Operations Plan

for the

GOES-R Proving Ground
Demonstrating Air Quality Products

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1 Introduction

1.1 Plan Purpose and Scope

The purpose of this plan is to identify the goals of the Air Quality (AQ) Product Demonstration, provide an overview of the GOES-R products being demonstrated, describe the activities necessary to conduct the experiment, identify the participants and their responsibilities, establish a project timeline/schedule with milestones and deliverables, and identify related activities within the AQ community.

1.2 Overview

The AQ community, made up of National Weather Service (NWS), the Environmental Protection Agency (EPA), various state and local air quality agencies, and select universities, will receive early exposure to GOES-R Proving Ground (PG) products during the 2011 Air Quality Product Demonstration. Pre-operational demonstrations of these GOES-R PG data will provide Air Quality forecasters an opportunity to critique and improve the products relatively early in their development. The project will be co-led by Ray Hoff of UMBC and Sundar Christopher of the University of Alabama at Huntsville (UAH) and coordinated by Shobha Kondragunta of National Environmental Satellite, Data and Information Service/Center for Satellite Applications and Research (NESDIS/STAR).

2 Goals of Proving Ground Project

The overall goal of the GOES-R Proving Ground Program is to ensure that the user community is ready for GOES-R products immediately after launch. The goals of this demonstration are to demonstrate identified GOES-R surrogate air quality related products in near real-time so the air quality user community can use, get familiar with, test, and evaluate the products and provide constructive feedback to algorithm/product developers on the value and needed changes to products for increased utility.

3 GOES-R products to be demonstrated

The GOES-R products to be demonstrated include those that use proxy Advanced Baseline Imager (ABI) data from the Moderate Resolution Imaging Spectroradiometer (MODIS), CMAQ (Community Multiscale Air Quality) model, and WRF-Chem (Weather Research and Forecasting with Chemistry) model. These products include GOES-R Baseline products as well as GOES-R Decision Aids and Risk Reduction and are listed in Table 1 and described further in the following subsections.

Table 1. Products to be demonstrated during Experiment

Demonstrated Product	Category
Suspended Matter/Aerosol Optical Depth, Aerosol Type	Baseline
Aerosol Detection (smoke/dust)	Baseline
Fire Detection	Baseline
RGB Imagery	Decision Aid
Category Definitions: **Baseline** - GOES-R products that are funded for operational implementation as part of the ground segment base contract. **Decision Aid -** Products or tools that aid the forecaster's decision process and/or automatically analyze the data and determine when the forecaster needs to react. **GOES-R Risk Reduction -** The purpose of Risk Reduction research initiatives is to develop new or enhanced GOES-R applications and to explore possibilities for improving the AWG products. These products may use the individual GOES-R sensors alone, or combine data from other in-situ and satellite observing systems or models with GOES-R.	

3.1 GOES-R Baseline

3.1.1 Aerosol Optical Depth (AOD)

Aerosols are suspended particles in the atmosphere that scatter and absorb sunlight. When present in high concentrations, they are easily visible in satellite imagery. For routine detection and quantitative retrieval of aerosol amounts, the challenge is to separate the aerosols from clouds and bright surfaces. The ABI does this by using measurements at different channels from the visible to thermal infrared. The 2.1 μm channel is transparent to most aerosols and is used to obtain surface contribution to the satellite observed radiances over dark vegetated surfaces. A suite of infrared channels is used to detect clouds. Once a surface is characterized and cloudy pixels are identified, aerosols are retrieved through ABI measured radiances in the visible bands using pre-computed look-up tables.

PM2.5, particulate matter with particles smaller than 2.5 μm in median diameter, has harmful health and economic impact and is monitored by the Environmental Protection Agency (EPA) for federal air quality standard compliance. The National Weather Service (NWS) provides numerical model based forecast guidance that is distributed by the EPA to local and state governments for providing forecasting and warnings. Satellite-derived aerosol optical depth (AOD), a dimensionless quantity, has been shown to be a good proxy for surface PM2.5 (Engel-Cox et al., 2004; Christopher and Wang, 2003; Gupta et al., 2006; Hoff and Christopher, 2009; Liu et al., 2005; Green et al., 2008). Exceptions are when aerosols are aloft due to long-range transport of dust and smoke. The urban/industrial aerosol pollution, which is of utmost importance to the EPA from air quality standard compliance, tends to be well mixed in the planetary boundary layer and is well correlated to the satellite-derived AOD. The currently operational GOES and MODIS AOD products are widely used by the EPA and other agencies in monitoring PM2.5.

The GOES-R ABI Suspended Matter/Aerosol Optical Depth and Aerosol Detection products are in the GOES-R baseline. These products have applicability within the NWS for visibility assessment and direct comparison to the NWS prototype aerosol forecast product. NWS modelers are a client of these products. In addition to other Federal users, the GOES-R ABI AOD product will not only assure the continued use of the geostationary satellite derived AOD product but also enhance the applications. First, GOES-R ABI AOD product will be at a very high spatial (2 km nadir) and temporal (5 minute) resolution. The 5-minute temporal frequency can be used to create a tailored 30-minute product or a 1-hr product with fewer gaps due to cloud cover. The GOES-R ABI AOD product is based on a multi-channel retrieval and will be more accurate than the current GOES product. Current GOES AOD product has limited use for low aerosol conditions as well as at certain viewing conditions due to the absence of 2.1 um channel; 2.1 um ABI channel is used to obtain surface reflectance. Additionally, the AOD product comes with information on "most likely" aerosol type and particle size (coarse mode or fine mode).

The ABI aerosol algorithm is currently at the 100% level – meaning the accuracy of the products meets specifications. This is based on the comparisons of the ABI AOD product, derived from 10 years of MODIS radiances to AERONET (AERosol Robotic NETwork) over the same period. The accuracy for the ABI AOD product specified is ±0.06 over land and ±0.02 over water for AODs ranging between 0.04 and 0.8. For AODs greater than 0.8, the accuracy specifications are ±0.12 and ±0.1 over land and water respectively.

One of the sources of errors in satellite-derived aerosol products is the cloud interference, especially for the Aerosol Detection product because some of the spectral tests are similar for both clouds and aerosols. In the current operational AOD product from the GOES Imager, there are several data screening procedures in place to flag the cloud-contaminated pixels (e.g., spatial variability tests). While similar tests have been adapted for the GOES-R ABI product, the ABI product is at a finer resolution temporally and spatially and will need additional understanding of product issues.

3.1.2 Aerosol Detection (smoke/dust)

Aerosol Detection (including smoke and dust) is a qualitative imagery product that provides presence/absence information of smoke or dust in a GOES-R ABI pixel. This information, combined with location of fires detected by the GOES-R ABI, is useful for the forecasters. The product helps the forecasters with the identification of the non-anthropogenic pollution sources and the spatial distribution patterns of the smoke and dust. For example, using this data, the forecasters can develop a database of regions in the United States that are prone to frequent fires or localized dust outbreaks. The ABI aerosol detection product has been extensively tested through comparisons with Cloud Aerosol Lidar with Orthogonal Polarization (CALIOP) and Interagency Monitoring of Protected Visual Environments (IMPROVE) datasets and is able to detect dust and smoke at the 80% accuracy level. The product has room for improvement, especially identifying thin smoke and dust over bright surfaces. The AQ Demonstration team will collaborate with the user group and obtain information on specific case studies that can be studied to further evaluate the product.

The NWS/NCEP is currently testing the MODIS dust mask product to use in verifying the operational Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) forecast. We have been working closely with the NWS Office of Science and Technology and its partners in testing the MODIS dust mask product and based on the NWS feedback, modified the algorithm to avoid classifying thin dust as cloud. This product will soon be used by the NWS in an operational mode to evaluate the forecasts. Based on the feedback from the NWS, we also include the IMPROVE- based validation of the satellite-derived dust mask product. Through the AQ Demonstration, this partnership with NWS will continue and evolve further to improve other GOES-R ABI products such as smoke detection and suspended matter/optical depth.

3.1.3 Fire Detection

The GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA) has been running in real-time since 2000 and operationally in NESDIS since 2002 (McNamara et al., 2004; Schmidt and Prins, 2003), and the GOES-R ABI fire algorithm builds on the WF_ABBA processing system developed at the University of Wisconsin (UW) Cooperative Institute for Meteorological Satellite Studies (CIMSS) as a collaborative effort between NOAA/NESDIS/STAR and UW-CIMSS personnel. The ABI fire algorithm is a dynamic multispectral contextual algorithm that is based on the sensitivity of the 3.9 µm band (Channel 7) to high temperature sub-pixel anomalies relative to the less sensitive 11.2 µm window band (Channel 14) and is derived from a technique originally developed by Matson and Dozier (1981) for NOAA Advanced Very High Resolution Radiometer (AVHRR) data. The GOES-R ABI fire product will be produced for each ABI image and provides diurnal fire detection and sub-pixel fire characterization (fire radiative power and fire size) for data within a satellite view angle of ±80°.

3.2 GOES-R Decision Aids

3.2.1 RGB Imagery

The development and distribution of GOES-R ABI RGB Imagery is part of "GOES-R ABI RGB Imagery Proving Ground" activity. However, air quality forecasters are very familiar with this product and currently use MODIS RGB imagery to monitor significant events. Similar imagery from ABI will be generated for the users to employ along with other quantitative products in understanding a particular weather/air quality event. Don Hillger of STAR at Colorado State University Co-operative Institute for Research in Atmosphere (CIRA) will be generating an RGB imagery product and Gary Jedlovec's group at SPORT is involved in placing this product on AWIPS-II. The AQ Demonstration Co-PI Christopher will monitor the developments at SPORT on the RGB imagery product and Dr. Huff will visit CIRA to discuss Air Quality applications of the RGB imagery so that these products can be demonstrated at future workshops.

4 Proving Ground Participants

The Proving Ground participants are broken into two categories, Providers and Consumers. Providers are those organizations that develop and deliver the demonstration product(s) and training materials to the consuming organization. The Consumers are those who work with the providers to integrate the product(s) for demonstration into an operational setting for forecaster interaction. For the Air Quality product demonstration there are several providers and consumers.

4.1 Providers

4.1.1 NOAA/NESDIS/STAR

NESDIS/STAR will provide GOES-R ABI aerosol products derived from proxy data (MODIS radiances and simulated radiances from WRF-Chem or CMAQ models) to the end users. For the summer experiment, ABI products will be generated in near real time using radiances from CMAQ developmental model forecast fields.

4.1.2 UMBC/Battelle Memorial Institute

UMBC will receive GOES-R AWG products from STAR via ftp push and will distribute the data products to the state and local forecasters participating in the summer experiment. UMBC/Battelle will monitor and collect forecaster feedback on the utility and value of the products. UMBC will also procure an AWIPS-II compatible HP Server/Workstation and install the AWIPS-II software to begin to evaluate the Air Quality related products on AWIPS-II and to begin to write scripts within the AWIPS-II platform for flat imagery production for web delivery to external users. UMBC will monitor NEXTGEN progressand aid in identifying requirements for external (non-NWS) users to access ABI products through NEXTGEN delivery services.

4.1.3 UAH

UAH will deliver three case studies in the US Southeast from WRF/CMAQ at 4km resolution which can be used as examples for the Fall 2011 AQPG Workshop. UAH will monitor RGB developments at SPORT.

4.1.4 CCNY

City College of New York (CCNY) will develop validated simulated ABI proxy data for proving ground applications.

4.2 Consumers

4.2.1 NWS

The NWS/NCEP through coordination with Ivanka Stajner will participate in the air quality experiment of the proving ground by evaluating the GOES-R aerosol products for forecast verification application.

4.2.2 EPA

The EPA will participate in the air quality experiment of the proving ground by evaluating the GOES-R aerosol products for exceptional event monitoring. EPA Region III will participate in the summer experiment.

4.2.3 UMBC

The UMBC will participate in the air quality experiment of the proving ground by developing a GOES-R AWG aerosol products distribution mechanism and also using the products in discussing the air quality in the U.S. on the Smog Blog. UMBC will coordinate inputs from the NASA DISCOVER-AQ mission running simultaneously with the AQPG Summer Demonstration to obtain ground and airborne truth data of the aerosol state in the US mid-Atlantic.

5 Responsibilities and Coordination

5.1 Project Authorization

- Shobha Kondragunta, NESDIS/STAR
- Steve Goodman; GOES-R Chief Scientist and PG Program Manager

5.2 Project Management

- Ray Hoff of UMBC
- Sundar Christopher of UAH

5.3 Product Evaluation

- James J. Szykman, EPA
- Ivanka Stajner, NWS
- Raymond Hoff, UMBC
- Amy Huff, Battelle Memorial Institute
- William Ryan, Pennsylvania State University
- Howard Schmidt, EPA Region 3
- Laura Landry, Maryland Department of Environment

5.4 Product Training

Dr. Huff conducted a training session at the National Air Quality Conference in March 2011. The training covered a brief description of satellite terminology and technology and an overview of the GOES-R satellite and Advanced Baseline Imager (ABI) instrument. Relevant satellite products for air quality analysis were presented, including AOD, aerosol detection, fires, and RGB imagery. Correct interpretation and application of the air quality satellite products was demonstrated, and the strengths and limitations of satellite products were reviewed. The training course included lectures and interactive activities designed to give participants "hands-on" experience with the various air quality satellite products. By the end of the course, participants had a basic understanding of the pertinent features of the ABI and are able to anticipate how ABI air quality products will fit into their routine duties. Similar training material will be presented to the users at the AMS and other EPA related meetings and workshops.

5.4.1 Suspended Matter/Aerosol Optical Depth

Several different AOD GOES-R ABI images generated from proxy data will be used in the training. The different features in the images such as clouds, clear areas (no clouds and no aerosols), surface, and water will be highlighted to train the user to look for these features. Then visual diagnostic analysis will be presented to show the user how to look for potential cloud interference/contamination, noisy retrievals, high solar zenith angles, extreme viewing geometry issues by providing information on the position of the Sun and the satellite based on the time for which the image is processed. Additionally, we will provide GOES-R ABI AOD validation results to demonstrate the accuracy of the product and various sources of errors that lead to bias in the retrievals.

5.4.2 Aerosol Detection (Smoke/Dust)

Aerosol detection product is not a heritage product from the current GOES and users will be told that this is a qualitative product that does not have any quantitative information similar to the RGB imagery. However, identification of smoke and dust is critical for both monitoring and forecasting applications. Users will be shown different examples of dust and smoke over different geographic surfaces and will be shown how to use the information in conjunction with fire products. Additionally, we will provide validation results comparing the GOES-R ABI aerosol detection with CALIPSO to demonstrate the accuracy of the product and reasons for errors in classifying the aerosols as smoke or dust.

5.4.3 Fire Detection

Fire products from GOES-R ABI proxy data will not be available for the field experiment. We will provide currently operational fire detections along with smoke analysis derived from MODIS and GOES to the users. The location of fires, fire size/burned area, and the smoke associated with these fires along with 15-minute loops of GOES visible imagery will be provided and information provided on how to interpret the imagery. Also, details of how the product relates to the GOES-R product will be provided.

5.4.4 False Color Imagery

Because of the absence of the green channel on GOES-R ABI, we will not be able to generate true RGB color imagery. CIRA is developing a method to generate true color imagery by interpolating the red and blue bands. However, this method is complicated due to competing and compensating effects of surface, aerosols, and clouds on top of the atmosphere radiances. While CIRA is developing an algorithm to generate RGB images, we will test false color images (use red, green, and blue bands to represent combination of different spectral channels) to highlight smoke, dust, and urban/industrial haze. The methodology used to generate the false color imagery and several different examples will be provided to the users in the training material.

5.4.5 General Sources

- Training on individual products will be posted on the GOES-R Proving Ground web page using the template for the other PG products (alg.umbc.edu/aqpg/).
- Links will be provided in the PG training pages to more in-depth material.

- Links will be provided to COMET training on false color imagery products.

6 Project Schedule

There are many activities that lead up to the successful execution of the AQ Product Demonstration such as identifying participants, coordinating schedules, delivering and integrating algorithms and products, and developing and delivering training materials. These specific activities are identified in the table below.

Air Quality Demonstration Event	**Date**
Identify Products for Air Quality Demonstration	04/30/11
Identify AWG Leads	04/30/11
Establish Operations Plan – Roles/Responsibilities	04/30/11
Training Material delivered to alg.umbc.edu/aqpg/	05/31/11
Demonstration Period Begins	07/11/11
Mid-term Report Due – to Principals	06/1/11
Demonstration Period Ends	07/24/11
Final Report Due	09/30/11

7 Milestones and Deliverables

7.1 Products from Providers

Products to be demonstrated within this year's demonstration will be beta tested in May-June 2011 time period. Products will be generated at NESDIS and provided to UMBC via FTP. The Demonstration period is 7/11-7/24/2011 to coincide with the DISCOVER-AQ experiment.

7.2 Training materials from Providers

Each product delivered to the AQ Demonstration user/focus group will be accompanied by related training material. Forecasters and scientists will receive training material at the first user workshop but tutorials will also be conducted at scientific meetings and air quality specific conferences such as the National Air Quality conference. Training materials will be provided to the attendees at the sessions and the syllabus and training package refined as the AQ Experiment matures. We will work towards providing these materials through the web and video training features of COMET. As Battelle Memorial Institute has extensive experience working with training of this air quality community, we will employ their services in providing the training workshops, assessing the value to the specific communities, and advising the AQ Experiment on clarifications and strategies which may build a stronger user advocacy base amongst this user community.

7.3 Mid-term evaluation report

A mid-term evaluation report shall be provided to the project authorization team at the date specified within the operations plan timeline. This report, which may be delivered in oral or powerpoint format, shall detail the current status and progress of the AQ Demonstration activities and suggest changes if needed.

7.4 Final report

A final report detailing the GOES-R PG demonstration of AQ products during the entirety of the experiment shall be provided to the GOES-R Program Office at the date specified within the operations plan timeline. This report will discuss how each product was demonstrated within the various experiments. The report will also present feedback provided by participants of the Experiment as well as suggestions for improvements upon the GOES-R PG demonstration activities for years to come.

8 Related activities and methods for collaboration

The high temporal resolution GOES fire location and emissions products can be used in regional models such as CMAQ to forecast particulate matter air quality. UAH a comprehensive strategy is being developed for studying the role of smoke aerosols on PM2.5 using a combination of various satellite data sets including GOES, MODIS, CALIPSO, AIRS, and other satellite sensors. Ground-based assets AERONET, TEOM) are being used to test and validate the models.

Efforts are also underway at the CCNY on two themes: 1) Development and Deployment of Surface Instruments which can be used for distributed validation of GOES-R ABI aerosol products. In particular, (1) the development of a distributed MFSRR network and using algorithms which take into account both diffuse and direct radiances to separate fine and coarse mode AOD as well as graphical tools to visualize performance, and (2) the development of GOES-R ABI radiances which take into account the regional urban surface reflection and aerosol structure in order to assess the errors and refinements that may need to be implemented.

9 Summary

This year's GOES-R PG demonstration of Air Quality products supports the PG effort to demonstrate the defined GOES-R products within an operational framework through various experimental programs. Feedback gathered from these activities will aid in successful product training for forecasters as well as improvements in product performance by product developers.

10 References

Engel-Cox, J., C. H. Holloman, B. W. Coutant, and R. M. Hoff, Qualitative and quantitative evaluation of MODIS satellite sensor data for regional and urban scale air quality, Atmos. Environ. 38, 16, 2495-2509 doi:10.1016/j.atmosenv.2004.01.039, 2004.

Gupta, P., S.A. Christopher, J. Wang, R. Gehrig, Y.C. Lee, N. Kumar, Satellite Remote Sensing of Particulate Matter and Air Quality over Global Cities, Atmos. Environ., 40, 5880-5892, 2006.

Hoff and Christopher, J. Air & Waste Manage. Assoc. 59:645–675 DOI:10.3155/1047-289.59.6.645

Liu, Y.; Sarnat, J.A.; Kilaru, A.; Jacob, D.J.; Koutrakis, P. Estimating Ground-Level PM2.5 in the Eastern United States Using Satellite Remote Sensing; Environ. Sci. Technol. 2005, 39, 3269-3278.

Wang, J. and Christopher, S.A. Intercomparison between Satellite-Derived Aerosol Optical Thickness and PM2.5 Mass: Implications for Air Quality Studies, Geophys. Res. Lett. 2003, 30, 2095; doi: 10.1029/2003gl018174.

Schmidt, C. S. and E. Prins, 2003: GOES wildfire applications in the Western Hemisphere. *Proceedings of the 2nd International Wildland Fire Ecology and Fire Management Congress and AMS 5th Symposium on Fire and Forest Meteorology,* Orlando, Florida, November 16-20, 2003, 4 pp.

McNamara, D., G. Stephens, and M. Ruminski, 2004: The Hazard Mapping System (HMS) - NOAA multi-sensor fire and smoke detection program using environmental satellites. *Preprints, 13th Conf. on Satellite Meteorology and Oceanography,* Norfolk, VA, Amer. Meteor. Soc., CD-ROM, 4.3.

Green, M., S. Kondragunta, P. Ciren, and C. Xu, Comparison of GOES and MODIS Aerosol Optical Depth (AOD) to AERONET AOD and IMPROVE PM2.5 Mass at Bondville, J. of Air and Waste Management, 2008.

Matson M. and J. Dozier, 1981: Identification of subresolution high temperature sources using the thermal IR, *Photogrammetric Engineer. and Remote Sens*., 47, 1311-1318.