GOES-R Algorithm Working Group Overview

Mitchell D. Goldberg, AWG Program Manager
Jaime Daniels, AWG Deputy Program Manager
Walter Wolf, Algorithm Integration Manager
Zhaohui Cheng, Quality Assurance Lead
Tess Valenzuela, EVM Lead
Deborah Dowling, Schedule Lead
Kenny Lowe, AWG Program Support
AWG Application/Development /Proxy Teams

NOAA/NESDIS Center for Satellite Applications and Research

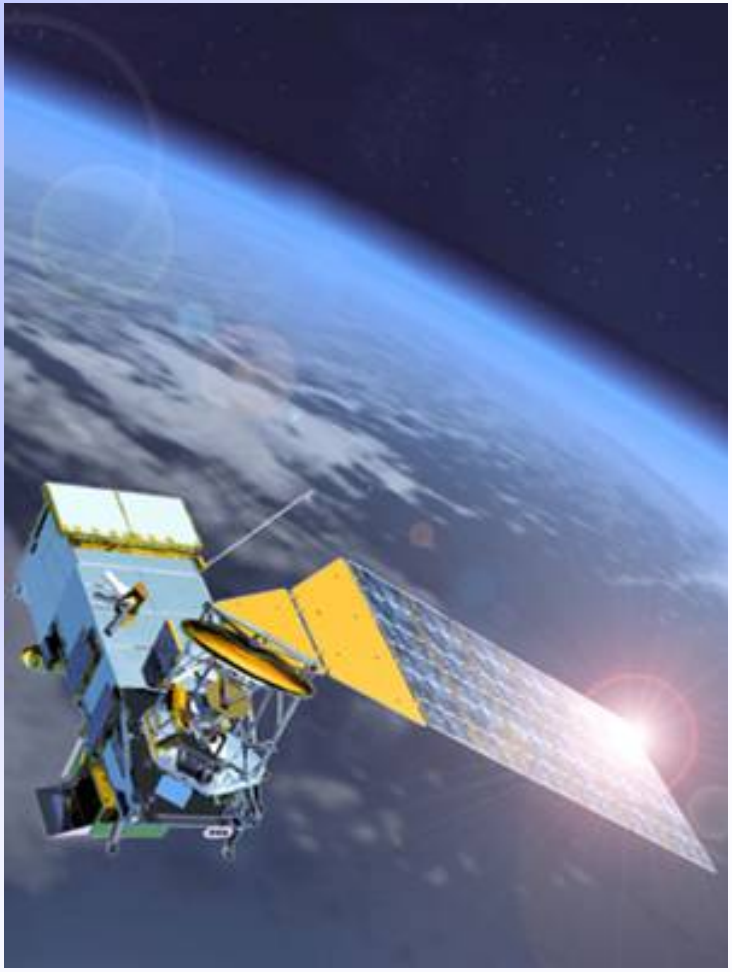
Algorithm Working Group

PURPOSE: 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

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

End-to-End Capabilities

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



From 2005 AWG first meeting

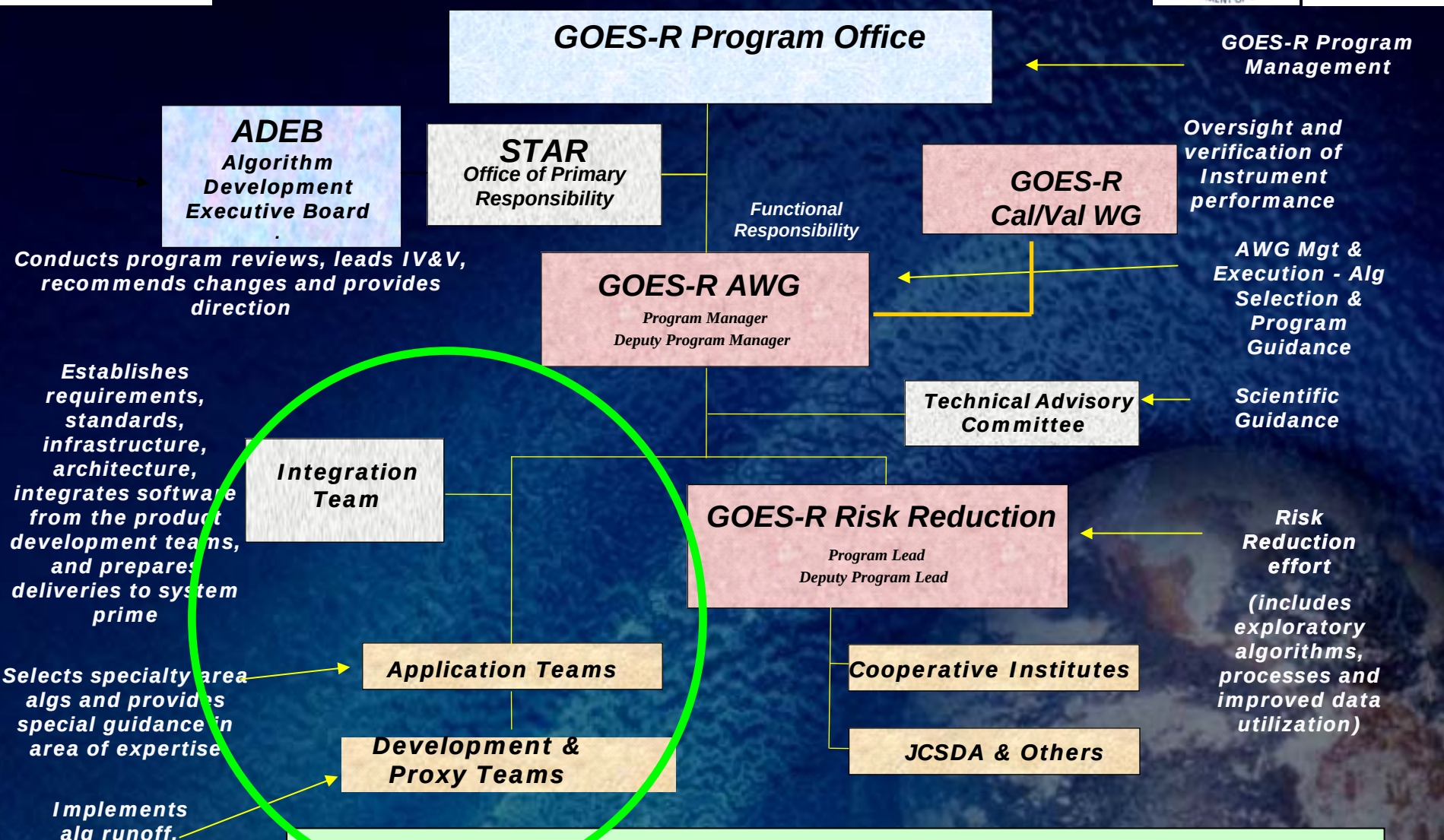
GOES-R Algorithm/Product Readiness

Underpinning Research & Development (initial algorithms, new applications & Day 2 Products)	Pre & Post Launch Sensor Calibration and Validation	Operational Algorithm Readiness Development and Transition to Operations	Sustained Post Launch Validation and Reactive Science Maintenance	User Readiness
Risk Reduction	Calibration Working Group	***Algorithm Working Group***	***Algorithm Working Group***	Proving Ground & Risk Reduction

Key components of a successful satellite program

Established GOES-R programs/activities and working groups that directly support these components

AWG Organizational Structure



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

ADEB Review Process

Two core components:

- ***Independent Peer Review – Independent Validation & Verification (IV&V):*** Detailed technical review of each algorithm, its theoretical basis, test and validation procedures, and the algorithm theoretical basis document (ATBD)
  - proxy datasets
  - validation methods
  - integration and related processes
  - assessment of algorithm compliance with GOES-R specifications

- ***Algorithm Development Executive Board:*** Overall review of the AWG processes, algorithm and documentation readiness, and associated deliverables for:
  - meeting program needs
  - providing capabilities to build a robust ground system
  - delivering quality algorithms and products to users
  - meeting user requirements

Technical Advisory Committee

The TAC is responsible for

- recommending priorities for GOES-R product research and development,
- providing technical guidance on the development and testing of GOES-R product processing systems
- soliciting technical advice from outside the GOES community when necessary.

AWG Teams

- ***Product Application Teams:*** Plan and execute the activities to assess, select, develop, validate, and deliver level-2 product algorithms

- ***Product Development Teams:*** Code, host, and test candidate level-2 product algorithms in a scalable operational demonstration environment and develop validation tools

- ***Proxy Team:*** Responsible for the development of high-quality GOES-R instrument simulated and proxy data sets for GOES-R product algorithm development, testing and validation

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

Product Application Teams

GOES-R Products Mapped to Algorithm Application Teams

- **Imagery**_____(Tim Schmit)
- **Soundings**_____(Tim Schmit, Chris Barnet)
- **Winds**_____(Jaime Daniels)
- **Clouds**_____(Andy Heidinger)
- **Aviation**_____(Ken Pryor, Wayne Feltz)
- **Hydrology**_____(Robert Kuligowski)
- **Land Surface**_____(Bob Yu)
- **Cryosphere**_____(Jeff Key)
- **Radiation Budget**_____(Istvan Lazslo)
- **Lightning** _____(Steve Goodman)
- **Space Environment**_____(Steven Hill)
- **SST and Ocean Dynamics**____(Alexander Ignatov)
- **Aerosols / Air Quality / Atmospheric Chemistry**_(Shobha Kondragunta)

- **Proxy Data**_____(Fuzhong Weng)
- **Cal/Val** (sensor)_____(Changyong Cao)
- **Algorithm Integration**_____(Walter Wolf)

GOES-R BASELINE & OPTION-2 PRODUCT SUMMARY

BASELINE Products

Advanced Baseline Imager (ABI)

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

GLM

- Lightning Detection

OPTION 2 Products

Advanced Baseline Imager (ABI)

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

AWG Follows a High Maturity Process and Adheres to Established Standards

(Development gates)

- **Processes**
  - Initial Requirements Analysis
  - Algorithm Design Review
  - Critical Design Review
  - Test Readiness Review
  - Code Unit Test Review
  - Algorithm Readiness Review
  - EVM Reporting (monthly)

- **Standards**
  - Algorithm Theoretical Basis Document
  - Metadata (FGDC guidelines)
  - Interface Control
  - System Description
  - Users Manual
  - Fortran Programming
  - C and C++ Programming
  - Test Plan
  - Algorithm Implementation Instructions
  - Latency Reports

AWG adherence to its established processes and standards in its algorithm development activity reduces risk associated with the development of the Level-2 product algorithms and their delivery to the GOES-R program

Application Team Assessment

- Review and Comment on the MRD Spec.
- Current State of Algorithms and any deficiencies
- Candidate Algorithms for GOES-R
- Instrument Requirements to meet MRD
- Proxy Data Needs
- Expectations for interaction and inputs from other teams
- Algorithm Action Plan
  - How are you going to reach consensus?
  - What issues must be resolved?
  - How are you going to intercompare algorithms?
  - Describe the testbed environment needed to select the algorithm
  - Schedule of activities needed to meet deliverables

From November 2005 AWG meeting ~ Initial Requirements Assessment

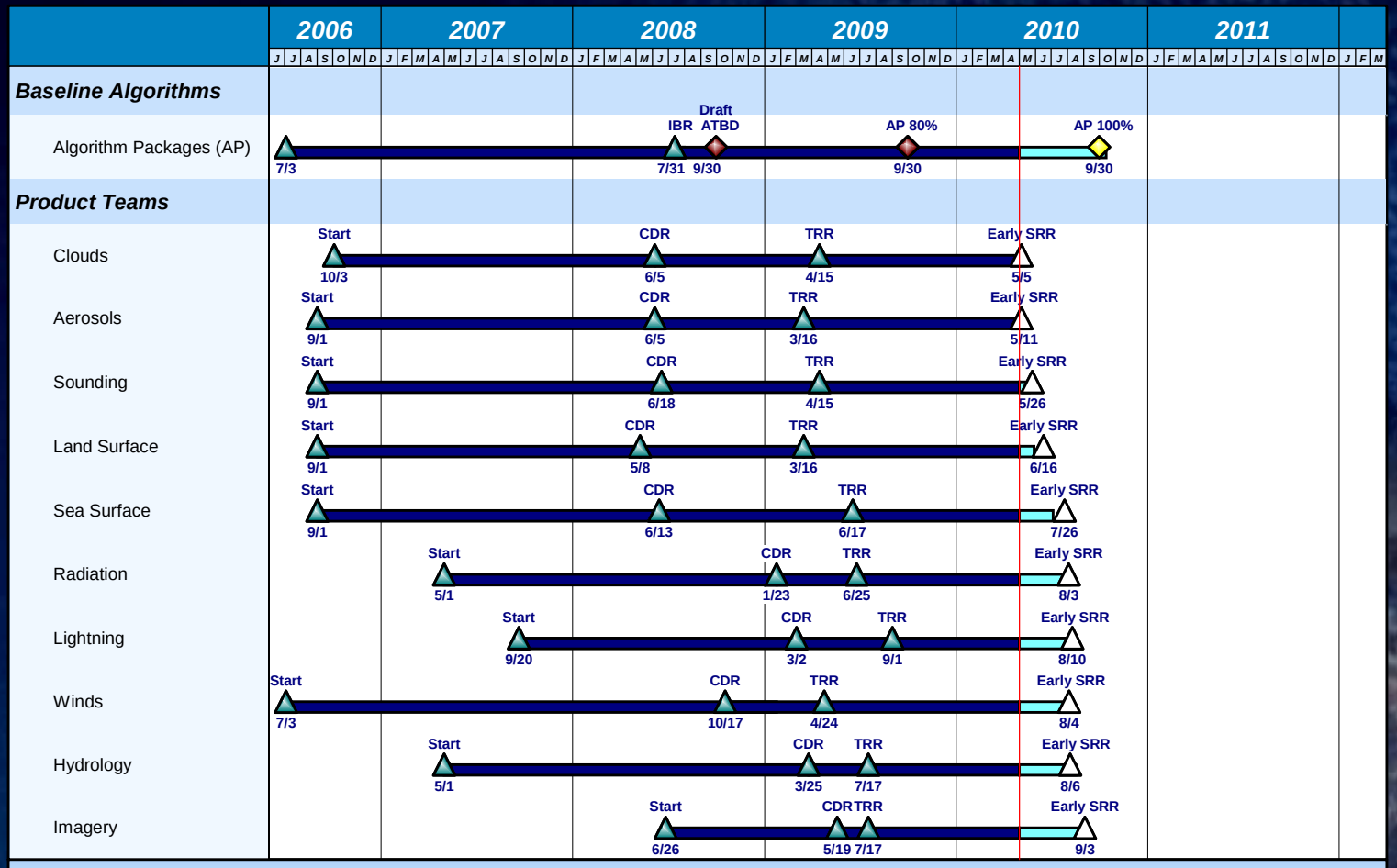
OUTCOME

AWG Deliverables…

- **Algorithm Packages (APs)**
  - Algorithm Theoretical Basis Documents (ATBD)
  - Instrument proxy datasets
  - Product output datasets (for comparison)
  - Algorithm Interfaces and Ancillary Data Description (AIADD) document

- **Schedule of Deliveries:**
  - ✓ September 2008: As-Is ATBDs
  - ✓ September 2009: 80% APs for Baseline Products
  - September 2010: 80% APs for Option 2 Products
    100% APs for Baseline Products
  - September 2011: 100% APs for Option 2 Products

Key Milestone Dates for Baseline



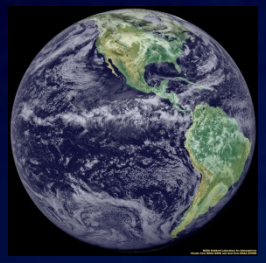
Algorithm Development Strategy

A wide variety of instrument proxy datasets have been assembled and are being used…

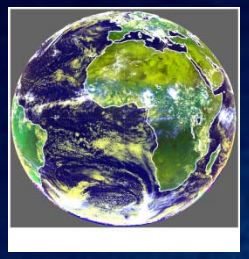
"Real" ABI PROXY Data Sources

"Simulated" ABI Proxy Data Sources

Current GOES

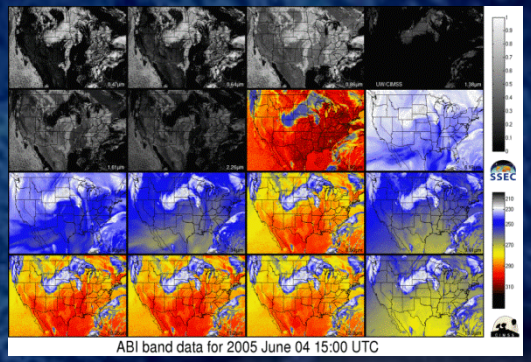


Meteosat/ SEVIRI

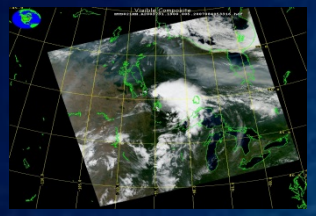


AVHRR

(FD, CONUS, Meso)

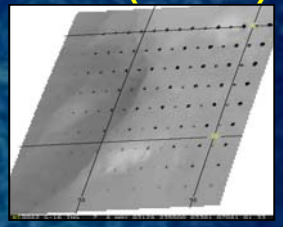


MODIS



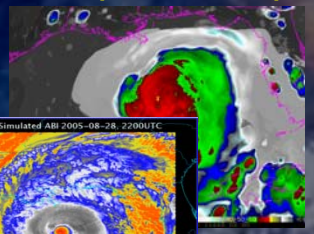
TRMM/LIS

3.9um (for fires)

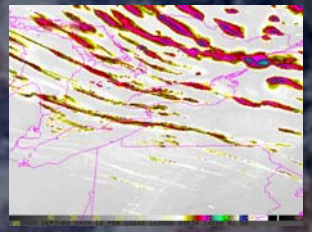


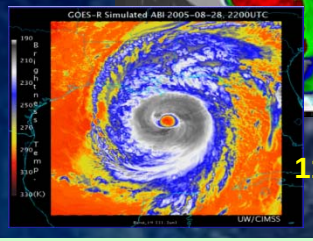
Case Studies

10.35um (Hurricane Lili)



10.35um (Lake Effect Snow)



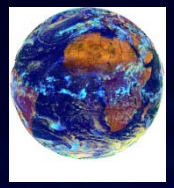
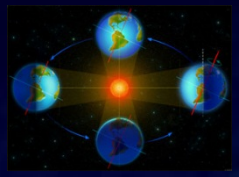


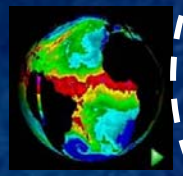
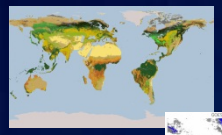
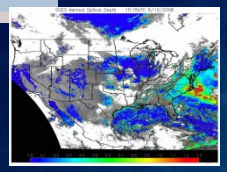
11.2 um (HurricaneKatrina)

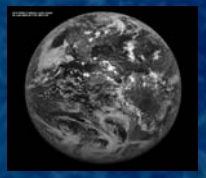
AWG Proxy and Product Application Teams have assembled a wide variety of instrument proxy and simulated datasets to use for algorithm development, testing, and validation activities

Algorithm Development and Validation Strategies

An iterative process…

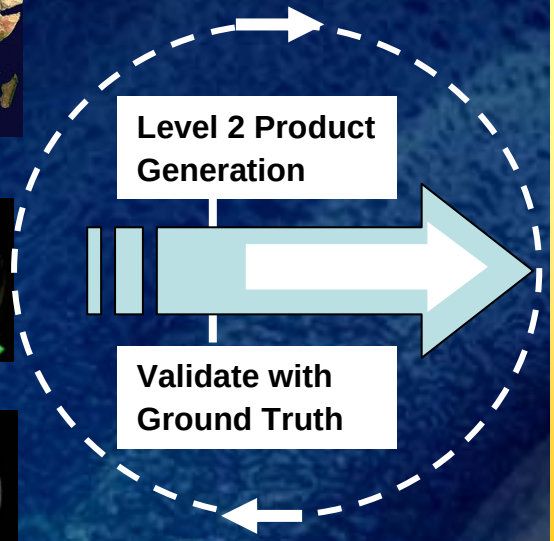






Seasonal conditions represented

Wide variety of atmospheric and surface conditions are represented

Algorithm Iterations



MORE IS BETTER!

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 is responsible for Level-2 product accuracy and precision specifications, and has therefore, worked to establish robust pre-launch validation strategies for each product

Purpose of this meeting

- Define requirements for instrument cal/val and product validation.
  - Implementation plan
  - Build software to demonstrate routine cal/val for post-launch in an operational environment
    - Monitor observing system and product performance
    - Find problems early
  - Build cal/val enterprise system for detailed analysis in our collaborative environment
    - Facilitate science discovery and algorithm improvement
    - Diagnosis root causes of problems identified in routine operational cal/val

From May 2007 AWG Meeting

Validation Scope

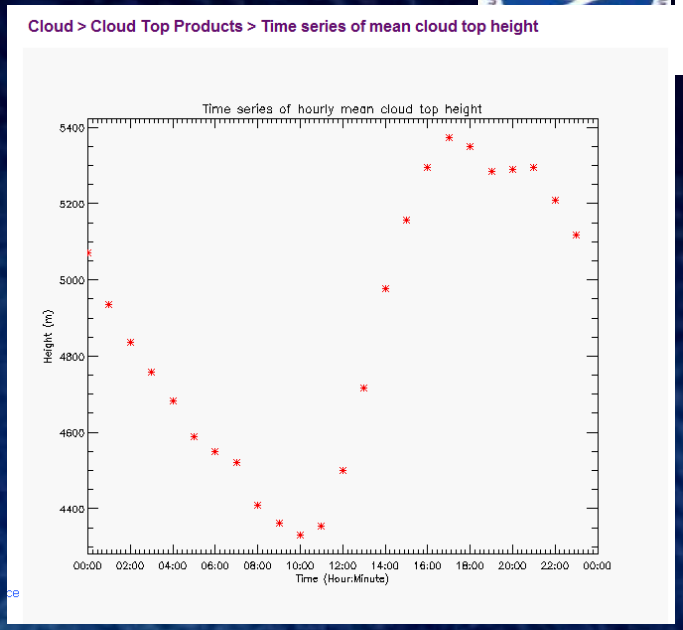
- Identify all relevant “ground truth” or comparative observations that will be needed to validate each Level-2 product according to the GS F&PS documentation

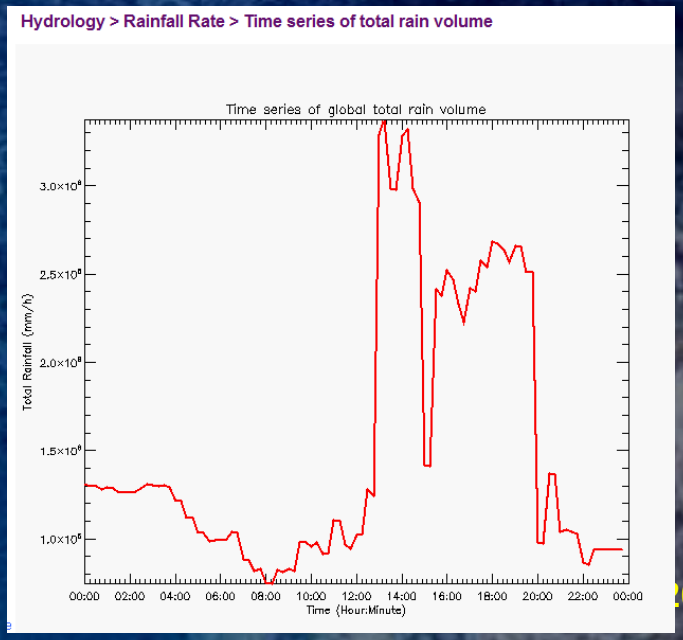
- Develop routine Cal/Val Tools for delivery to GPO for Ground System Implementation
  - Scheduled delivery two years after 100% DAPs (2012, 2013)

- Identify and develop the Cal/Val Tools for use in STAR’s Calibration/Validation Enterprise System (a component of its Collaborative Environment) that will enable “Deep-Dive” assessments of products to be performed. These tools will bring an unprecedented and sustaining capability for validating the ABI and GLM products

Validation Layers

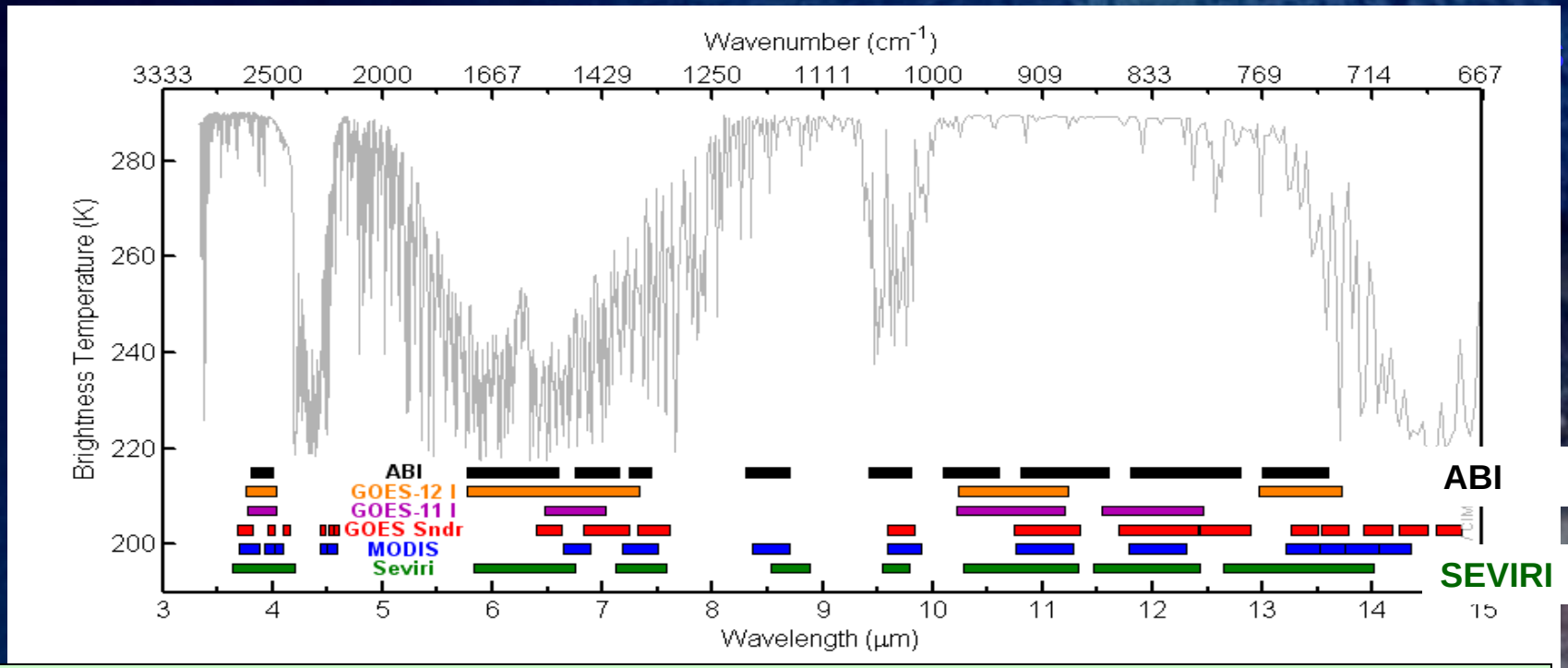
- Layer 1: Product trending
- Layer 2: Routine operational collocations with ground truth
- Layer 3: Deep dive tools to detailed assessments of algorithm accuracy/precision performance





High Confidence in ABI Algorithms Meeting Requirements

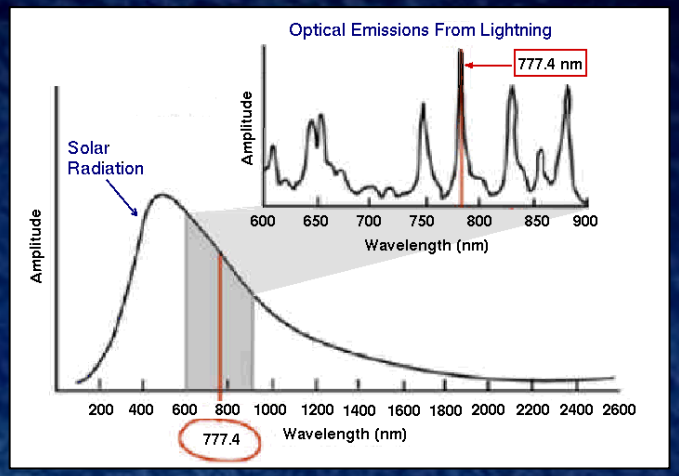
- Algorithms from MODIS and current GOES program are being leveraged
- EUMETSAT SEVIRI instrument serves as excellent proxy data source
- Current GOES and MODIS instruments serve as ABI proxy datasets
- High fidelity simulated datasets for ABI have been generated

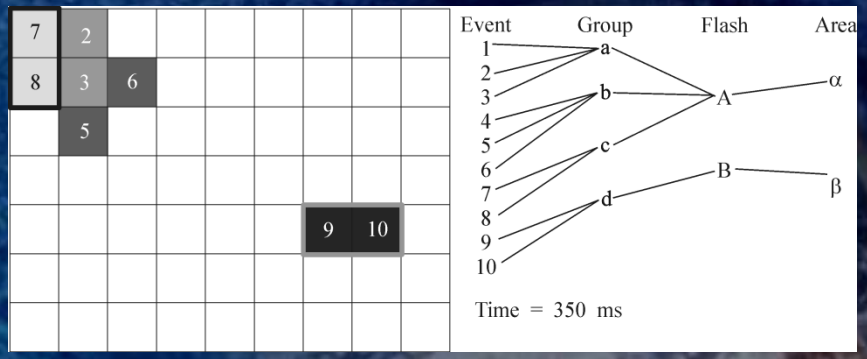


Similar spectral channel experience provides confidence the algorithms will be delivered with minimal program risk while meeting the required accuracies

High Confidence in Geostationary Lightning Mapper (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)
- Geostationary Lightning Mapper (GLM) lightning detection algorithm based on LIS algorithm heritage
- Proxy data sets derived from LIS and from ground based total lightning mapping arrays
- Government and University expertise from current programs





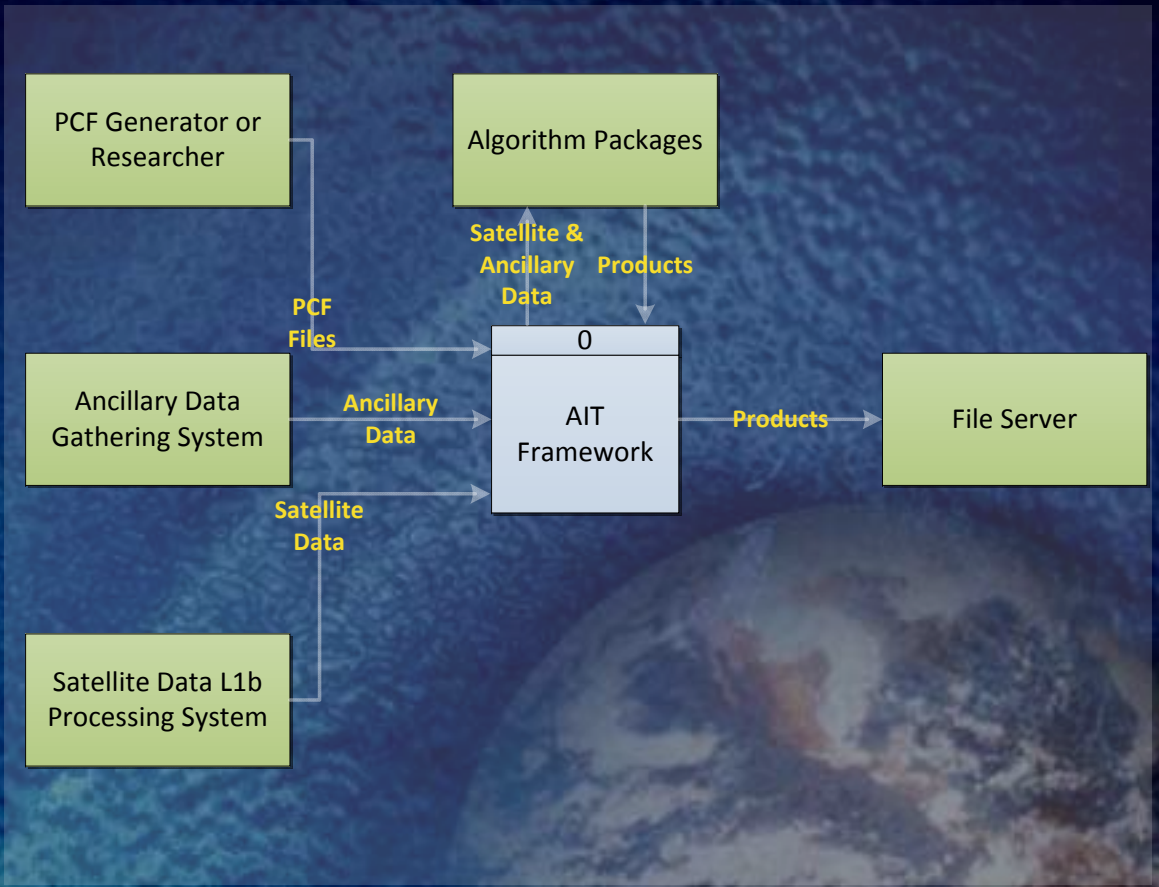
Lightning Clustering Algorithm, Mach et al., JGR, 2007)

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

AWG Algorithm Framework

Prototype developed by AIT…

- Test bed for algorithm development and performance testing.
- Enables testing of code, algorithm integration, compilers, use of common ancillary data and forward models
- Used for verification of Level-2 algorithm performance (accuracy & precision specifications)

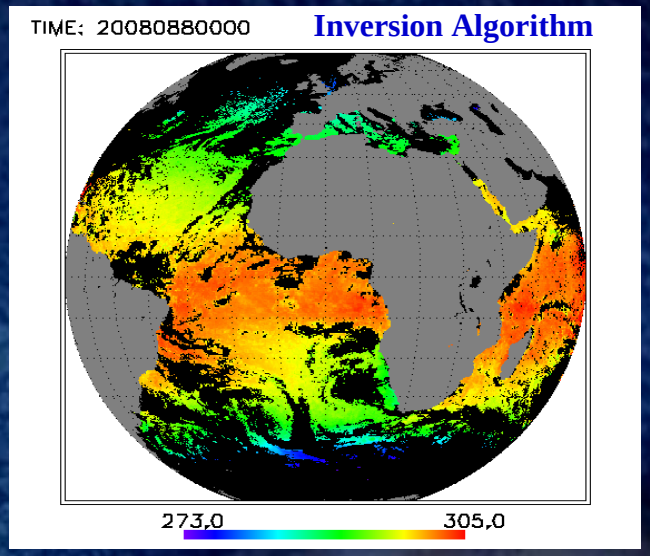


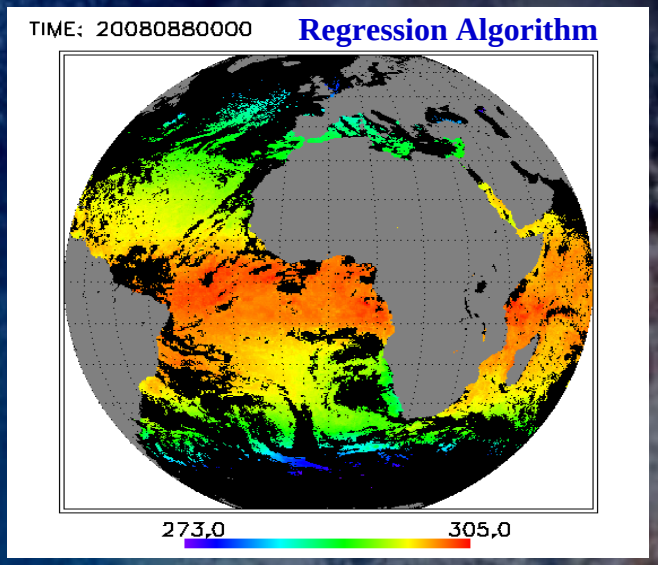
Sea Surface Temperature

- **Algorithm Highlights**
  - Hybrid approach that combines the advantages of regression (heritage approach) with a physical retrieval approach (optimal estimation)
  - Utilizes the 3.9, 8.5, 10.35, 11.2, 12.3μm bands
  - Exploits recent improvements in fast clear-sky radiative transfer models
  - Leverages increased ABI temporal resolution

- **Operational Applications**
  - Assimilation into atmospheric and oceanic models
  - Climate monitoring/forecasting
  - NOAA' Coast Watch Program
  - Harmful Algal Bloom monitoring
  - Sea turtle tracking
  - Vessel positioning
  - Upwelling identification
  - Commercial fisheries management
  - NOAA's Coral Reef Watch Program
  - Coral bleach warnings and assessments

SST product derived from MSG2/SEVIRI observations for 28 March 2008





Outline for Baseline Product Presentations

- Executive Summary
- Algorithm Description
- ADEB and IV&V Response Summary
- Requirements Specification Evolution
- Validation Strategy
- Validation Results
- Summary

Algorithm Development Progress

	ADR	1st Del. to AIT	2nd Del. to AIT	ATBD Draft	CDR	Test Plan	3rd Del. to AIT	TRR	Val Plan	ATBD 80%	4th Del. to AIT	CUTR		5th Del. to AIT	ATBD 100%	ARR (SRR)	1st Val. Del.
												Comments	Review				
Air Quality																	
Aerosol Imagery	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			08/05/10	
Aerosol	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			08/05/10	
Total Ozone	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			08/05/10	
Clouds																	
Cloud Layers/Heights and Thickness	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			07/07/10	
Cloud Mask	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●	✓		07/07/10	
Cloud Phase and Cloud Type	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			07/07/10	
Daytime Cloud Optical Depth, Particle Size, LWP and IWP	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●	✓		07/07/10	
Nighttime Cloud Optical Depth, Particle Size, LWP and IWP	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			07/07/10	
Land																	
LST	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●	✓		07/15/10	
NDVI	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●	✓		07/15/10	
Fire	●	✓	✓	●	●	●	✓	●	●	✓	✓	●	●			07/15/10	

Proxy Archive in STAR's Collaborative Enviroment

Proxy Data from Simulations

Proxy Data	Location	Format	Data Volumn	Reader/Readme	time coverage	space coverage	temporal reso.	spatial reso.	# of channels	Produ
MM5 simulation of Hurricane Katrina	/net/orbit178l/disk4/pub/MESOSCALE	BINARY	16 GB	readv3b2.f90	Aug. 25, 2005	Domain 1: 2079 X 1971 km2 Domain 2: 1386 X 1305 km2 Domain 3: 678 X 597 km2	hourly/ 3-hourly at 10-min interval	27/9/3km	n/a	STAR
WRF simulation	/net/orbit178l/disk4/pub/MESOSCALE/WRF/WRF	NetCDF	43 GB		Jun. 25, 2003	12640x14640 km2	40 min	8 km	n/a	CIMSS
WRF Hyperspectral radiance	/net/orbit178l/disk4/pub/MESOSCALE/WRF/HighSpectralData	NetCDF	100 GB		Jun. 25, 2003	12640x14640 km2	40 min	8 km	n/a	CIMSS
ABI simulation (WRF)	/net/orbit178l/disk4/pub/MESOSCALE/WRF/ABI	NetCDF	452 MB		Jun. 25, 2003	12640x14640 km2	40 min	8 km	9IR	CIMSS
ABI Full disk (WRF)	/net/orbit178l/disk4/pub/MESOSCALE/WRF/WRF2/fulldisk	NetCDF	18 GB		2hr 06/04/2005	Full disk	30 min	6 km	9IR	CIMSS
ABI CONUS (WRF)	/net/orbit178l/disk4/pub/MESOSCALE/WRF/WRF2/conus	NetCDF	16.6 GB		2hr 06/04/2005	CONUS	5 min	2 km	16ABI	CIMSS
ABI FD (WRF)	/net/orbit178l/disk4/pub/MESOSCALE/WRF/WRF3	NetCDF	28 GB		24hr 26-27 Jun 2008	Full disk(west)	5 min	2 km	9IR	CIMSS
ABI (WRF) Aug2006	/net/orbit178d/disk5/pub/TestData/ABI_WRF/200608	Binary	4.7 GB	ABI-TestData-Aug2006.txt	18hr 24-25 Aug 2006	CONUS	1 hour	4 km	16 ABI	CIMSS
ABI CONUS (WRF)	/net/orbit178d/disk5/pub/TestData/ABI_WRF/CONUS/	NetCDF	4.9 GB	README	24hr 04-05 Jun2005	CONUS	30 min	2 km	16ABI	CIMSS
ABI MESO (WRF)	/net/orbit178d/disk5/pub/TestData/ABI_WRF/MESO/	NetCDF	400MB	README	24hr 04-05 Jun2005	MESO	30 min	1/2 km	16ABI	CIMSS
RAMS Simulation (Lili)	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/Lili/model	BINARY	196 GB	read_data.f90/ read_me.txt	6hr 10/02/2002	1862x1562km2	5 min	2 km	n/a	CIRA
ABI Simulation (Lili)	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/Lili/netcdf	NetCDF	41 GB		6hr 10/02/2002	1862x1562km2	5 min	2 km	10 IR	CIRA
RAMS Simulation (LES)	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/LES/model	BINARY	120 GB	read_me_12feb03.txt	6hr 02/12/2003	1462x1042km2	5 min	2 km	n/a	CIRA
ABI Simulation (LES)	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/LES/netcdf	NetCDF	25 GB		6hr 02/12/2003	1462x1042km2	5 min	2 km	10 IR	CIRA
RAMS Simulation Simulation_SVWX	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/SVWX/model	BINARY	70 GB	read_me_8may03.txt	6hr 05/08/2003	1002x1042km2	5 min	2 km	n/a	CIRA
ABI Simulation Simulation (SVWX)	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/SVWX/netcdf	NetCDF	15 GB		6hr 05/08/2003	1002x1042km2	5 min	2 km	10 IR	CIRA
RAMS Simulation Simulation_Wilma	/net/orbit178l/disk4/pub/MESOSCALE/RAMS/Wilma/model	BINARY	366 GB		120hr 10/19/2005	1002x1042km2	5 min	2 km	n/a	CIRA

Summary and Future Work

- **AWG has made significant progress**
  - Established processes and standards are in place and being executed
  - Algorithm processing framework is in place
  - All baseline product algorithms have successfully gone through development review gates (ADR, CDR, TRR)
  - Successfully delivered baseline product algorithm packages (80%) to the GOES-R Ground Segment Project (Sept 30, 2009)

- **Complete our scheduled algorithm development activities**
  - Baseline (100%) & Option-2 (80%) algorithm deliveries (Sept 2010)
  - Option-2 (100%) algorithm deliveries (Sept 2011)

- **Support algorithm implementation activity being done by the Harris Team via TIMS**

- **Ramping up the sustained validation effort**

- **Support User Readiness and Training Activities**
  - GOES-R Proving Ground
  - GOES-R Risk Reduction