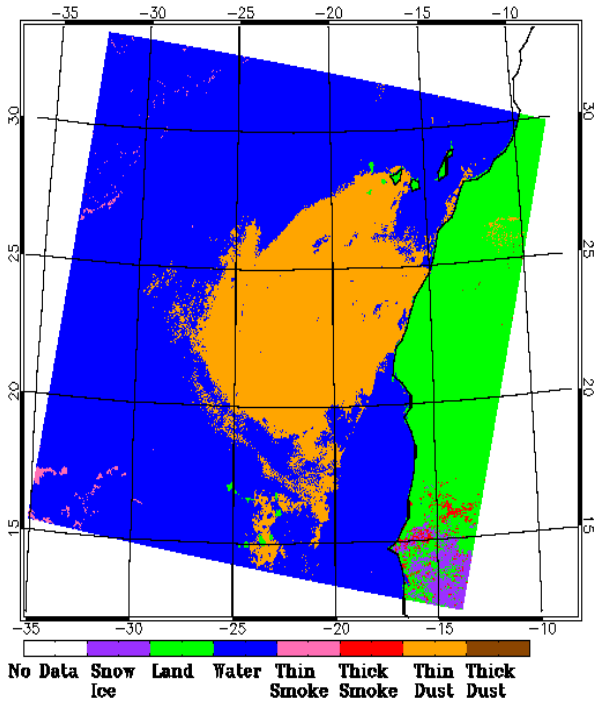
GOES Imager



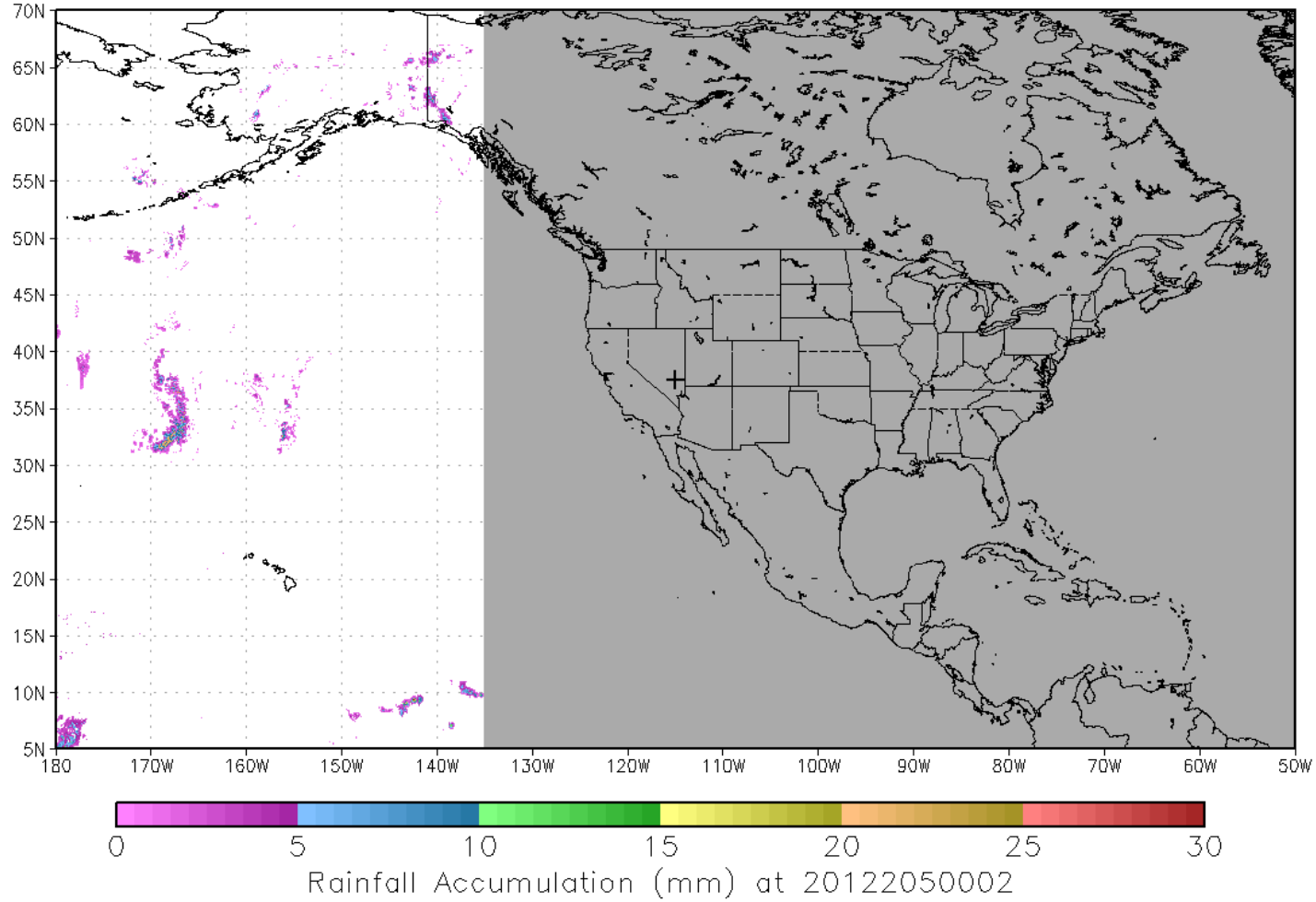
Smoke from fires in California on October 28, 2003

Saharan dust storm off of Africa on September 4, 2005

Meteosat/SEVIRI



Rainfall Rate Product

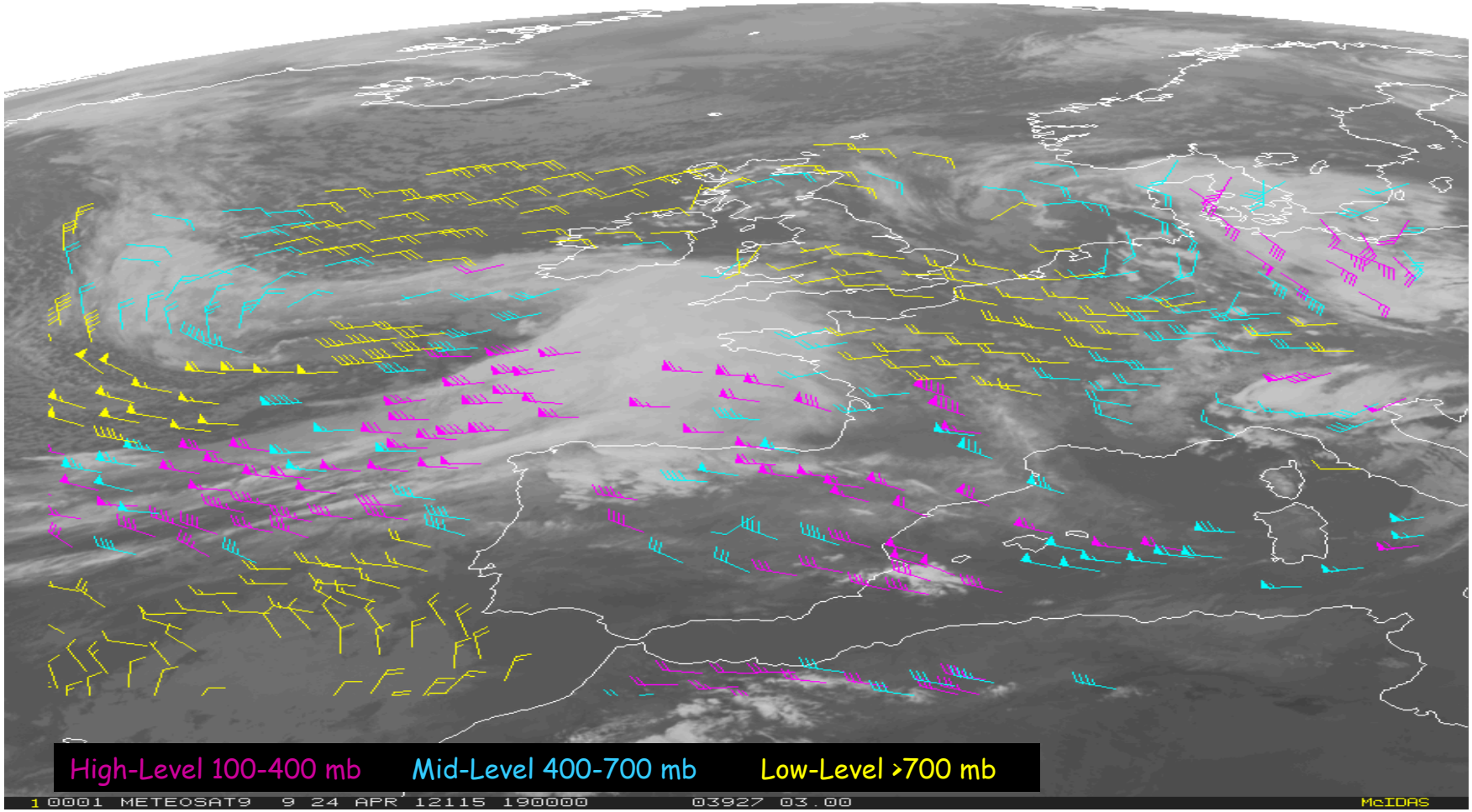


Example from 23 July 2012

GrADS: COLA/IGES

Derived Motion Winds Product

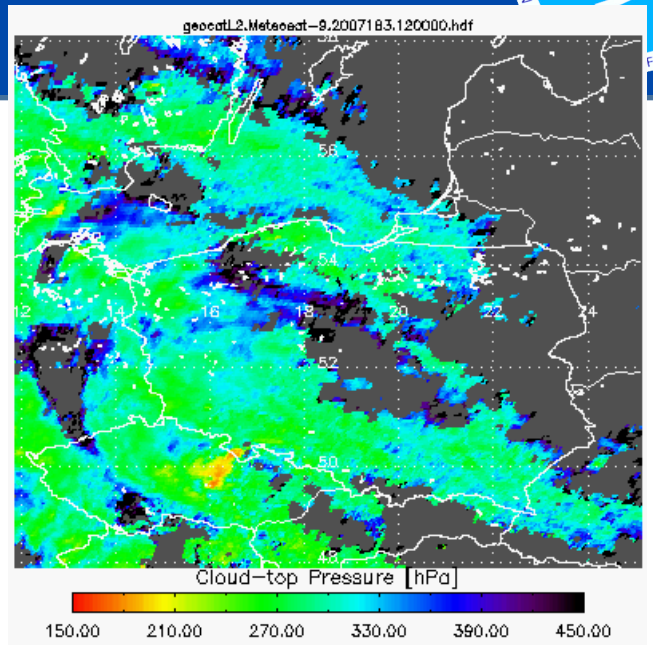
Loop of winds derived from hourly Full Disk Meteosat-9 SEVERI 10.8 μm imagery (22 UTC Apr 24 – 08 UTC Apr 25, 2012

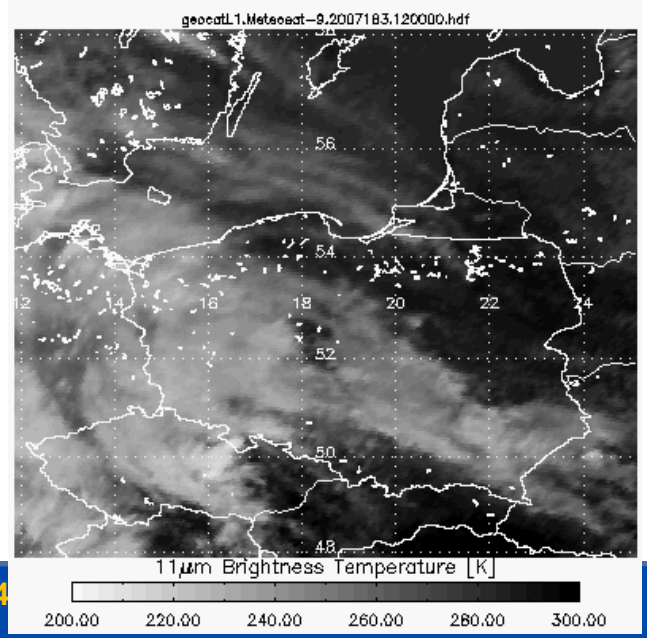


Cloud-Top Pressure Product

- **Algorithm Highlights**
  - Algorithm uses the 11, 12 and 13.3μm channels to estimate cloud temperature, cloud emissivity and a cloud microphysics.
  - Algorithm uses an optimal estimation approach that provides error estimates.
  - Cloud pressure and height are computed from NWP profiles.
  - Identifies multi-layer cloud situations.
  - Cloud heights in the presence of low level inversions are handled using similar logic that is employed in the MODIS algorithms.

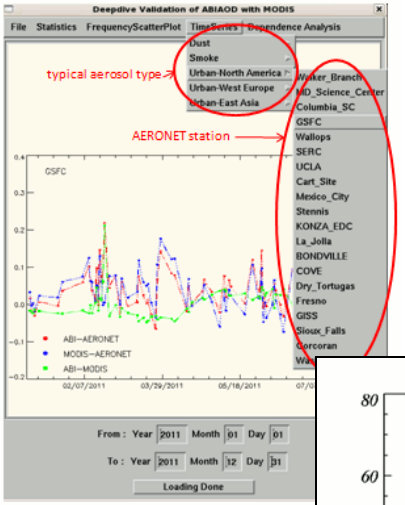
- **Operational Applications**
  - Aviation Terminal Aerodrome Forecasts (TAFs)
  - Supplements Automated Surface Observing System (ASOS) with upper-level cloud information
  - Assimilation into NWP models
  - Climate studies, prediction

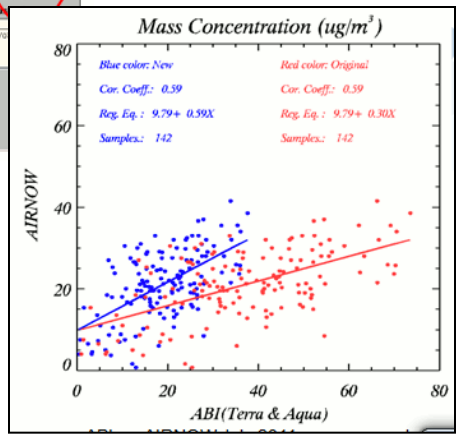




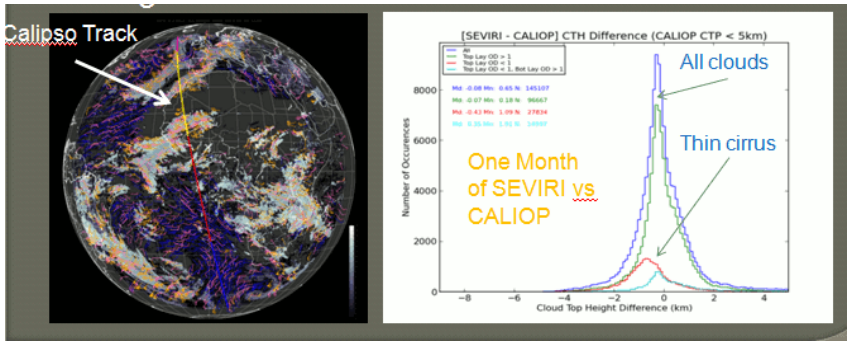
Product Validation Tools

AWG teams have developed a cadre of product validation tools as part of their ongoing product validation activities



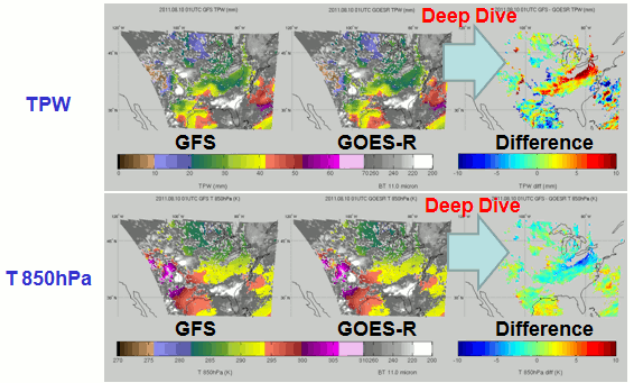


Aerosols



Clouds

Imagery of 2D variables in Validation Tool



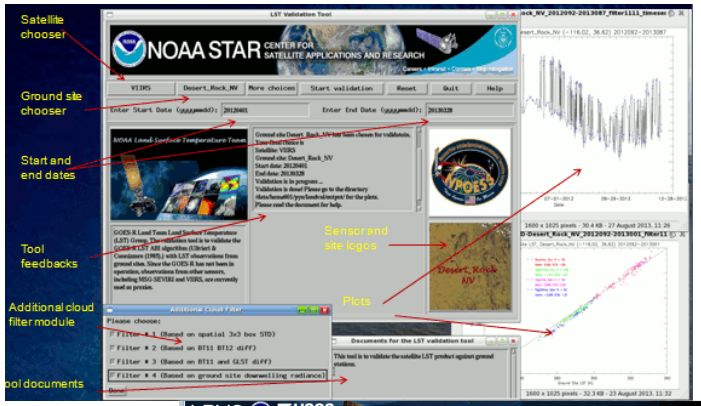
TPW

Temp

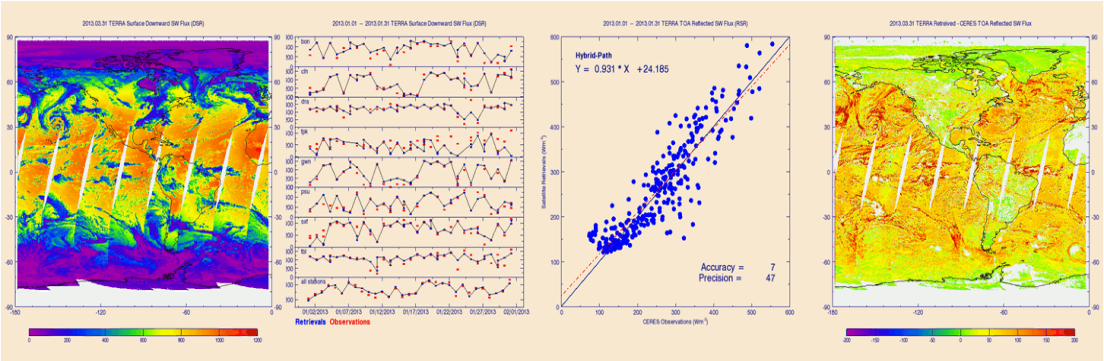
Significance: The tools will enable the routine monitoring of L2 product performance and for "Deep-dive" assessments and analysis of products to resolve any issues/anomalies that may arise

Product Validation Tools

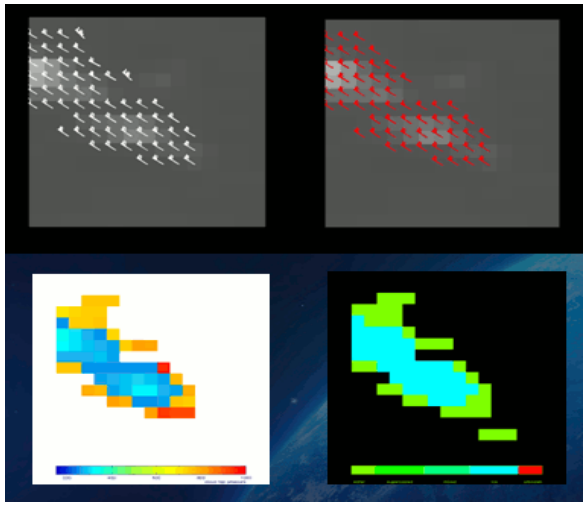
AWG teams have developed a cadre of product validation tools as part of their ongoing product validation activities



LST



Radiation



Winds

Significance: The tools will enable the routine monitoring of L2 product performance and for "Deep-dive" assessments and analysis of products to resolve any issues/anomalies that may arise

Planning for Post-Launch

- Learning and working with the new GOES-R core ground system and L2 product algorithm software
- Complete development of L2 product validation tools needed for the Post Launch Test (PLT) period and for long-term monitoring
- Continue efforts to generate, demonstrate, and validate L2 products using available proxy/simulated data
- Increase user engagement and readiness activities
- Participate in GOES-R Program-led rehearsal exercises that test data flows, product generation, product monitoring and validation tools, and more
- Develop and test procedures transition L2 algorithm updates into the operational system

Questions

Jaime Daniels: jaime.daniels@noaa.gov

NESDIS STAR AWG web page: http://www.star.nesdis.noaa.gov/goesr

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

Level-2 products outlined in red

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