NOAA/NESDIS GOES-R Algorithm Working Group (AWG) and its Role in Development and Readiness of GOES-R Product Algorithms

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Application Team Leads
AWG Team Members

Presented by Steven J. Goodman, STAR Deputy Director
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GOES-R Proving Ground Workshop, Boulder, CO
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Outline of Presentation

- Overview of AWG
  - Organizational structure
  - Roles and Responsibilities
- Progress
  - Proxy Data
  - Examples of prototype products
- Summary

Algorithm Working Group

PURPOSE: To develop, test, demonstrate, validate and provide algorithms for end-to-end GOES-R Ground Segment capabilities and to provide sustained life cycle validation and product enhancements

- Leverages nearly 100 scientists from NOAA, NASA, DOD, EPA, and NOAA's Cooperative Institutes (University partners)
- Apply first-hand knowledge of algorithms developed for POES, GOES, DMSP, EOS-AIRS/MODIS/LIS, MetOP and Space Weather.
- Leverage other programs & experience (GOES, MODIS, AIRS, IASI, NPOESS and other prototype instruments and international systems)
- Facilitate algorithm consistency across platforms -- prerequisite for GEOSS (maximize benefits and minimizes integration)

Capabilities and Experience

AWG End-to-End Capabilities

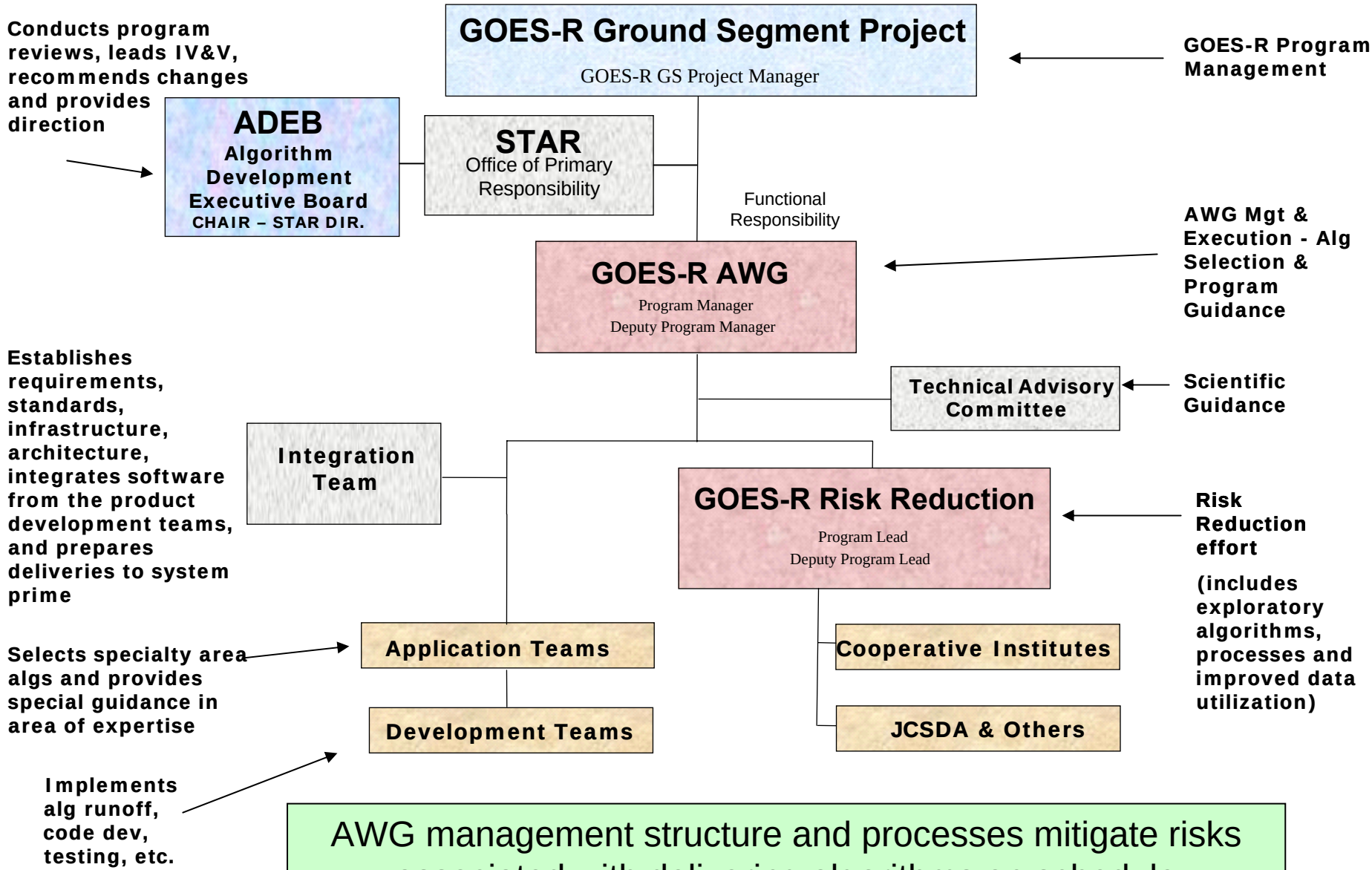
- Instrument Trade Studies
- Proxy Dataset Development
- Algorithm Development and Testing
- Product Demonstration Systems
- Development of Cal/Val Tools
- Integrated Cal/Val Enterprise System
- Sustained Radiance and Product Validation
- Algorithm and application improvements
- User Readiness and Education

Experience in Algorithm Delivery and Implementation

Developed, tested, delivered and implemented operational product generation systems

- POES
- GOES
- DMSP (NOAA applications)
- NASA EOS (AIRS, MODIS, LIS)
- MeTOP (IASI, GOME, ASCAT)
- NPOESS (NDE Project)

AWG Management Structure



AWG management structure and processes mitigate risks associated with delivering algorithms on schedule

Defined Roles & Responsibilities and Outcomes

- Application Teams: plans and executes the activities to assess, select, develop, and deliver algorithms (including cal/val)

- Development teams: hosts and tests candidate algorithms in a scalable operational demonstration environment

- AWG Integration Team: establishes requirements, standards, infrastructure, architecture, integrates software from the product development teams, and prepares deliveries to Ground Segment Project

Outcome -- Demonstrated algorithms, documentation and test data sets delivered to the Ground Segment Project:

- Algorithm Theoretical Basis Documents (ATBD)
- Proxy datasets
- Pre-operational code with all supporting materials – test plans, software, data sets (with results for comparison) and implementation documentation
- Routine cal/val tools

Application Teams

GOES-R Products Mapped to Algorithm Application Teams

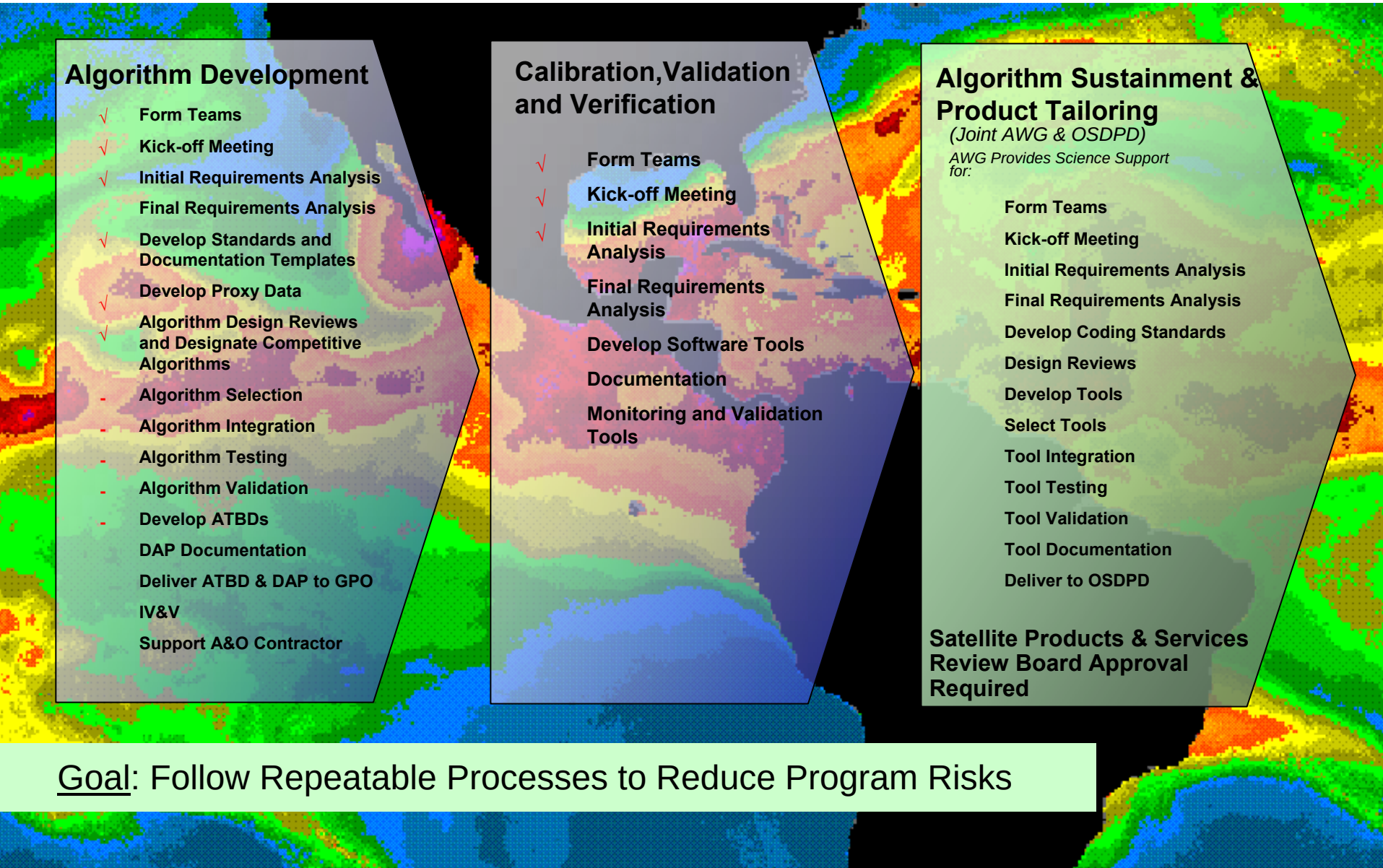
- **Soundings (Chris Barnet, Tim Schmit)**
- **Winds (Jaime Daniels)**
- **Clouds (Andy Heidinger)**
- **Aviation (Ken Pryor, Wayne Feltz)**
- **Aerosols / Air Quality / Atmospheric Chemistry (Shobha Kondragunta)**
- **Hydrology (Robert Kuligowski)**
- **Land Surface (Bob Yu)**
- **SST and Ocean Dynamics (Alexander Ignatov)**
- **Cryosphere (Jeff Key)**
- **Radiation Budget (Istvan Lazslo)**
- **Lightning (Steve Goodman)**
- **Space Environment (Steven Hill)**
- **Proxy Data (Fuzhong Weng)**
- **Cal/Val (Changyong Cao)**
- **Algorithm Integration (Walter Wolf)**
  - Product System Integration
  - KPP/Imagery/Visualization
  - Product Tailoring

Example: AAA Application Team Make-up

Kondragunta, Shobha (STAR), Chair
Ackerman, Steven (CIMSS)
Hoff, Raymond (UMBC)
Pierce, Brad (NASA -> STAR)
Szykman, James (EPA)
Laszlo, Istvan (STAR)
Lyapustin, Alexie (NASA)
Li, Zhanqing (CICS))
Schmidt, Chris (CIMSS)

GOES-R Program requested the AWG to establish broad and cross-cutting support for the algorithms and products

AWG Process Flow



Algorithm Development

- √ Form Teams
- √ Kick-off Meeting
- √ Initial Requirements Analysis
- Final Requirements Analysis
- √ Develop Standards and Documentation Templates
- √ Develop Proxy Data
- √ Algorithm Design Reviews and Designate Competitive Algorithms
- - Algorithm Selection
- - Algorithm Integration
- - Algorithm Testing
- - Algorithm Validation
- - Develop ATBDs
- DAP Documentation
- Deliver ATBD & DAP to GPO
- IV&V
- Support A&O Contractor

Calibration,Validation and Verification

- √ Form Teams
- √ Kick-off Meeting
- √ Initial Requirements Analysis
- Final Requirements Analysis
- Develop Software Tools
- Documentation
- Monitoring and Validation Tools

Algorithm Sustainment & Product Tailoring

(Joint AWG & OSDPD)

AWG Provides Science Support for:

- Form Teams
- Kick-off Meeting
- Initial Requirements Analysis
- Final Requirements Analysis
- Develop Coding Standards
- Design Reviews
- Develop Tools
- Select Tools
- Tool Integration
- Tool Testing
- Tool Validation
- Tool Documentation
- Deliver to OSDPD

Satellite Products & Services Review Board Approval Required

Goal: Follow Repeatable Processes to Reduce Program Risks

GOES-R Product List (Total: 68)
Product Set Number: 1-4

Set 1/2 - September 2010
Set 3/4 - September 2011

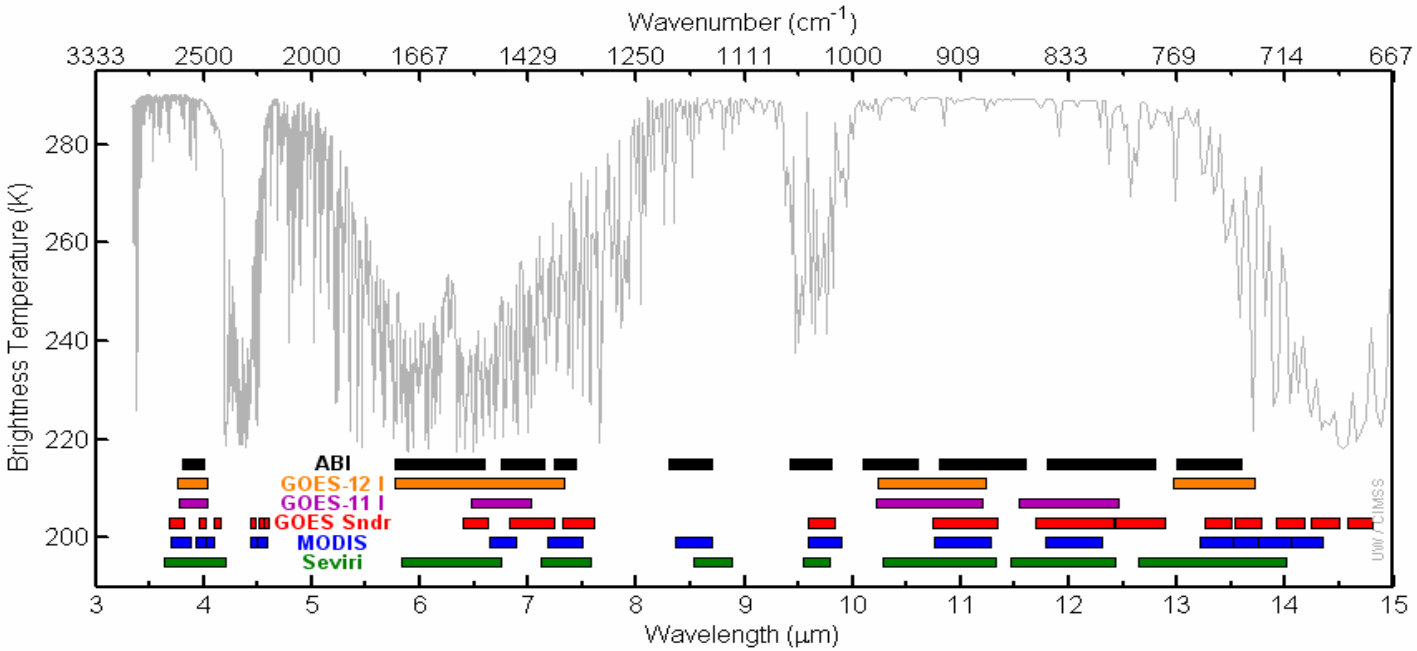
AWG Test Bed will provide demonstration products

1 Aerosol Detection (including Smoke & Dust)	2 Geomagnetic Field	3 Surface Albedo
3 Aerosol Particle Size	4 Probability of Rainfall	3 Surface Emissivity
1 Suspended Matter / Optical Depth	4 Rainfall Potential	4 Vegetation Fraction: Green
2 Volcanic Ash: Detection and Height	2 Rainfall Rate / QPE	4 Vegetation Index
4 Aircraft Icing Threat	1 Legacy Vertical Moisture Profile	4 Currents
3 Cloud Imagery: Coastal	1 Legacy Vertical Temperature Profile	4 Currents: Offshore
1 Cloud & Moisture Imagery (KPPs)	2 Derived Stability Indices (5)	4 Sea & Lake Ice: Age
3 Cloud Layers / Heights & Thickness	1 Total Precipitable Water	4 Sea & Lake Ice: Concentration
3 Cloud Ice Water Path	3 Total Water Content	4 Sea & Lake Ice: Extent
3 Cloud Liquid Water	1 Clear Sky Masks	4 Sea & Lake Ice: Motion
1 Cloud Optical Depth	1 Radiances	4 Ice Cover / Landlocked: Hemispheric
1 Cloud Particle Size Distribution	3 Absorbed Shortwave Radiation: Surface	2 Snow Cover
1 Cloud Top Phase	3 Downward Longwave Radiation: Surface	4 Snow Depth (Over Plains)
1 Cloud Top Height	2 Downward Solar Insolation: Surface	2 Sea Surface Temps
1 Cloud Top Pressure	2 Reflected Solar Insolation: TOA	2 Energetic Heavy Ions
1 Cloud Top Temperature	3 Upward Longwave Radiation: Surface	2 Mag Electrons & Protons: Low Energy
3 Cloud Type	3 Upward Longwave Radiation: TOA	2 Mag Electrons & Protons:Med & High Energy
3 Convective Initiation	3 Ozone Total	2 Solar & Galactic Protons
4 Enhanced "V" / Overshooting Top Detection	3 SO_2 Detection	2 Solar Flux: EUV
2 Hurricane Intensity	2 Derived Motion Winds	2 Solar Flux: X-Ray
3 Low Cloud & Fog	2 Fire / Hot Spot Characterization	2 Solar Imagery: X-Ray
2 Lightning Detection- events, groups, flashes	4 Flood / Standing Water	
3 Turbulence	2 Land Surface (Skin) Temperature	
4 Visibility		

ABI – Advanced Baseline Imager	Continuity of GOES Legacy Sounder Products from ABI	SEISS – Space Env. In-Situ Suite	EXIS – EUV and X-Ray Irradiance Sensors	GLM – Geostationary Lightning Mapper	Magnetometer	SUVI – Solar extreme UltraViolet Imager

High Confidence in ABI Algorithms Meeting Requirements

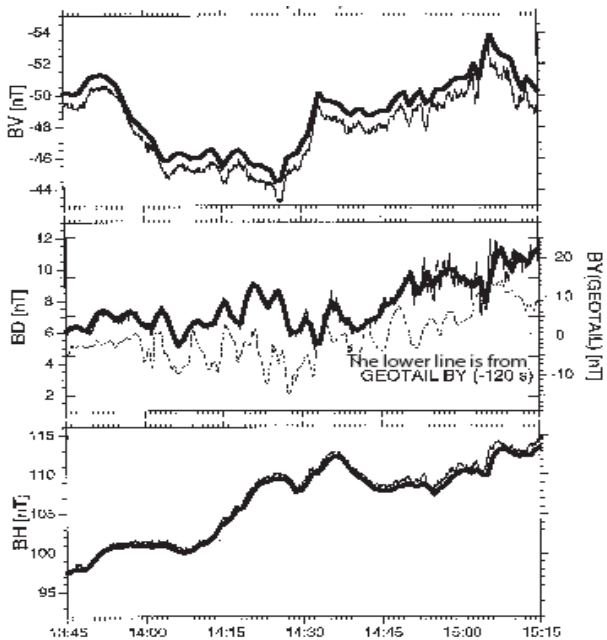
- Algorithms from MODIS and current GOES program are being leveraged
- EUMETSAT SEVIRI Instrument serves as excellent proxy
- High fidelity simulated datasets for ABI



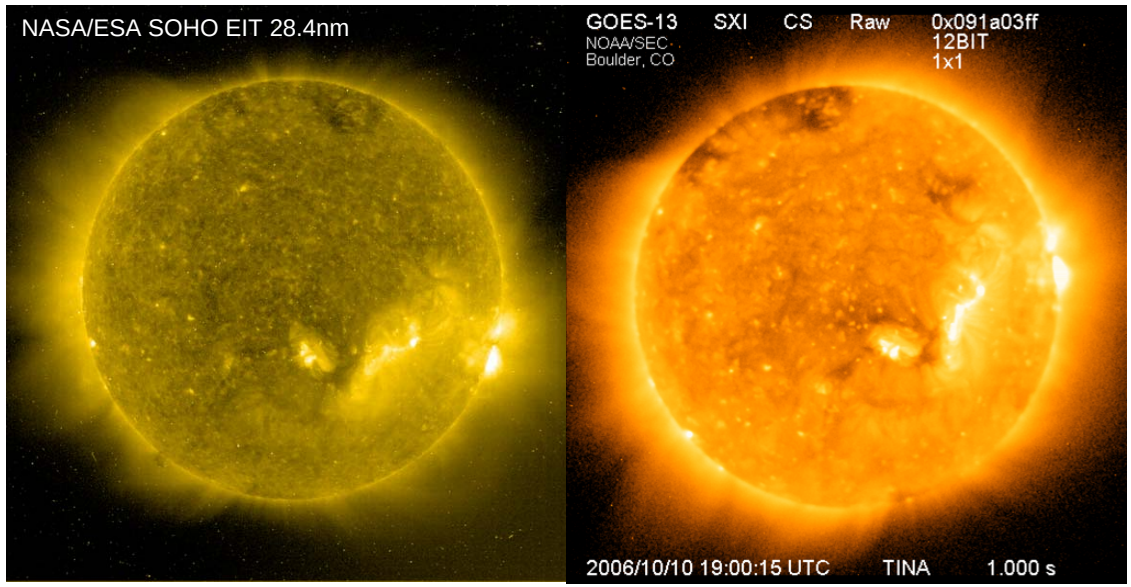
Similar spectral channel experience provides confidence the algorithms will be delivered with minimal program risk while meeting the required accuracies

High Confidence in Space Weather Algorithms Meeting Requirements

- Algorithms for space weather cover both solar and in situ observations:
  - Solar: Extreme Ultraviolet and X-ray Irradiance Suite (EXIS) and Solar Ultraviolet Imager (SUVI)
  - In Situ: Space Environment In Situ Suite (SEISS) and Magnetometer (MAG)
- Algorithms from current GOES program are being leveraged
- Current GOES instrument data serve as excellent proxies
- High fidelity simulated datasets for SUVI derived from GOES SXI and ESA/NASA SOHO EIT
- Government and University expertise from relevant current programs



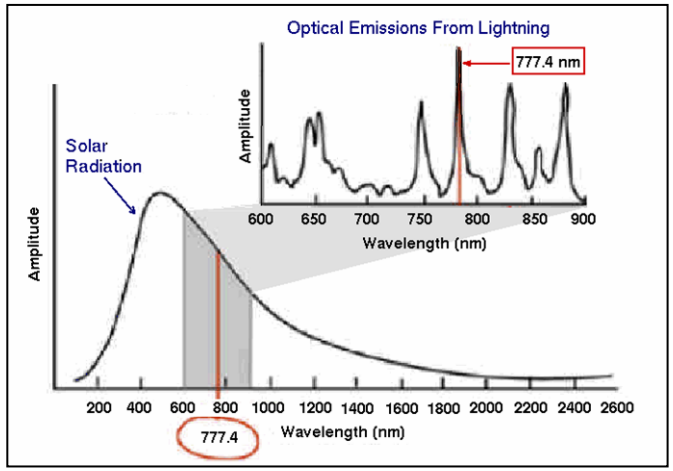
External research results help validate GOES magnetometer products.

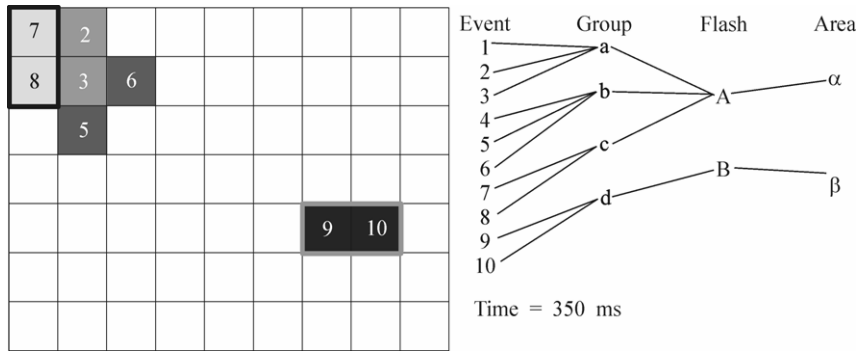


SXI and EIT provide basis for temporal and spectral characteristics of SUVI observations

High Confidence in GLM Algorithms Meeting Requirements

- Lightning algorithm maturity from over 12 years of on-orbit experience with NASA's:
  - Optical Transient Detector (OTD) (1995-2000)
  - Tropical Rainfall Measuring Mission's (TRMM) Lightning Imager Sensor (LIS) (1997-Present)
- ATBD for Geostationary Lightning Mapper (GLM) lightning detection based on LIS
- Proxy data sets derived from LIS and from ground based total lightning mapping arrays
- Government and University expertise from current programs





Lightning Clustering Algorithm, Mach et al., JGR, 2007)

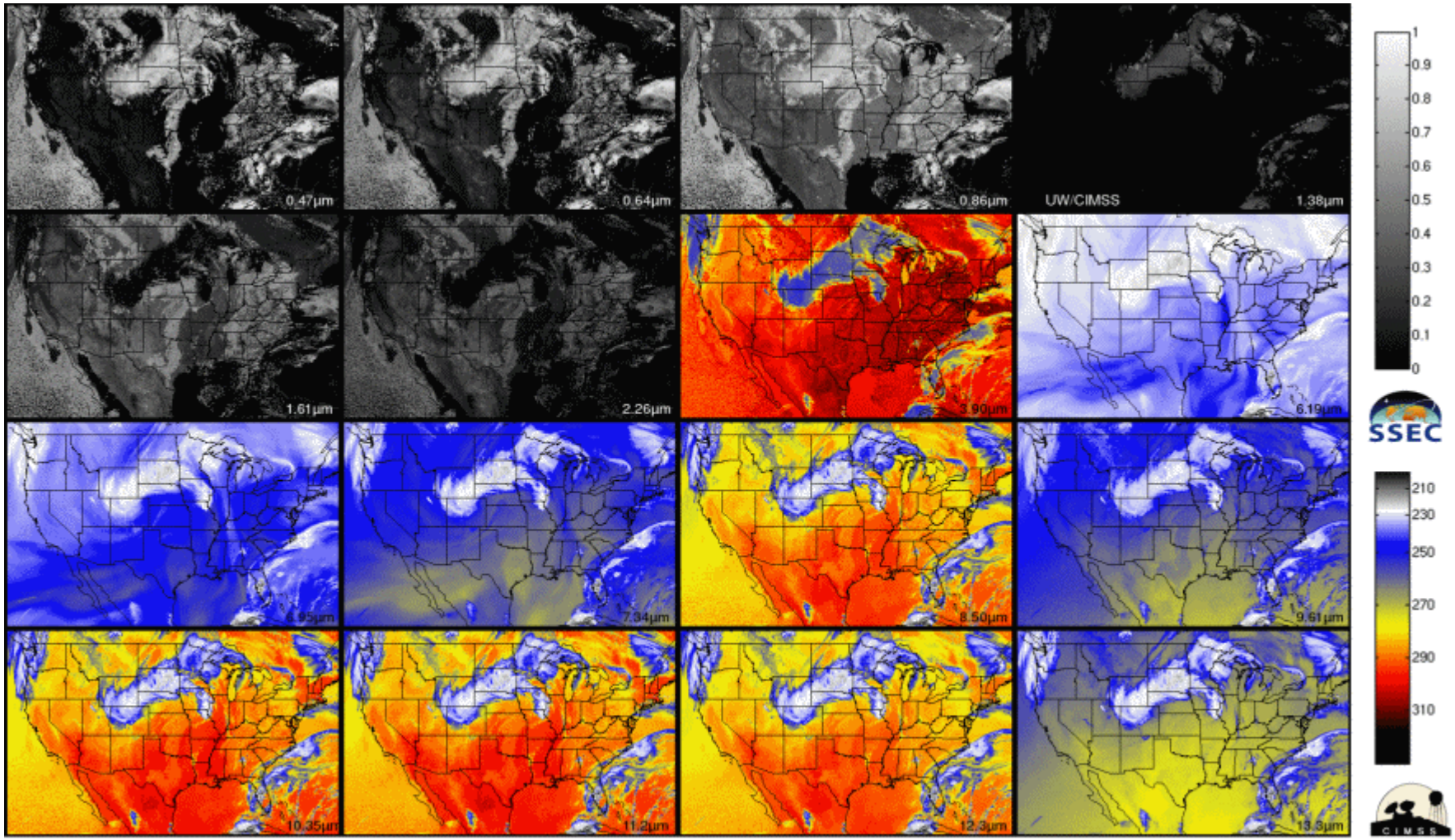
Similar experience provides confidence the algorithms will be delivered with minimal program risk while meeting the required accuracies

Current Status

- Completed 95% of the Algorithm Design Reviews
- Initial algorithms recently delivered to Algorithm Integration Team
  - Derived Motion Winds
  - Hurricane Intensity
  - Land Surface Temperature
  - Fire
  - Temperature, Moisture Sounding Retrieval
  - Cloud Mask
  - Cloud Height
  - Cloud Type
  - Cloud Optical Thickness
  - Cloud Effective Particle Size
- AWG demonstration system providing many GOES-R products from proxy data will be available in 2009
  - Demonstration system can provide products to proving grounds
- ABI proxy datasets
  - Full disk, CONUS, and mesoscale ABI simulations
  - SEVERI from Meteosat
    - SEVERI datasets
    - ABI channels derived from SEVERI
  - MODIS
    - MODIS datasets
    - ABI channels derived from SEVERI
- Lightning (LIS, LMA, NLDN) and Space Weather (GOES) proxy data

Results from prototype demonstrations

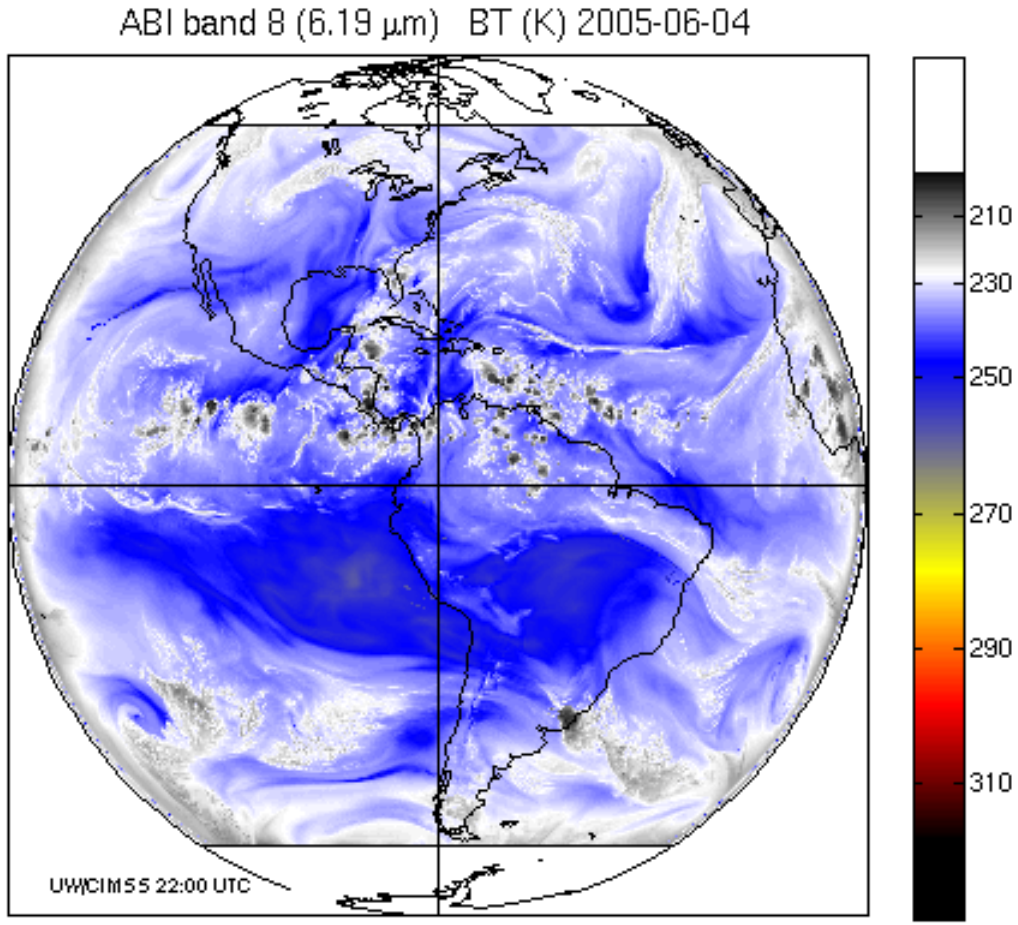
Animations of Simulated GOES-R ABI (16 channels) over CONUS



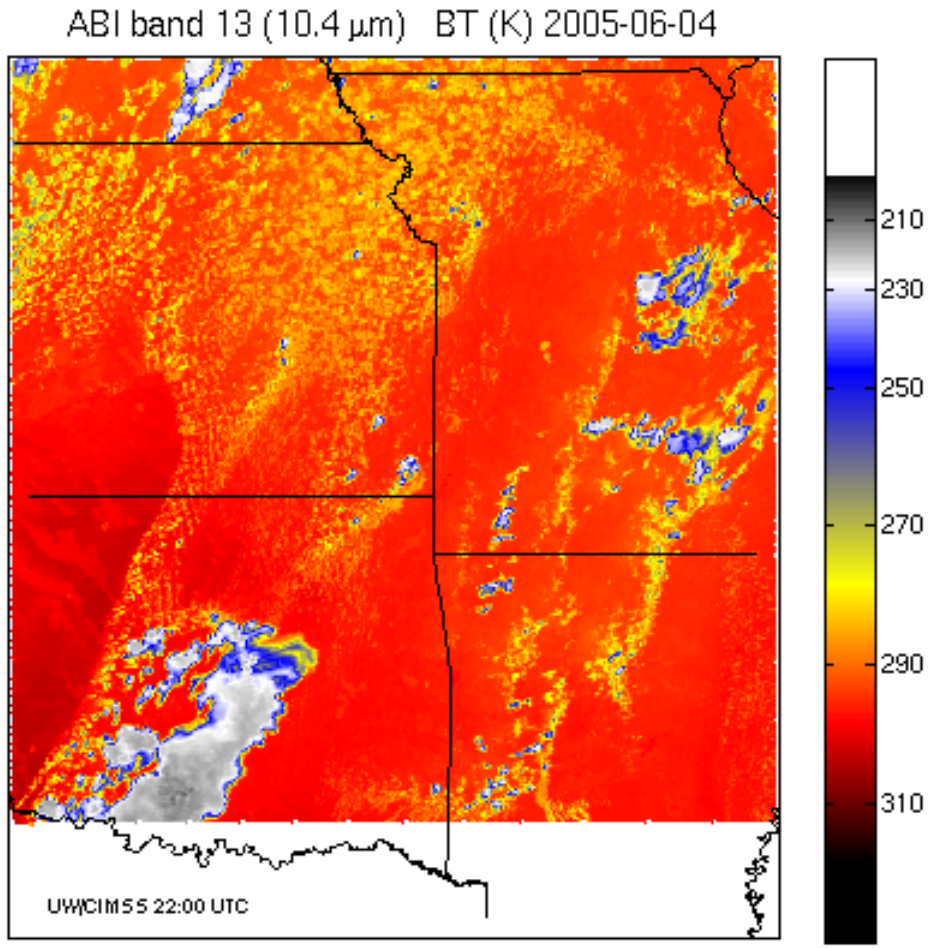
ABI band data for 2005 June 04 15:00 UTC

AWG Proxy Team has the capability to provide high fidelity simulated datasets that will be critically important for algorithm development and validation activities

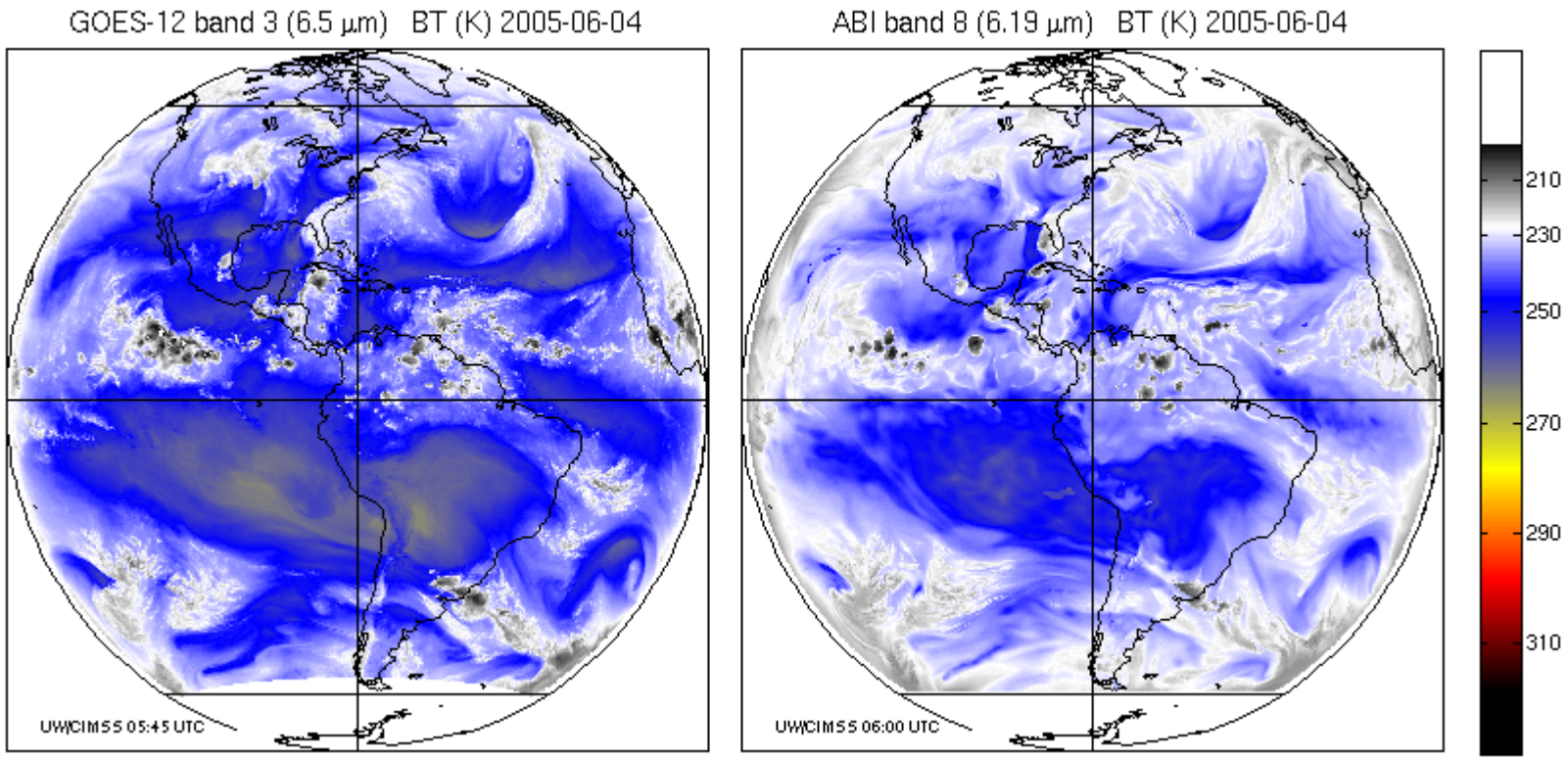
8 (6.19 µm) 22:00 – 00:00 UTC



13 (10.4 µm) 22:00 – 00:00 UTC

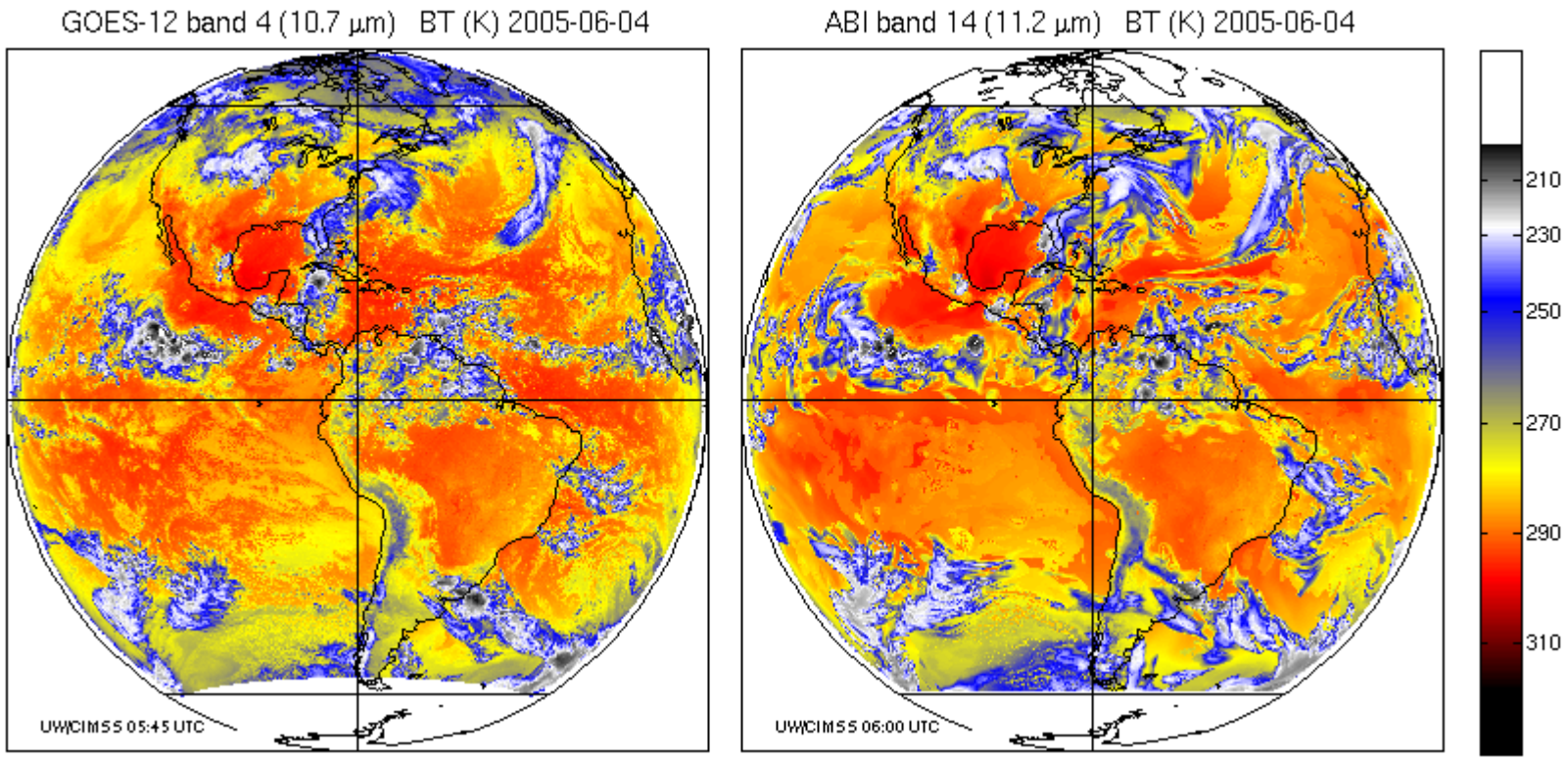


GOES-12 Band 3/ABI Band 8



- Note GOES-12 Band 3 is warmer than ABI Band 8 due to Spectral Response Function (SRF) differences

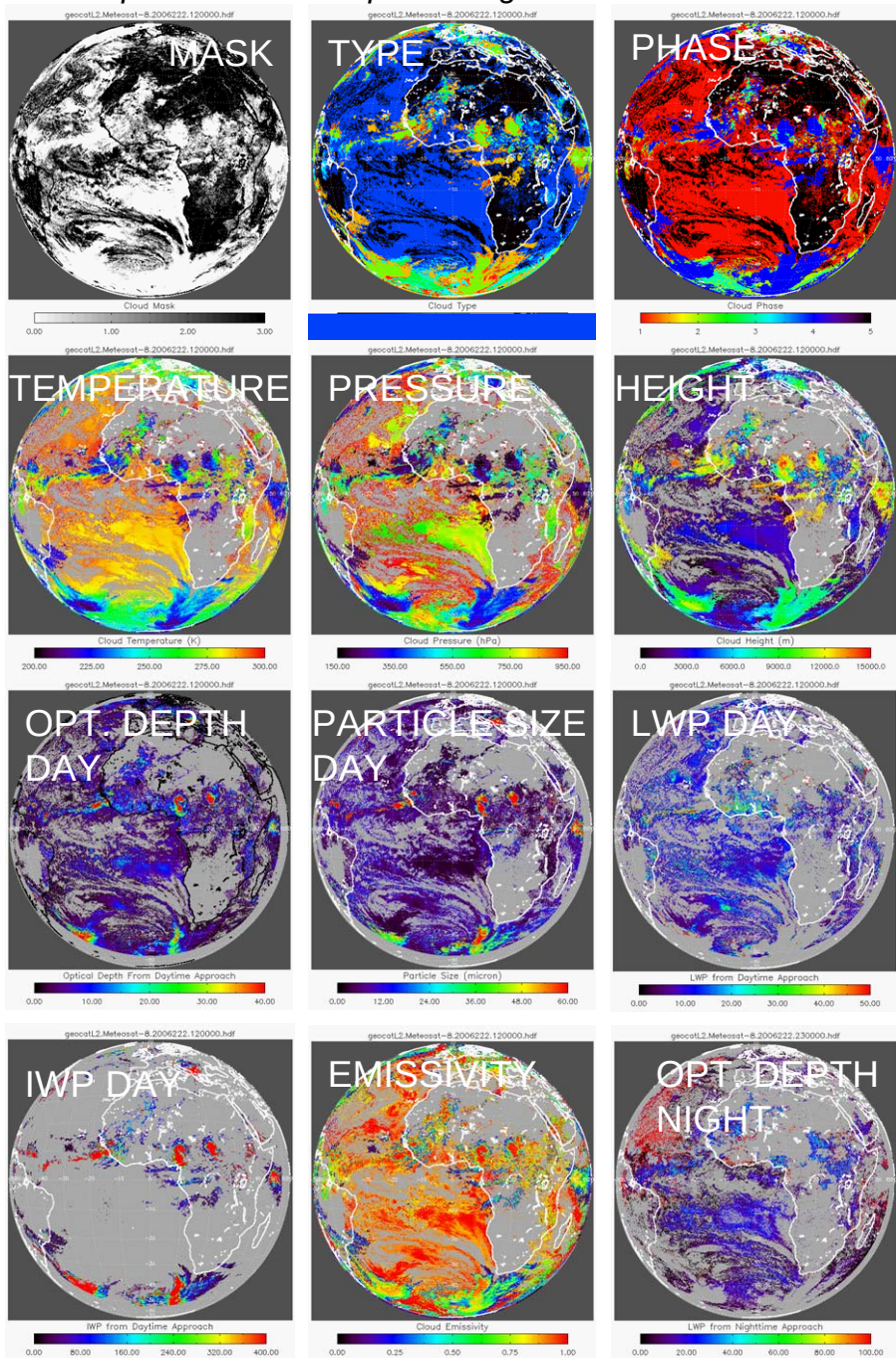
GOES-12 Band 4/ABI Band 14



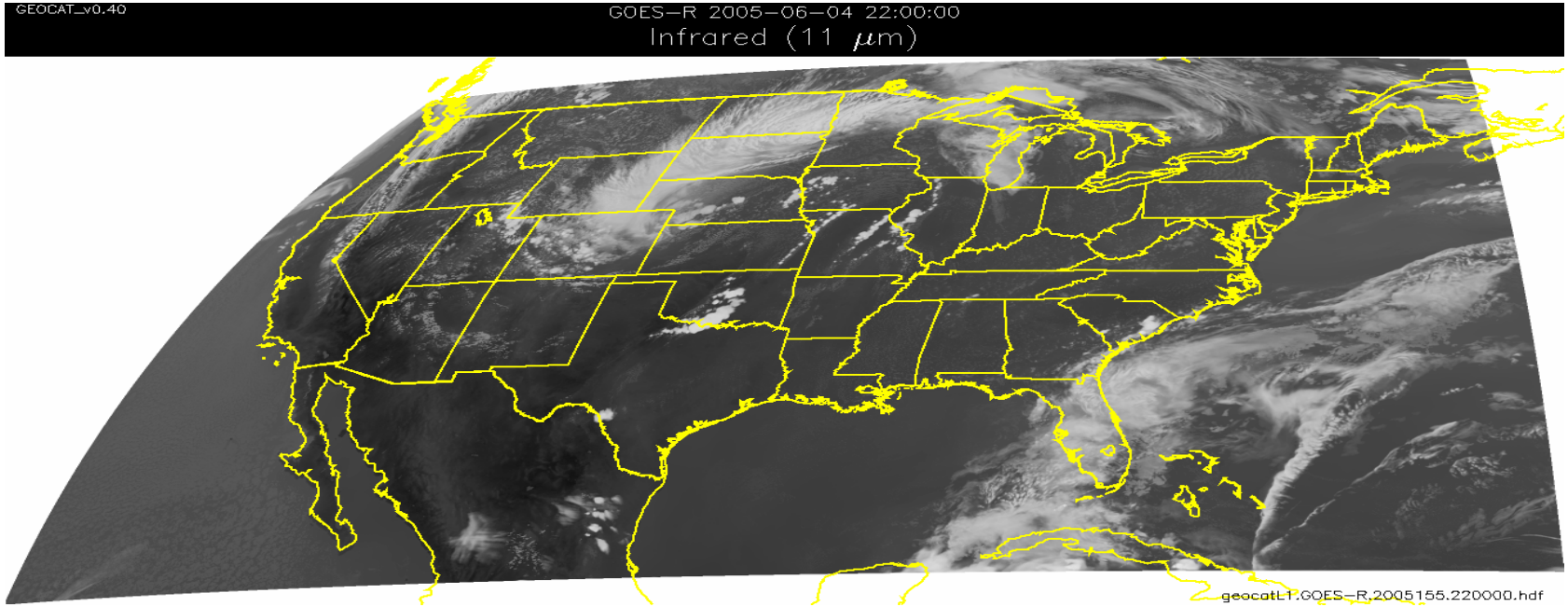
Cloud Application Team

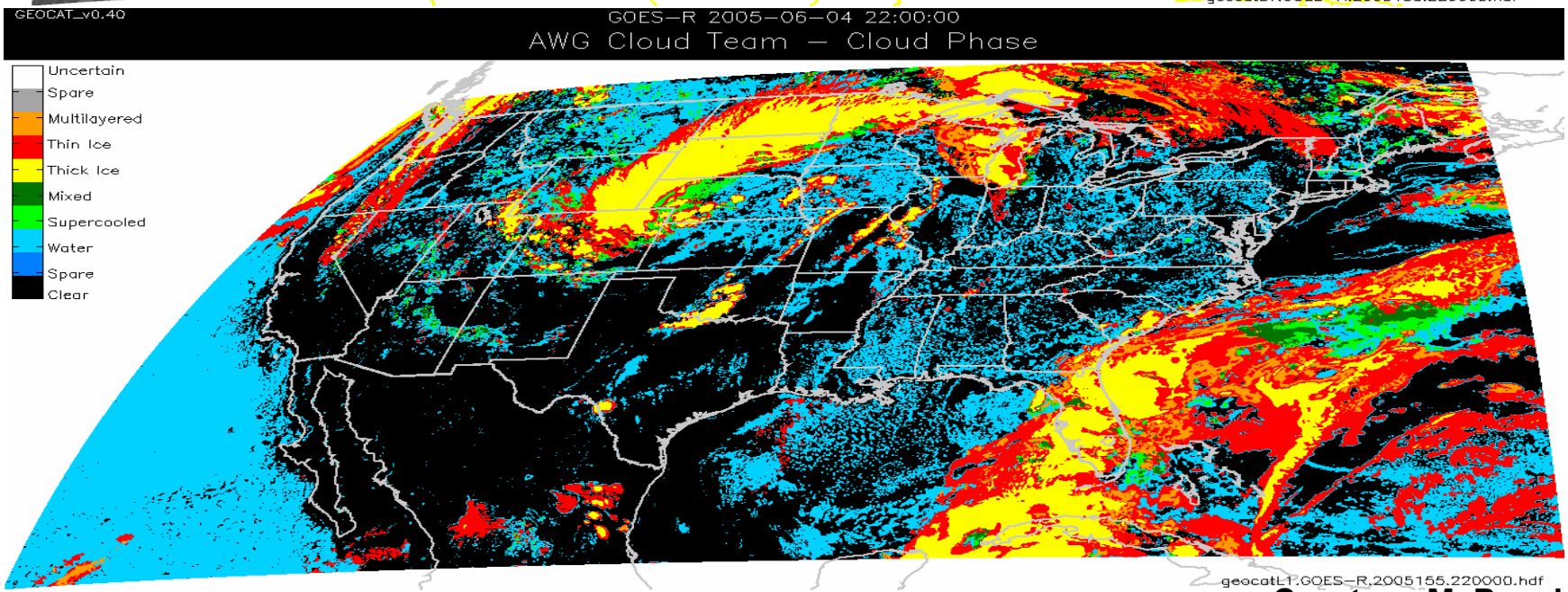
- Directly responsible for 12 GOES-R products.
- Generated from 5 main algorithms
- Team consists of NOAA, NASA and Academia scientists with most effort being done at UW/CIMSS.
- Significant development required to ensure approaches fully exploit GOES-R ABI's capabilities.
- EUMETSAT's SEVIRI imager being used as our main test platform.
- Algorithm development and validation is ongoing. CALIPSO and CLOUDSAT are our main validation sources.
- Modified versions of GOES-R ABI algorithms being run on GOES in real-time to demonstrate robustness.

Example GOES-R ABI products generated from SEVIRI



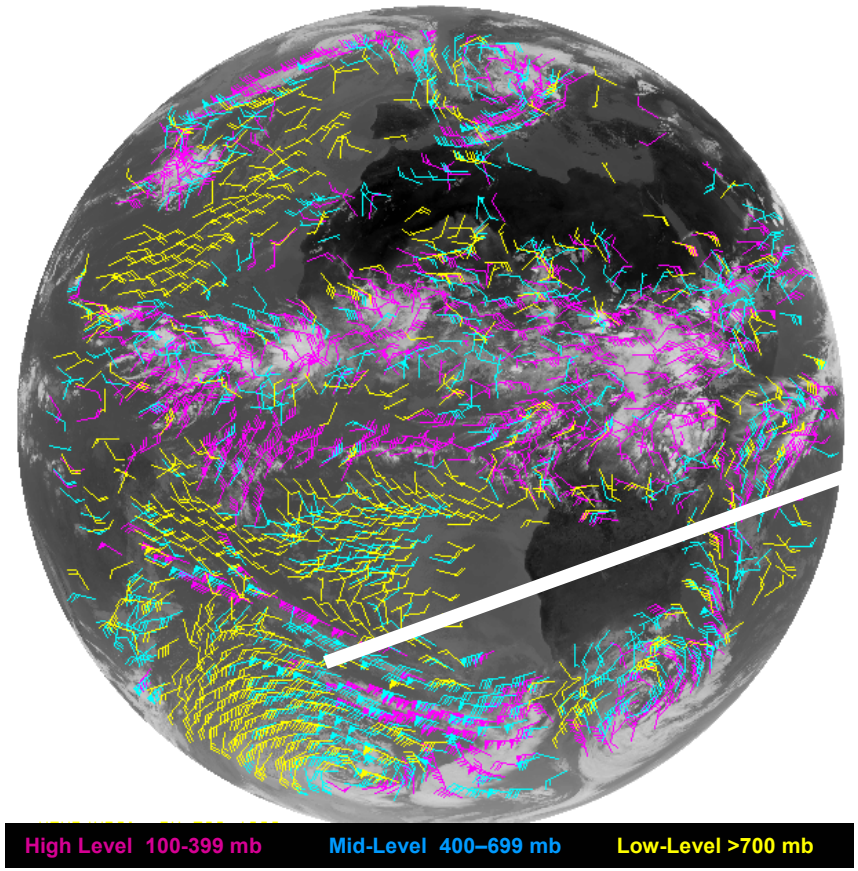
AWG Cloud Phase Product

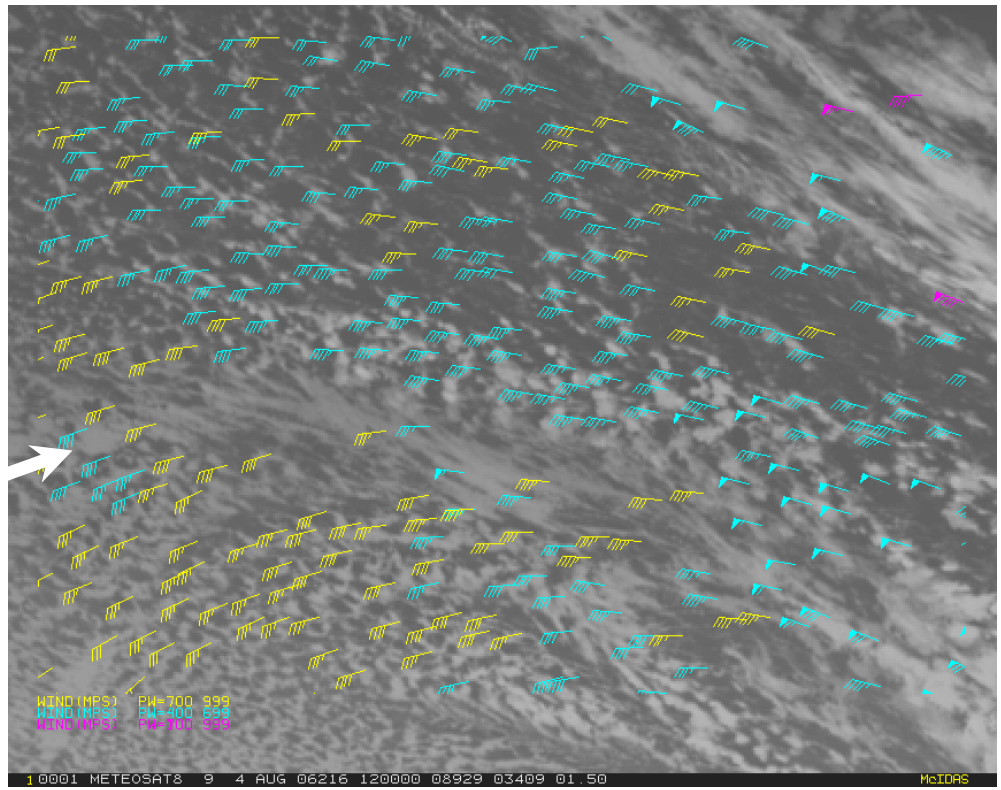




Courtesy M. Pavolonis

MSG/SEVERI imagery are being used as proxy datasets for GOES-R ABI Atmospheric Motion Vector (AMV) algorithm development, testing, and validation activities.

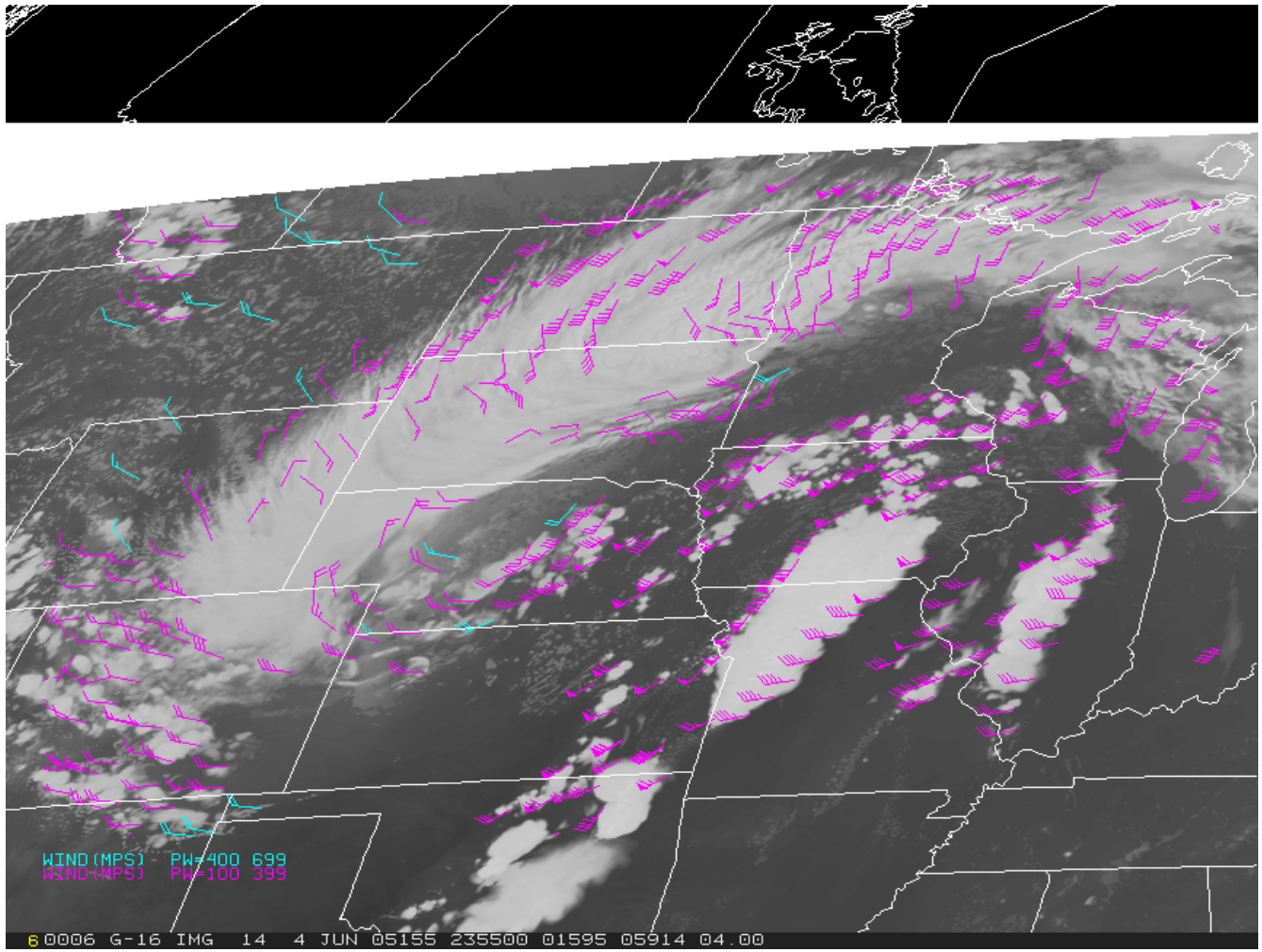




Cloud-drift AMVs derived from a Meteosat-8 SEVERI image triplet centered at 1215Z on 04 August 2006

(Figures provided by the GOES-R Algorithm Working Group (AWG) Winds Application Team)

Simulated GOES-R ABI imagery are also being used for GOES-R ABI Atmospheric Motion Vector (AMV) algorithm development, testing, and validation activities.

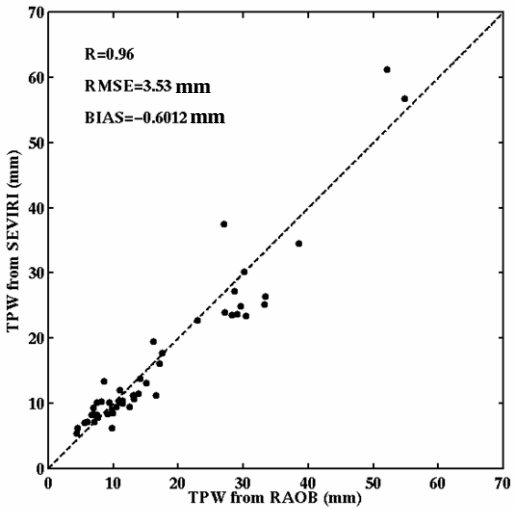


Cloud-drift AMVs derived from a Simulated GOES-R ABI image triplet centered at 0000Z on 05 June 2005

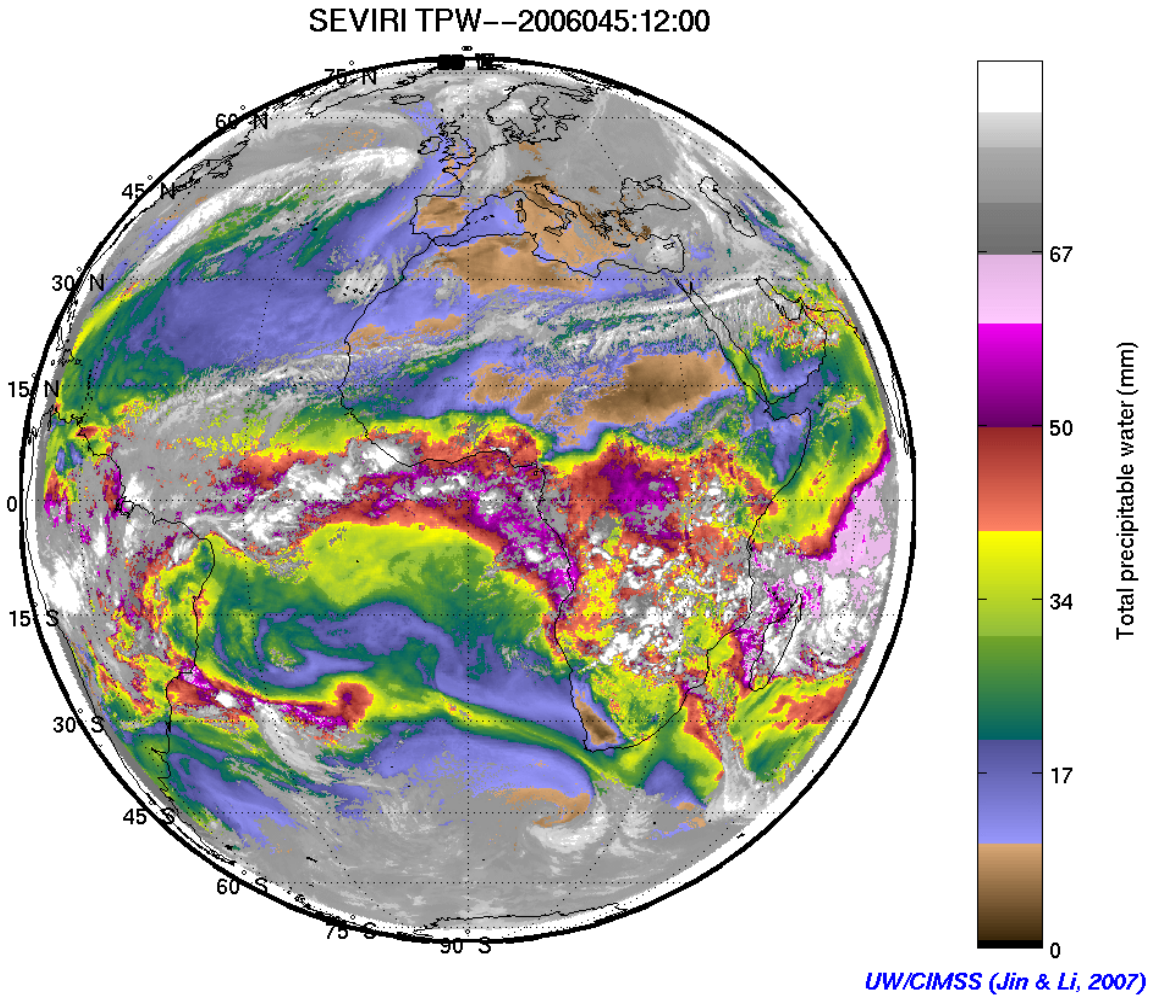
AMVs generated by the GOES-R Algorithm Working Group (AWG) Winds Application Team

Simulated GOES-R ABI imagery generated by CIMSS

Example GOES-R Product Using EUMETSAT SEVIRI Instrument Measurements as the Proxy Data Set

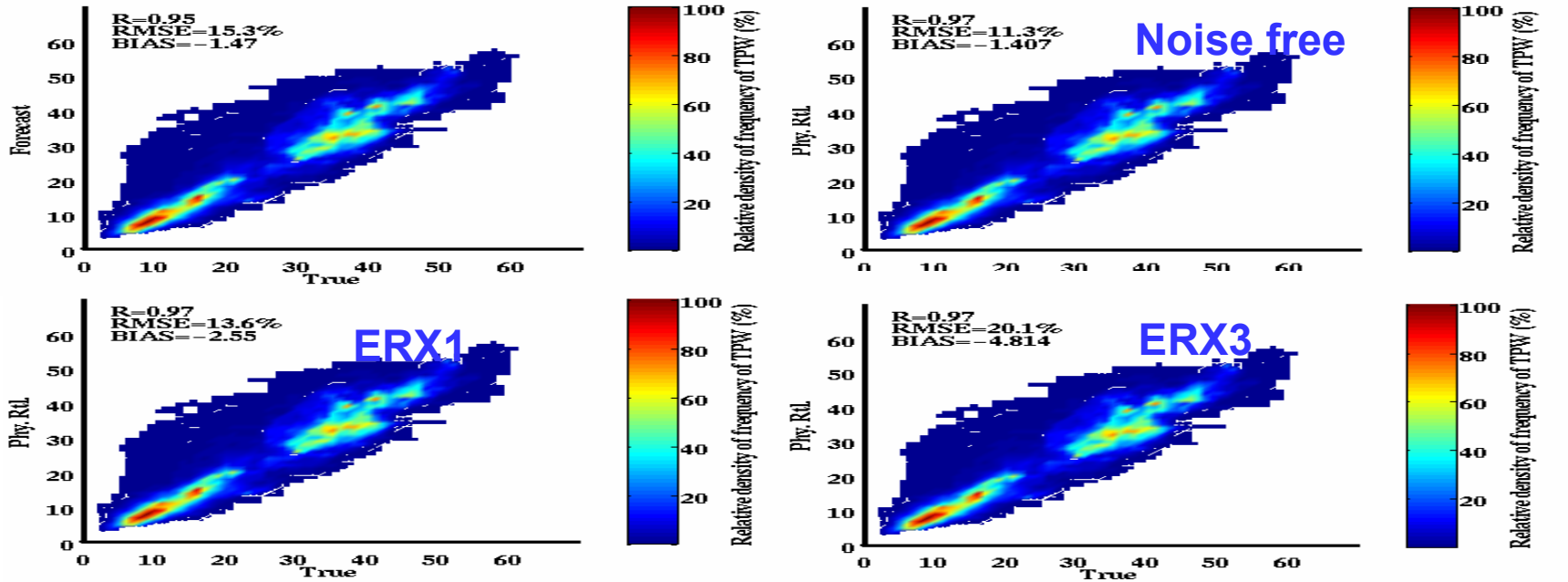


STAR's AWG has already started to test and demonstrate the clear sky mask, temperature and water vapor profiles, and land surface temperature algorithms



Total Precipitable Water using GOES-R AWG algorithms and SEVIRI

GOES-R Analysis Facility Instrument Impacts on Requirements (GRAFIIR)



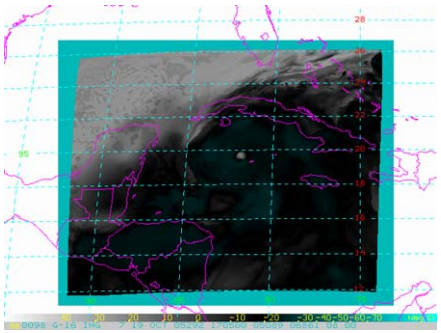
Noise impact on TPW retrievals (mm) – with nominal noise in algorithm

Production of GOES-R Synthetic Imagery

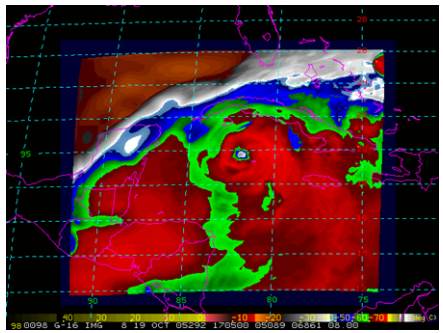
- **Use the Colorado State University - Regional Atmospheric Modeling System (CSU-RAMS) to simulate an observed mesoscale weather or hazard event with horizontal grid spacing as small as 400 m.**
- **The RAMS output is used as input to an observational operator. In conjunction with OPTRAN code and radiative transfer models, synthetic radiances and brightness temperatures are produced for the 10 infrared GOES-R ABI wavelengths (3.9 μm to 13.3 μm) with a footprint size of 400 m.**
- **GOES-R ABI synthetic imagery is produced at the appropriate footprint by using an approximation for the point spread function and the latitude and longitude of the data point.**
- **McIDAS and GIF imagery is being created for all datasets.**

Courtesy of RAMMB / CIRA AWG Proxy Data Team

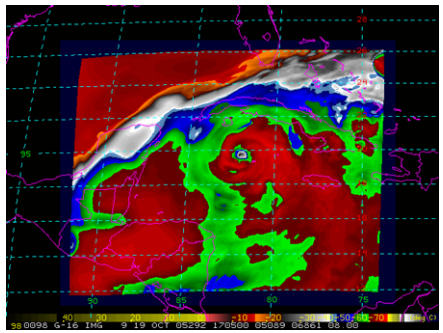
Hurricane Wilma - Synthetic Imagery
10 upper ABI Bands - 19 October 2005 1705 UTC



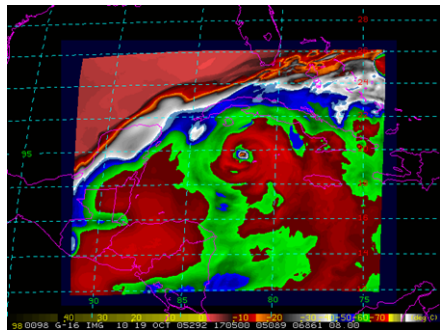
3.9 µm



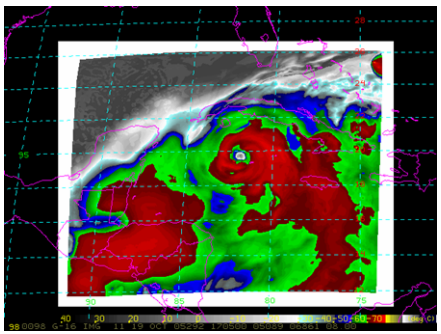
6.19 µm



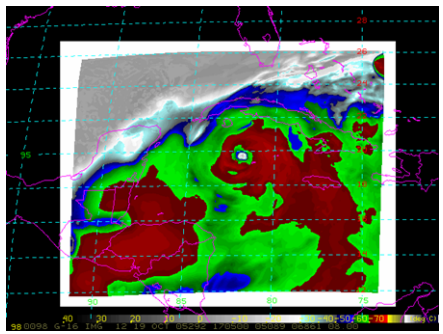
6.95 µm



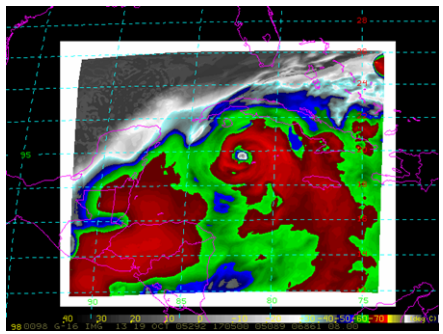
7.34 µm



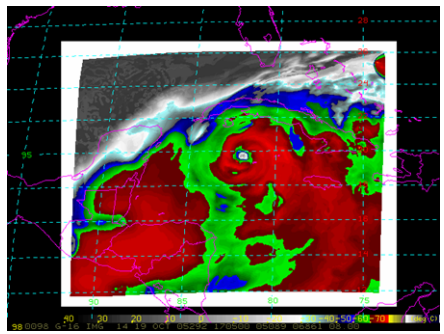
8.50 µm



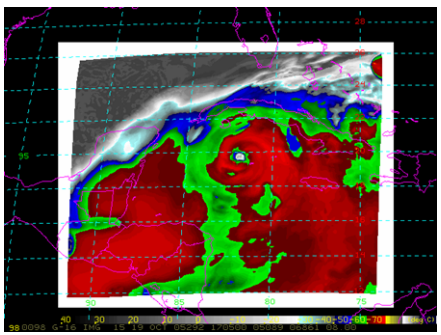
9.61 µm



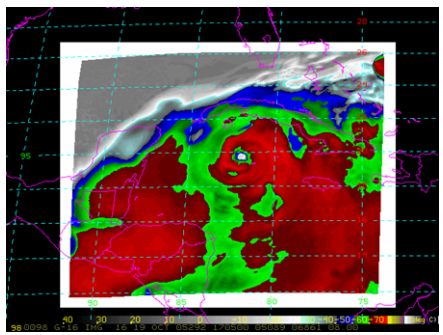
10.35 µm



11.20 µm



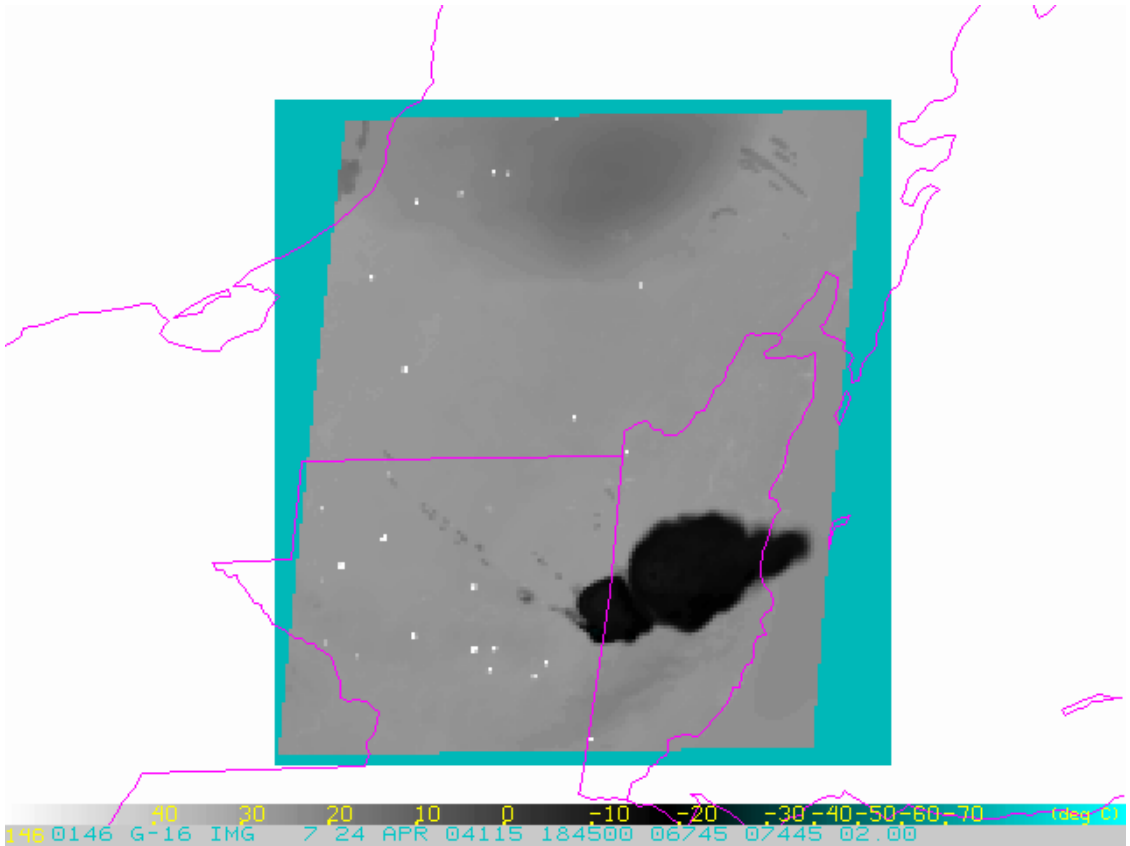
12.30 µm



13.30 µm

Courtesy of RAMMB / CIRA AWG Proxy Data Team

Central America – 24 April 2004
Agricultural Fires in Mexico, Guatemala, and Belize

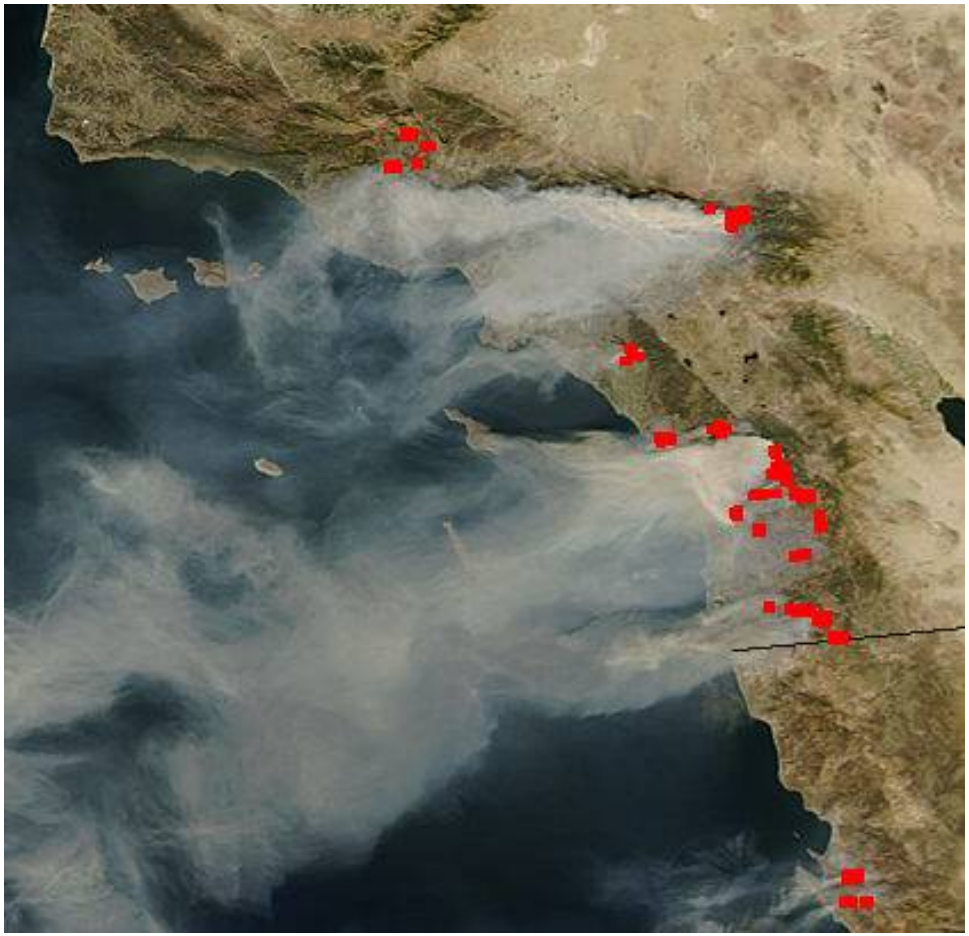


Synthetic GOES-R ABI 3.9 µm
24 April 2004 1840 to 2100 UTC (5 min interval)

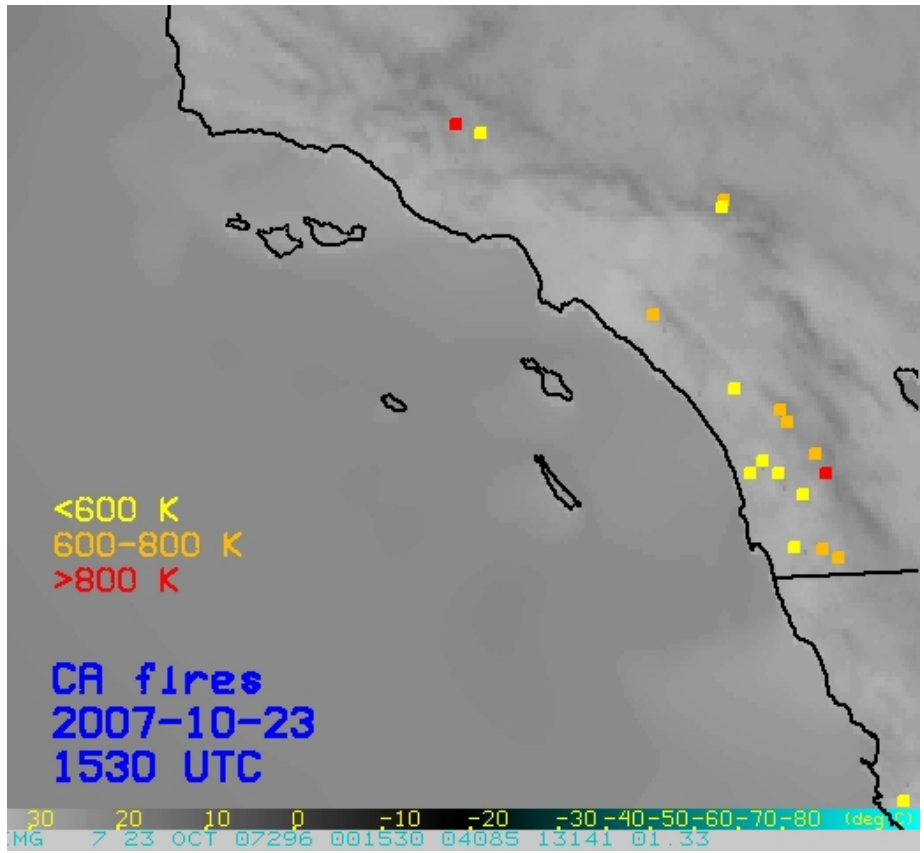
Click here to view GOES-12 observations of the same fire event

Courtesy of RAMMB / CIRA AWG Proxy Data Team

California Fires 23 October 2007



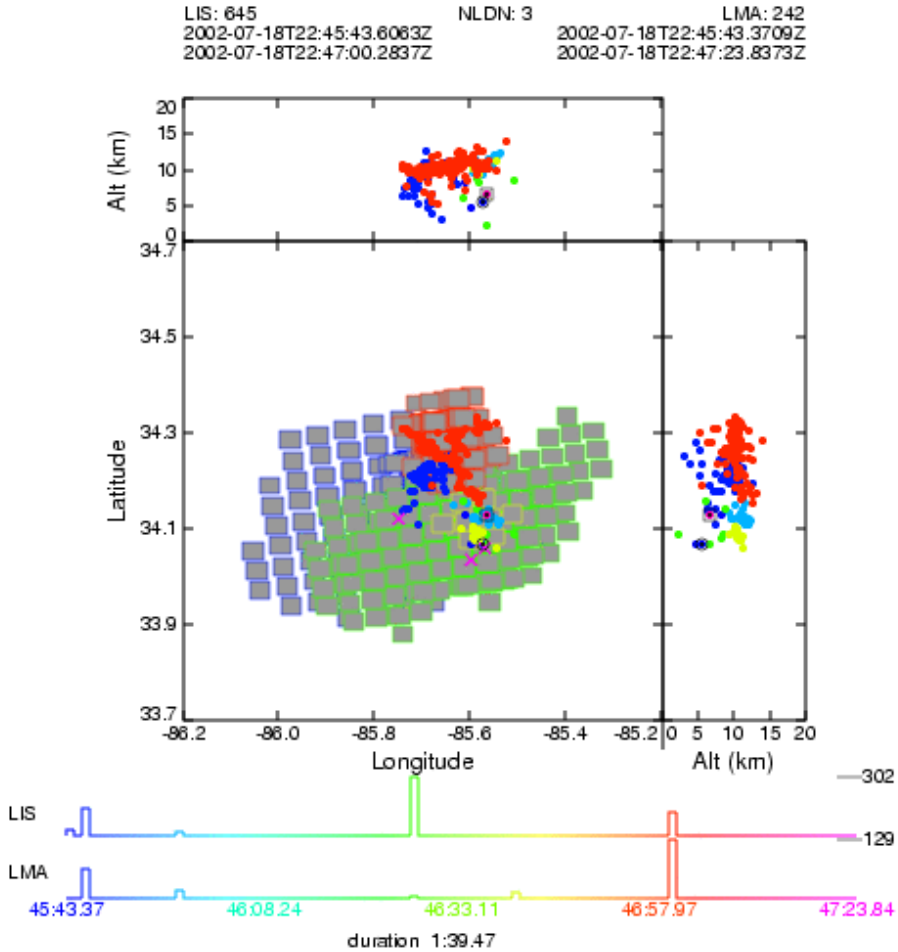
MODIS Satellite Image
True color - Satellite: Aqua - Pixel size: 1 km
Date: 2007/10/23 (created by NASA)



Synthetic ABI 3.9 µm Image
produced by CIRA's RAMM Branch.
Date/time: 2007/10/23 15:30 UTC

Courtesy of RAMMB / CIRA AWG Proxy Data Team

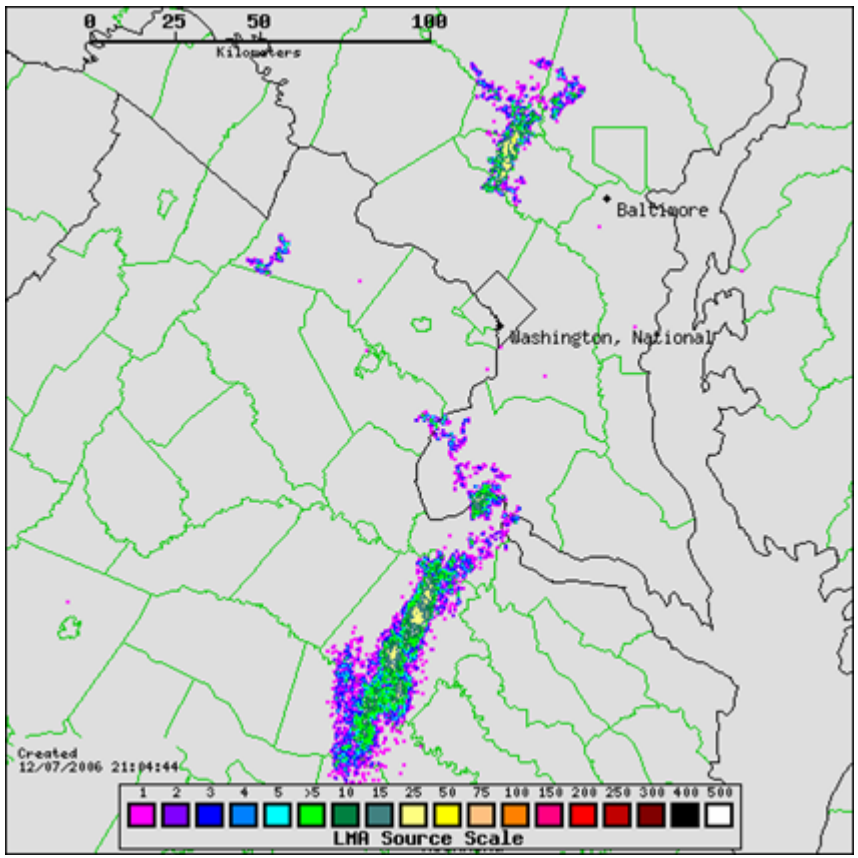
GLM Proxy Data



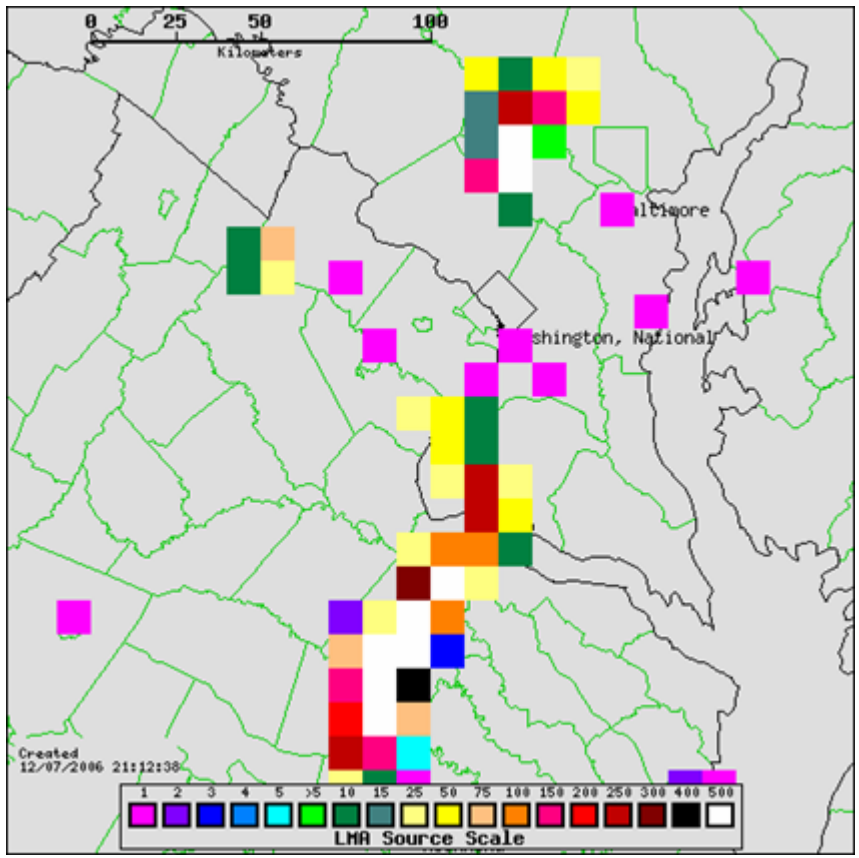
Tool developed to start inter-comparing LIS (squares), LMA (dots), and NLDN (Xs) for Proxy Data Development.

DC Regional Storms November 16, 2006

Resampled 5-min source density at 1 km and 10 km



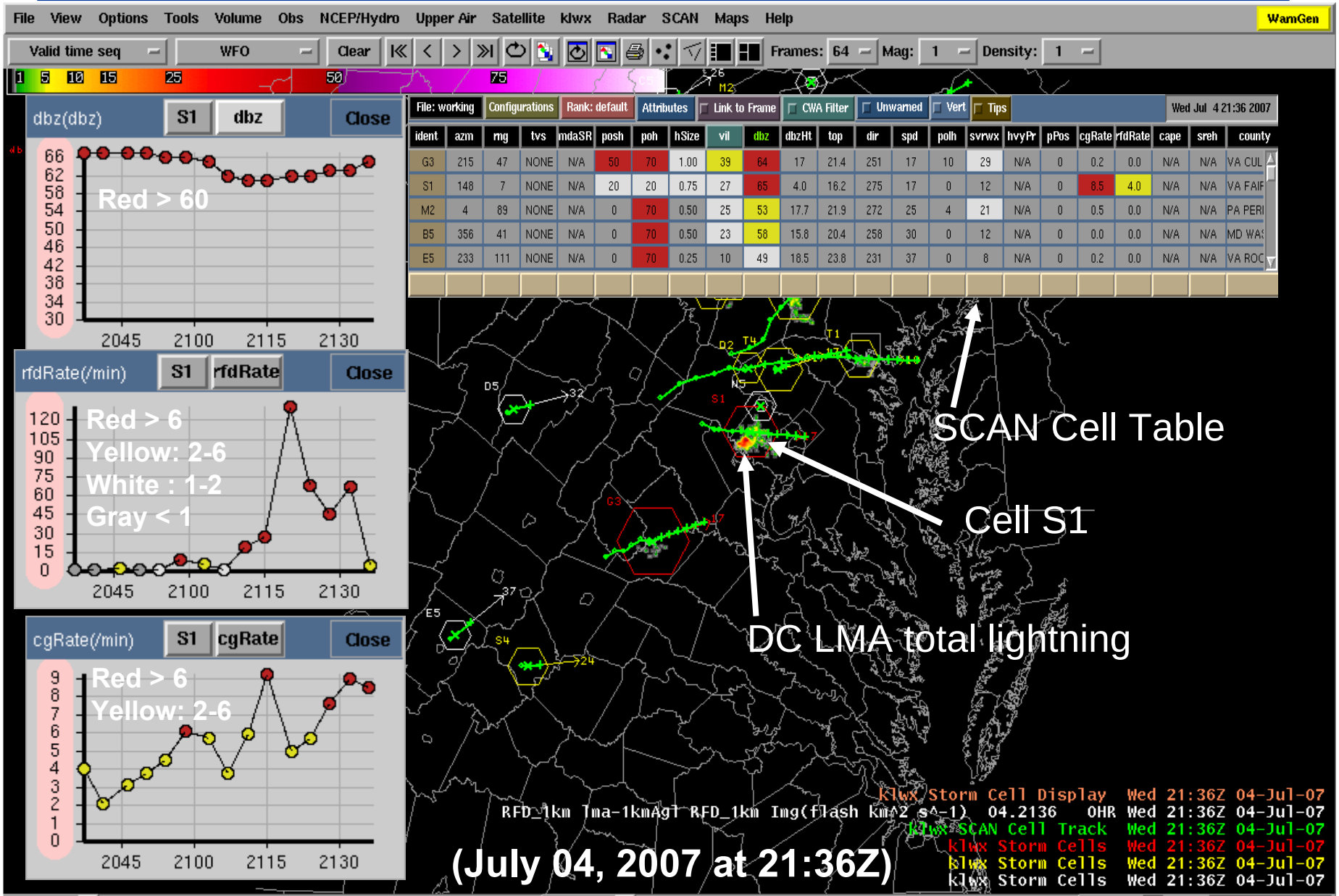
LMA 1 km resolution



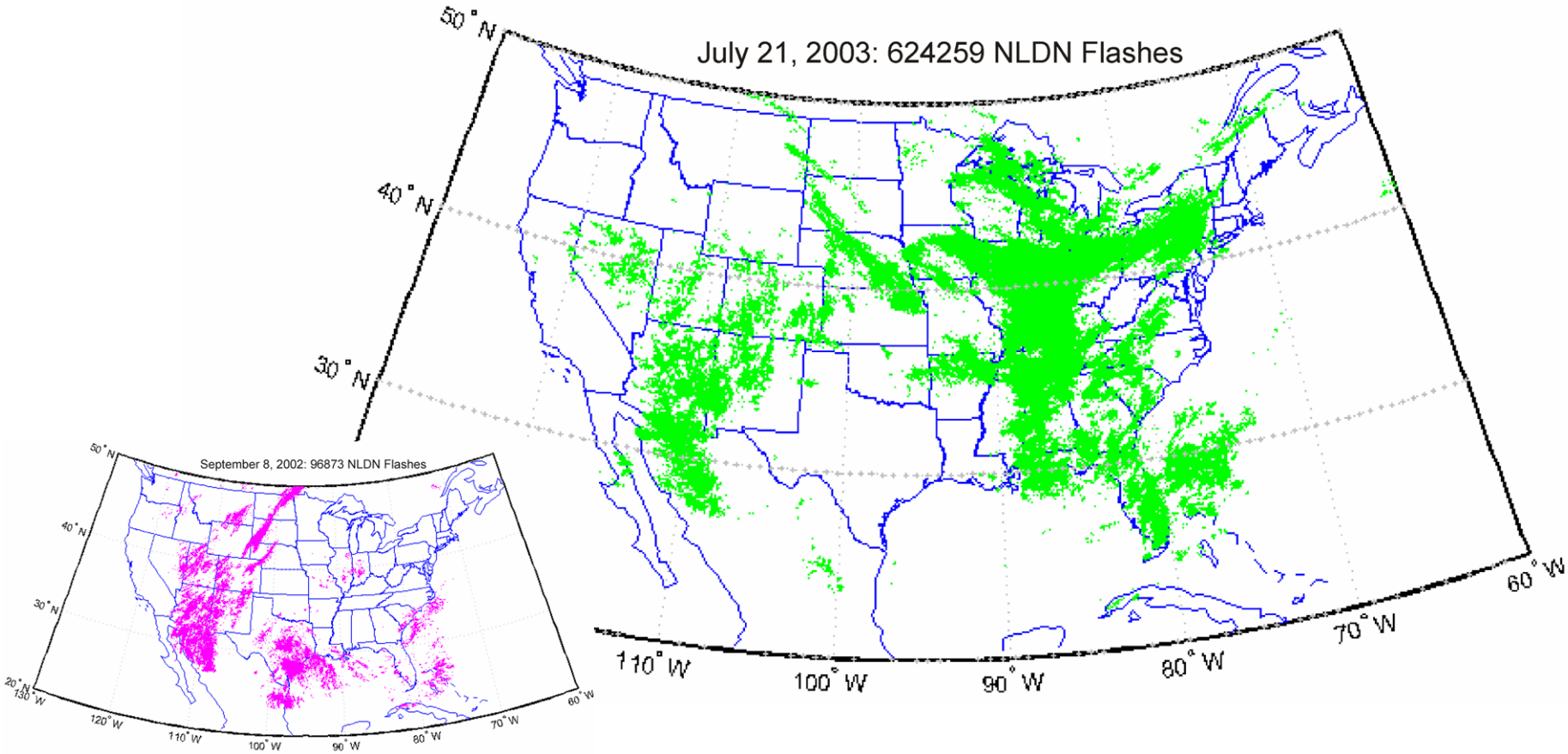
LMA @ GLM 10 km resolution

Lightning Jump Algorithm:

Experimental Trending Implementation in AWIPS/SCAN



Regionalization Test Dataset



Since all we are testing is the regionalization code (no clustering), we do not need event-like data for this test. All we need is data that can be 'regionalized' and NLDN data works for that. Note that the day we chose (7-21-03, green) has more than 6X the NLDN lightning of a 'typical' day (e.g., 9-8-02, magenta).

Summary

- **Experienced:** Developed the algorithms for NOAA's satellite programs since their inception over 40 years ago
- **Knowledgeable:** Understand how to calibrate, validate and verify algorithms using techniques appropriate for instrument, product, and spectral characteristics
- **Efficient:** Capable of generating proxy data sets for all GOES-R instruments (ABI, GLM, Space Wx) for use in program activities
- **Coordinated:** Will develop, host, demonstrate, document, and deliver algorithms to meet program specifications
- **Consistent:** Established AWG management processes with a defined schedule that is aligned with GOES-R Program to provide status and track progress
- **On Track:** Demonstrated clear progress toward our algorithm development plan
  - 95% of algorithm design reviews have been completed
  - Numerous proxy and simulated datasets have been created
  - First versions of some product algorithms have been completed
  - First draft of ATBDs for all products will be completed by September 2008