GOES-R Algorithm Working Group Overview

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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*
### Key components of a successful satellite program

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

GOES-R Program Office

ADEB
Algorithm Development Executive Board
Conducts program reviews, leads IV&V, recommends changes and provides direction

STAR
Office of Primary Responsibility

GOES-R AWG
Program Manager
Deputy Program Manager

Integration Team

GOES-R Risk Reduction
Program Lead
Deputy Program Lead

Application Teams

Development & Proxy Teams

Cooperative Institutes

JCSDA & Others

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

AWG Risk Reduction effort (includes exploratory algorithms, processes and improved data utilization)

Scientific Guidance

Risk Reduction effort

AWG Mgt & Execution - Alg Selection & Program Guidance

Oversight and verification of Instrument performance

GOES-R Cal/Val WG

Technical Advisory Committee

Functional Responsibility

GOES-R Program Management

6/14/2010
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
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.
**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
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

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<th>BASELINE Products</th>
<th>OPTION 2 Products</th>
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<td>- Clouds and Moisture Imagery (KPP)</td>
<td>- Cloud Layer/Heights</td>
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<td>- Cloud Top Pressure and Height</td>
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<td>- Temperature and Moisture Profiles</td>
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<td>- Visibility</td>
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<td>- Ocean Currents, Currents: Offshore</td>
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**Advanced Baseline Imager (ABI)**

- GLM

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**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
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- 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 adheres 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

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- **Current Schedule**
- **Review Date Span**
- **Schedule Progress**
Algorithm Development Strategy

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

“Real” ABI PROXY Data Sources

- Current GOES
- Meteosat/SEVIRI
- AVHRR
- MODIS
- TRMM/LIS

“Simulated” ABI Proxy Data Sources

- MODIS
- AVHRR
- Current GOES

Case Studies

- 10.35um (Hurricane Lili)
- 10.35um (Lake Effect Snow)
- 3.9um (for fires)
- 11.2 um (Hurricane Katrina)

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

Level 2 Product Generation

Validate with Ground Truth

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
• 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

6/14/2010
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:
  - 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

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

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</table>
# Proxy Data from Simulations

<table>
<thead>
<tr>
<th>Proxy Data</th>
<th>Location</th>
<th>Format</th>
<th>Data Volume</th>
<th>Reader/Reader</th>
<th>Time coverage</th>
<th>Space coverage</th>
<th>Temporal resolution</th>
<th>Spatial resolution</th>
<th>% of channels Prod.</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFS Simulation of Hurricane</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE</code></td>
<td>BINARY</td>
<td>16 GB</td>
<td>reader/reader</td>
<td>Aug 25, 2005</td>
<td>Domain: 1: 378x1971 km² Domain: 2: 1196x1195 km² Domain: 3: 1792x597 km²</td>
<td>24 hour</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>WRF Simulation</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/WRF</code></td>
<td>NetCDF</td>
<td>43 GB</td>
<td>reader/reader</td>
<td>Jun 23, 2003</td>
<td>Domain: 1: 1280x1050 km²</td>
<td>30 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>WRF Hyperspectral Radiance</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/HighSpectralData</code></td>
<td>NetCDF</td>
<td>100 GB</td>
<td>reader/reader</td>
<td>Jun 23, 2003</td>
<td>Domain: 1: 1280x1050 km²</td>
<td>30 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/ADE</code></td>
<td>NetCDF</td>
<td>452 MB</td>
<td>reader/reader</td>
<td>Jun 23, 2003</td>
<td>Domain: 1: 1280x1050 km²</td>
<td>30 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/WRF2/full_disk</code></td>
<td>NetCDF</td>
<td>18 GB</td>
<td>reader/reader</td>
<td>2hr 05/04/2005</td>
<td>Full disk</td>
<td>30 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/WRF2/comus</code></td>
<td>NetCDF</td>
<td>16.6 GB</td>
<td>reader/reader</td>
<td>2hr 06/04/2005</td>
<td>COMUS</td>
<td>5 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/WRF3</code></td>
<td>NetCDF</td>
<td>38 GB</td>
<td>reader/reader</td>
<td>24hr 29-31 Jun 2006</td>
<td>Full disk (west)</td>
<td>5 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF) Aug2006</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/ADE_TestData_Aug2006.tar.gz</code></td>
<td>Binary</td>
<td>147 MB</td>
<td>ADE_TestData_Aug2006.tar.gz</td>
<td>16hr 24-25 Aug 2006</td>
<td>COMUS</td>
<td>1 hour</td>
<td>1 km</td>
<td>a/a</td>
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<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/CONUS/</code></td>
<td>NetCDF</td>
<td>4.1 GB</td>
<td>reader/reader</td>
<td>24hr 04-05 Jun 2005</td>
<td>CONUS</td>
<td>30 min</td>
<td>1 km</td>
<td>a/a</td>
</tr>
<tr>
<td>ADE Simulation (WRF)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/WRF/MESO/</code></td>
<td>NetCDF</td>
<td>400 MB</td>
<td>reader/reader</td>
<td>24hr 04-05 Jun 2005</td>
<td>Meso</td>
<td>30 min</td>
<td>1/3 km</td>
<td>a/a</td>
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<tr>
<td>RAMS Simulation (LID)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/LID/model</code></td>
<td>BINARY</td>
<td>148 GB</td>
<td>reader_data_300/reader_model.dat</td>
<td>6hr 10/10/2002</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>a/a</td>
</tr>
<tr>
<td>RAMS Simulation (LID)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/LID/netcdf</code></td>
<td>NetCDF</td>
<td>41 GB</td>
<td>reader/reader</td>
<td>6hr 10/10/2002</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>10 IR</td>
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<tr>
<td>RAMS Simulation (LID)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/LID/model</code></td>
<td>BINARY</td>
<td>120 GB</td>
<td>reader_model.010400.dat</td>
<td>6hr 12/10/2008</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>a/a</td>
</tr>
<tr>
<td>RAMS Simulation (LID)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/LID/netcdf</code></td>
<td>NetCDF</td>
<td>25 GB</td>
<td>reader/reader</td>
<td>6hr 12/10/2008</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>10 IR</td>
</tr>
<tr>
<td>RAMS Simulation (SVWx2)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/SVWx2/model</code></td>
<td>BINARY</td>
<td>70 GB</td>
<td>reader_model.010400.dat</td>
<td>6hr 05/08/2003</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>a/a</td>
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<tr>
<td>RAMS Simulation (SVWx2)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/SVWx2/netcdf</code></td>
<td>NetCDF</td>
<td>15 GB</td>
<td>reader/reader</td>
<td>6hr 05/08/2003</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>10 IR</td>
</tr>
<tr>
<td>RAMS Simulation (SVWx2)</td>
<td><code>/set/orbit/1701/disk/ps/MESOCASCADE/RAMS/SVWx2/model</code></td>
<td>BINARY</td>
<td>398 GB</td>
<td>reader_model.010400.dat</td>
<td>12hr 10/15/2005</td>
<td>101x1025 km²</td>
<td>5 min</td>
<td>2 km</td>
<td>a/a</td>
</tr>
</tbody>
</table>
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