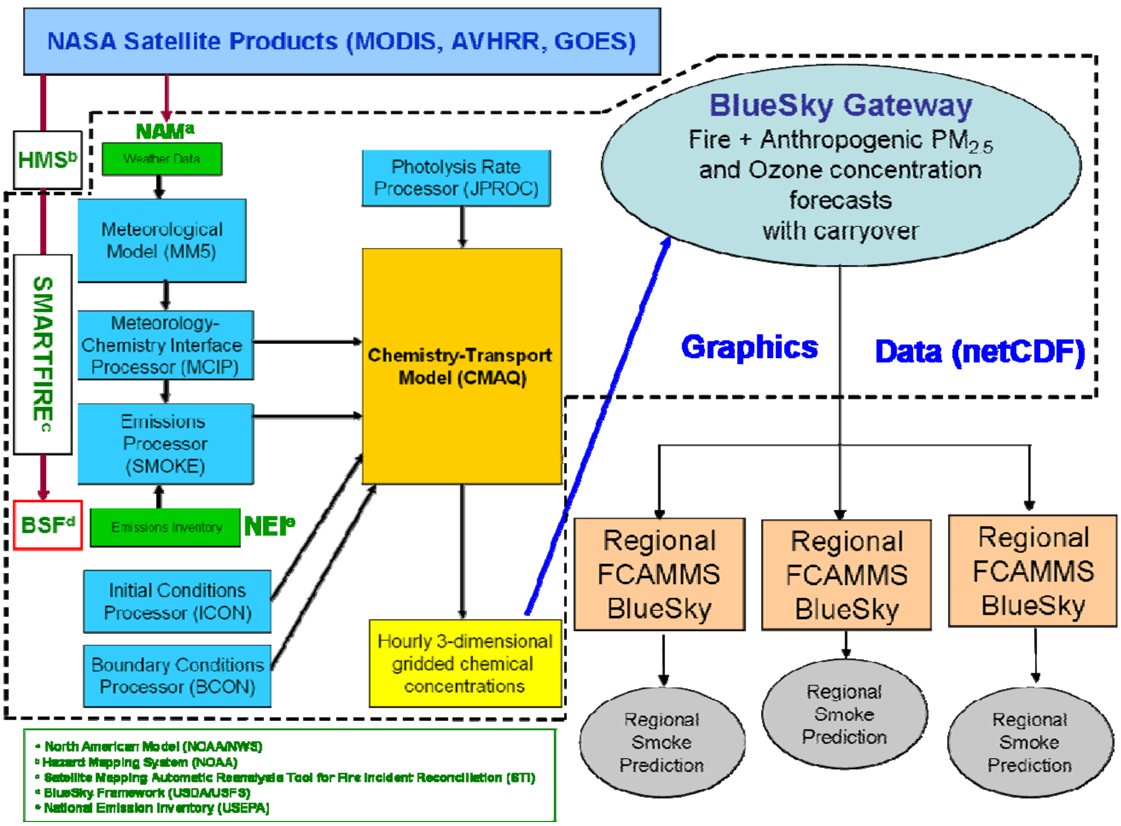
Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

Enhancements to the BlueSky Emissions Assessment and Air Quality Prediction System



Benchmark Report Prepared for the

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Enhancements to the BlueSky Emissions Assessment and Air Quality Prediction System

Benchmark Report for
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Cover graphic illustrates workflow of BlueSky-enabled systems configured to produce twice-daily predictions of air quality for the BlueSky Gateway; see Section 2.

Acknowledgments

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1. Introduction

This Benchmark Report concludes the National Aeronautics and Space Administration (NASA)-funded project, "Enhancements to BlueSky Emissions Assessment and Air Quality Prediction Systems."[1] The project purpose was to improve decision-support information about fires and their associated air quality impacts as routinely accessed by smoke and fire managers and air quality agencies across the United States. To meet this purpose, the project team enhanced and expanded on pre-existing decision support tools—i.e., BlueSky systems—which (prior to the inception of this project) were referenced routinely by a limited constituency of smoke and fire managers operating primarily in the Pacific Northwest.[2] The project team demonstrated applications of the improved BlueSky systems, reached out to new user constituencies across the United States, facilitated novel applications and adoption of improved BlueSky systems by these targeted constituencies, and prepared the pathways for ongoing and future use of BlueSky systems. The project's accomplishments, measures of progress (benchmarks), and expectations and plans for continuing and future use of BlueSky systems are described in this Benchmark Report.

1.1 What Are the BlueSky and Associated Systems?

BlueSky systems facilitate evaluations of the air quality impacts of fires in the context of public policy decision-making and scientific research. Smoke and fire managers use BlueSky systems to make operational decisions about prescribed burns and wildland fire-fighting programs. Air quality agencies, regional planning organizations (RPOs), and the U.S. Environmental Protection Agency (EPA) use BlueSky systems to support analyses and policy decisions related to the Regional Haze Rule, National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIP), and the National Emission Inventory (NEI). Researchers in the fields of fire sciences and atmospheric sciences apply BlueSky systems to study and improve the underlying science and behavior of fire science models (i.e., models representing fuels, fuel consumption, emissions rate, and pollutant dispersion).

The BlueSky Framework is the heart of the BlueSky systems. The BlueSky Framework is a model-management system that facilitates ease and flexibility in running independently developed models to simulate the cumulative impacts of multiple fires (Larkin et al., 2009). Originally developed by the U.S. Department of Agriculture Forest Service (USFS) and re-engineered through this NASA-funded project, the BlueSky Framework facilitates coordinated operation of models to predict emissions from fires and resultant ground-level concentrations of fine particulate matter ($PM_{2.5}$) and other pollutants.

The Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation (**SMARTFIRE**) originated during this NASA-funded project. SMARTFIRE is an algorithm and

[1] The project was conducted February 2006 through June 2009 by Sonoma Technology, Inc. (STI) and the AirFire Team of the USFS. The project was made possible by funding from the NASA Cooperative Agreement program, *Decision Support through Earth Science Results* (cooperative agreement number NN506AB52A), with significant in-kind contributions by the USFS.

[2] Although BlueSky smoke output data were available and used throughout the country, they were not relied on as they were in the Pacific Northwest.

database system developed and built within a geographic information system (GIS) framework. SMARTFIRE prepares fire activity data for input to the BlueSky Framework. It integrates and reconciles fire activity data from multiple information sources—databases of satellite-detected fires, records of human-reported fires, or other sources. Hence, SMARTFIRE harnesses the advantages of multiple information sources by retaining the value added by each data set while minimizing double-counting. Through this NASA-funded project, SMARTFIRE was developed and configured to acquire and reconcile the National Oceanic and Atmospheric Administration's (NOAA) Hazard Mapping System[3] (HMS) data and ICS-209 reports.[4]

The BlueSky Framework and SMARTFIRE were configured and deployed for several decision-support applications and operational demonstrations during the period of this NASA-funded project. These applications and the most current form of BlueSky systems were made possible by the re-engineering activities, systems developments, and associated project activities of this NASA-funded project.

1.2 BlueSky Systems—Past, Present, and Future

The BlueSky Framework was originally developed in 2001-2002 as a tool for prescribed burners to assess the smoke impacts from their proposed fires. The success of BlueSky contributed in part to the USFS' decision to invest in five regional modeling centers (Fire Consortia for the Advanced Modeling of Meteorology and Smoke, FCAMMS). In 2005, in response to a request from the EPA, BlueSky was evaluated for use in predicting wildfire smoke impacts—an effort that culminated in the 2005 BlueSkyRAINS West demonstration project. The findings of this interagency project of the Department of the Interior, USFS, and the EPA noted the significant potential of BlueSky, but also several issues impeding operational adoption. In particular, several needs were highlighted, including the need for (1) improved reliability of the software producing increased operational "uptime"; (2) scientific refinements to component models and settings (e.g., technical issues with models of plume rise, boundary layer structure, smoldering emissions, weather, carryover smoke, and fire growth); (3) better fire information—including satellite-based observations, higher quality and more timely Incident Command Summary (ICS)-209 reports—that should be widely available via electronic data transmittal; (4) sound management, policy, and funding decisions concerning BlueSky (e.g., multi-year funding, coordinated participation of stakeholder agencies, and structured plans for moving from experimental to fully operational status); (5) rigorous testing, evaluation, and validation programs; and (6) greater movement toward meeting user needs, expanding the scope of the user community, and promoting national acceptance of the system by key stakeholder agencies. With this recognition of BlueSky's potential (as well as the acknowledgment of needed

[3] The HMS is a quality-controlled fire and smoke analysis for the United States produced by the Satellite Services Division (SSD) of NOAA's National Satellite and Data Information Service (NESDIS) and updated several times per day (Ruminski et al., 2006). The HMS integrates satellite data from three instrument types (Geostationary Operation Environmental Satellite (GOES), Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced High Resolution Radiometer (AVHRR)) onboard seven different satellite platforms.

[4] For large wildfires and wildland fire use (WFU) fires for which there is a federal response, ICS-209 reports are created on a near-daily basis. ICS-209 reports are generated by incident command teams on the ground and contain useful information about particular fires or fire complexes, such as descriptions of the fuel loading, growth potential, and type of fire.

improvements), development of BlueSky and collaboration with the National Weather Service (NWS) continued. These efforts resulted in adoption of BlueSky emissions calculations into the NWS smoke forecast products (deemed experimental in 2006 and operational in 2007).

The NASA-funded project discussed in this Benchmark Report has addressed many of the issues identified by the 2005 BlueSkyRAINS West project and has advanced the state of the science and modeling for smoke impacts evaluations. First, the BlueSky Framework was completely rewritten using modern programming standards, updating the code to use Python. Significant work was done to update the functioning of the Framework, making it more reliable by standardizing input and output file structures and making it modularly upgradeable and expandable. The outcome is a system that now functions more rapidly and reliably and in a more maintainable manner. In addition, significantly more models were added (including fire emissions models that calculate smoke from smoldering) and/or parsed within the Framework in ways that would facilitate scientific investigations and refinements. (For example, plume-rise calculations were removed to a separate modeling step so that alternative calculations and related scientific advances could be more easily implemented and tested.) As a result of these improvements, BlueSky is rapidly, and more widely, being adopted for use.

Additionally, the need for reliable and complete fire information for input to BlueSky was addressed through the creation of SMARTFIRE. As mentioned in Section 1.1, SMARTFIRE was developed and configured to process two input data sources: (1) ICS-209 reports and (2) NOAA's HMS data. This represents the first time that both ground-based and satellite-based fire data have been routinely reconciled. The addition of the HMS data as a routine input to BlueSky systems produced enormous improvements in the consistency, completeness, and reliability of BlueSky outputs. Observations of relatively small fires, fires in remote areas or outside U.S. borders, and even fires in agricultural or urban areas are now routinely used in a manner that is relatively consistent across jurisdictions and at a national or continental scale.

The re-engineering of the BlueSky Framework and the development of SMARTFIRE have enhanced the ability of BlueSky systems to function as a smoke forecasting system, but also have enabled new projects and new possibilities. The BlueSky Framework's enhanced modularity is allowing the fire research community to directly compare models of similar function (e.g. consumption models or plume rise models) through the newly funded JFSP Smoke and Emission Model Intercomparison Project. The BlueSky systems' expandability has resulted in the ability to connect BlueSky to regional information systems such as the Canadian Fire Service's fire information system, enabling the use of BlueSky systems in regions such as Alberta and British Columbia, where they could not previously be applied. SMARTFIRE's collected fire information is allowing easier compilation of fire information for other uses such as the EPA's NEI.

New tools have also been made possible by the advances produced by this NASA-funded project. Because of the rationalized output formats, alternative user and system interfaces are now available to those desiring smoke forecasts, including visualization in Google Earth. BlueSky's standard input/output structure has also led to the ability to access BlueSky calculations through standard web-service calls—a functionality that is being examined by the Joint Fire Science Program (JFSP) as a potential standard for all new model development in this area. The BlueSky Playground web application uses this functionality to allow students and managers to directly interact with all of the models contained in BlueSky through a common interface. Through all these new tools and advances, the BlueSky Framework is being used as a standard for integrative modeling, and also as a paradigm for modeling in other areas, such as the new JFSP Interactive Fire Treatment Decision Support System (IFT-DSS). **Table 1-1** provides a snapshot of some of the main benefits to BlueSky systems produced through the NASA-funded project as described in more detail in the remainder of this report).

BlueSky's future is envisioned as a modular modeling system that serves as an organizing standard for fire information, fuel loading, fire consumption, rate of consumption, fire emissions, plume rise, and smoke dispersion models. In this mode, BlueSky systems will not only serve as the basis for smoke forecasting systems, but will also help advance the science (e.g., through comparisons of different models); provide a foundation for development of new models (e.g., by enabling cross-communication of models); serve as the basis for fire information reporting systems (e.g., by enabling fire consumption and greenhouse gas [GHG] emission calculations); and provide support for the development of in-progress and future decision support applications by allowing application developers simple access to BlueSky calculations through web-service calls. Specific applications in progress include ensemble modeling and the explicit evaluation of multiple sources of uncertainties in the modeling chain.

Table 1-1. Summary of benefits produced by the NASA-funded project.

Performance Area	Status Prior to NASA Project	Current Status
System reliability	Achievable up-time 95% (with approximately 2-3 hours of labor per day required [Riebau et al., 2006])	Achievable up-time about 99% (with approximately 1 hour per day of labor required on average for minimal maintenance)
Scientific improvements to modeling	Six available models; only two possible modeling pathways	20 available models, more than 1,000 possible modeling pathways
	Plume rise algorithm not a separate step	Plume rise algorithm a separate modeling step available for evaluation
General system improvements		Standardization of inputs and outputs; modular; expandable
Fire activity data	Ground-based reporting systems (the only system applicable to national-scale coverage was ICS-209 reporting)	Use of HMS represents a two-fold increase in estimated area burned; five-fold increase in number of fires detected above ICS-209 reporting, 2003-2006
Predictive accuracy	Under-prediction of $PM_{2.5}$ concentrations by available modeling scheme (generally factor of 5–10)	Predictions by current Gateway modeling scheme generally within a factor of 2 during recent major California fire events
Routine users	Users in the Pacific Northwest (Washington, Oregon, Idaho, Montana), stable for three years	Users in 45 U.S. states, Alberta, and British Columbia; Internet site traffic doubling every six months
Supported activities	Smoke impacts forecasting, dispersion-based; ArcIMS-based visualization	Smoke impacts forecasting—dispersion-based; smoke impacts forecasting—photochemistry-based; model intercomparison studies and uncertainty analyses; customizable visualization; emission inventory development; support for long-range (climate-based) smoke impacts planning for forest management; “what-if” scenarios
Cost to prepare comparable NEI for EPA	Approximately $1,000,000	$50,000
Far-reaching implications for the future: facilitation of rapid evolution and technical improvement of fire science models—BlueSky serves as a paradigm		

2. Summary of Systems Engineering Activities

2.1 Past Evaluations of BlueSky Systems

2.1.1 Technical Status of BlueSky Systems as of 2005

Prior to 2006 (when the NASA-funded project began), BlueSky had undergone several major development cycles funded through a large number of generally small grants and appropriated funds from the USFS, EPA, JFSP, and Department of the Interior (DOI). Because of the nature of these grants, development activities were highly focused. While adding functionality and utility to BlueSky, these efforts also introduced various implementation idiosyncrasies and quirks. The resulting code generally functioned but required significant man-hours to both maintain and monitor. Any given run could fail in a number of different ways.

In general, these failures could be categorized in three modes: (1) a lack of resiliency in response to formatting, timing, and other variances on the input data; (2) an inability to account for underlying model problems; and (3) a highly implementation-specific and arcane set of configurations (system, models, and desired pathway) causing a delicate modeling setup. Hence, although the USFS AirFire Team could maintain a quasi-operational server, groups outside AirFire could only maintain similar servers with continued ongoing help from AirFire. (This situation existed with the four other FCAMMS; the NWS was able to maintain its own BlueSky system only after significant implementation-specific rewriting.) The fragility of the system generally limited its utility and distribution. Additionally, only AirFire had the specific experience required to upgrade BlueSky installations. Often, outdated or outmoded installations were continued because nobody had the time or knowledge to bring them up to date.

As of 2005, BlueSky ingested wildfire incident data only from ground-based reporting systems. Of these systems, the ICS-209 system was the most comprehensive, offering national-scale coverage and daily updates.[5] The ICS-209 report is a two-page form, the main purpose of which is to provide incident information for operational decision support and firefighting resource allocation at a regional level. ICS-209 reports are required reports typically created daily for large wildfires (>100 acres) and WFU[6] fires—i.e., those fires receiving a response from a federal agency. Because ICS-209 reports were not created to provide information for smoke modeling, their use is limited in this context. Each ICS-209 report contains a latitude and longitude pair that represents the point of origin of the incident and/or point of first detection. This location does not change, even as a fire propagates several kilometers away from the point of origin after weeks of burning. Daily ICS-209 reports contain a fire size value expressed as acreage. This value is cumulative and represents an estimate of the total acreage burned by the fire since the beginning of the incident. Significant added value that could be offered by satellite-borne fire-detection instruments was readily recognized in 2005. The spatial and

[5] Some states administer fire-reporting systems (most do not) but with inconsistent quality across jurisdictional boundaries and lack of timely information (availability after periods of days, weeks, or months).

[6] WFU fires are wildland fires that originate from natural causes and are allowed to burn (monitored by fire managers, but not actively suppressed) as long as risks to valued resources remain low or until they are extinguished naturally.

temporal resolutions of these data are significantly better than ICS-209 reports (see **Figure 2-1**). In addition, many fires detected by satellite do not have associated ICS-209 reports (see **Figure 2-2**).

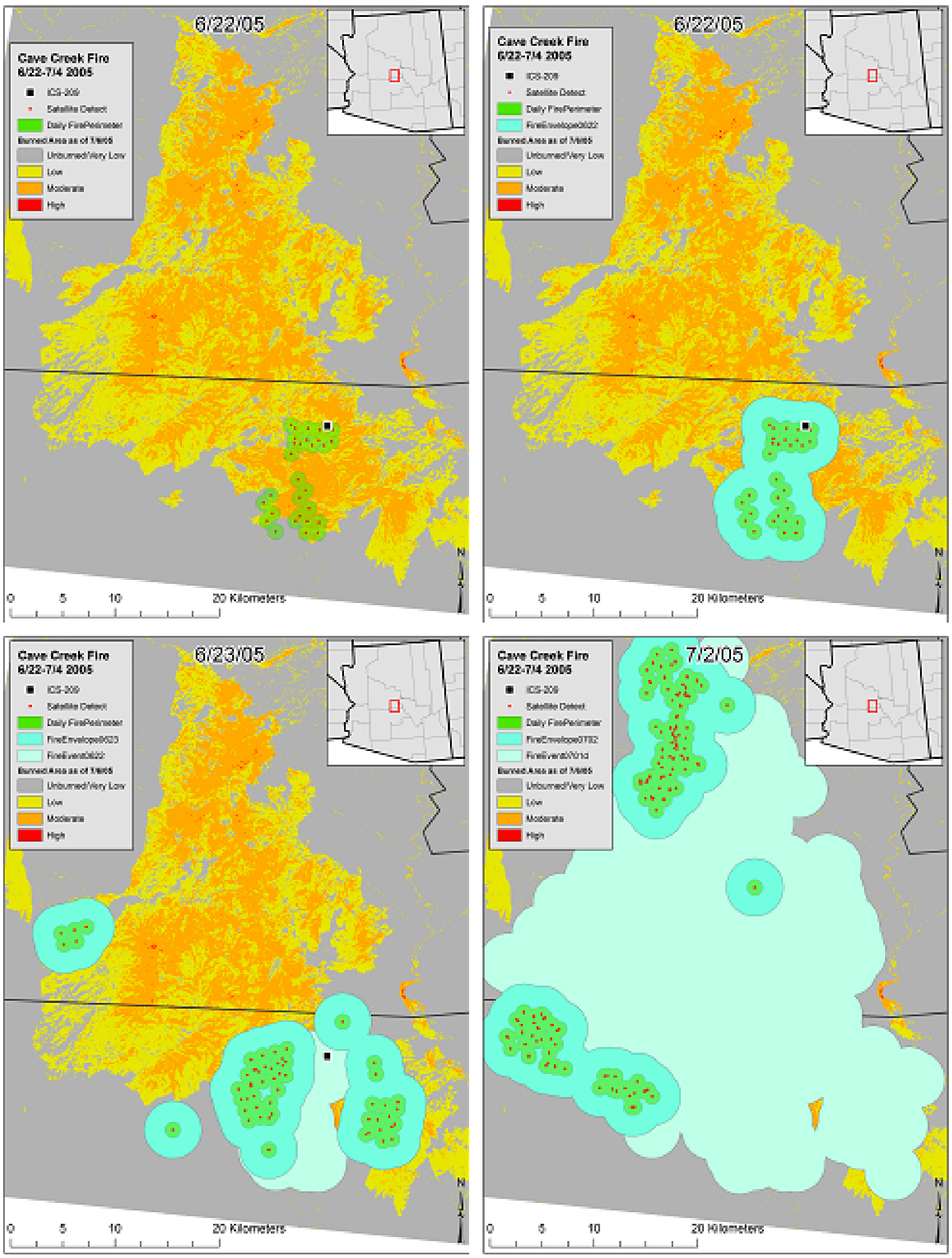


Figure 2-1. SMARTFIRE fire event development over time (compared to fixed-location ICS-209 reports, which are shown as black boxes).

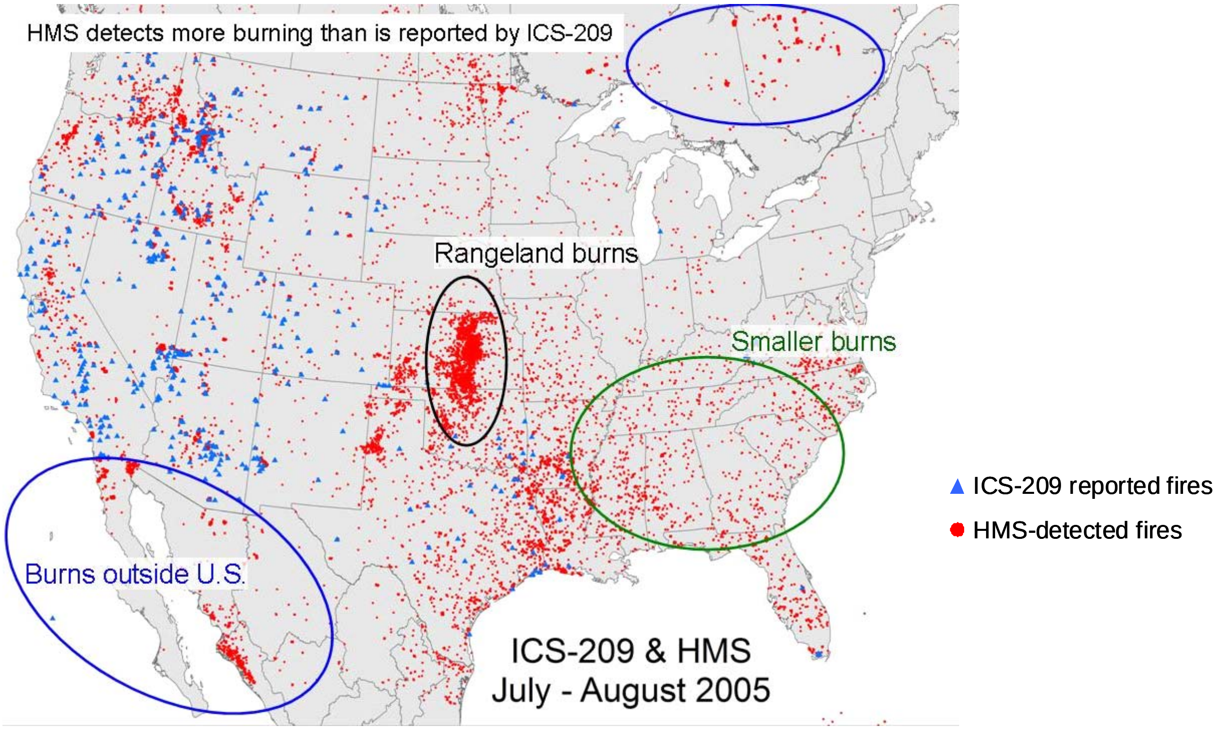


Figure 2-2. Spatial distributions of ICS-209 fire report locations and HMS fire locations.

2.1.2 BlueSkyRAINS-West 2005 Demonstration Project

Despite the systems' shortcomings in 2005, BlueSky still provided an adaptable smoke modeling setup for real-time smoke prediction. It was chosen by the EPA, USFS, and DOI for a western U.S.-wide demonstration project to show how smoke impacts from wildfires could be predicted by the modeling framework. During summer 2005, BlueSky was used to model wildfire smoke on both a 12-km resolution western U.S.-wide (western CONUS) and 4-km Pacific Northwest modeling grid. Maintenance of the western U.S.-wide modeling setup was led by the USFS Rocky Mountain Station with help from the USFS AirFire Team, and the 4-km grid was maintained directly by AirFire. Additionally, during the most intense wildland fire episode—the Frank Church WFU fire in Idaho—mobile monitors were set up to supplement existing in-situ $PM_{2.5}$ monitoring grids in order to collect ground-truth data to validate the model.

Model operations and accuracy were measured and documented in the internal BlueSkyRAINS-West 2005 Demonstration Project Final Report (Riebau et al., 2006). A detailed user survey was conducted both before and after the study period. With respect to operations, findings frmo the demonstration project included the following.

1. Significantly greater installation and modification time than expected was required to get the system running.
2. Significant ongoing man-hours were required to ensure model output availability.
3. Improvements were needed in the structure of the program in order to improve adaptability and reliability

With respect to accuracy, findings were as follows.

1. BlueSky systems represented large-scale transport well when compared with satellite observations of aerosol optical depth and visible smoke.
2. Ground-level concentrations of smoke were often under-predicted. Improved fire information and a better scientific understanding of the individual models and settings were needed.
3. The general lack of available information on the uncertainty of the model results, including choice of model pathway, was a problem.

Subsequent analyses indicated that the choice of model pathway was indeed important, but that some embedded models—models that were only component parts of other models and, in particular, the plume rise models—were likely highly inaccurate. These findings led directly to an emphasis during this NASA-funded project on making BlueSky systems (1) more resilient, (2) easier to install, and (3) easier to configure, particularly with respect to model pathway choice. Additionally, the problems identified with plume rise modeling resulted in splitting apart the dispersion models that usually handled plume calculations, and removing the plume-rise calculations into a separate modeling step so that future configurations and scientific advances could be more easily implemented and tested.

While many of the findings described above were also mirrored in the user surveys, the user comments often focused on the user interface of the visualization system (RAINS at the time), where the users were able to obtain the BlueSky modeled output. The comments generally were bifurcated: some advanced users greatly appreciated the advanced functionalities found in RAINS and desired more features, and many others found RAINS far too confusing and slow for everyday use. These results were interpreted by the BlueSkyRAINS-West project team (which consisted of managers and scientists from the three agencies) as revealing a significant divergence in user needs based on their exact management task and background. Indeed, additional questions on the survey revealed a large number of potential uses for smoke forecasts that were not being addressed because the information displays or tailored forecasts needed by individual users were not available. These findings were a major reason why, in the rework performed during this NASA-funded project, a bright-line distinction was made between the BlueSky Framework, which produces model output information, and the use of this information in graphical display and other decision support systems. The goal was to make the Framework support any number of existing and future visualization systems through the use of easy to understand and portable data standards.

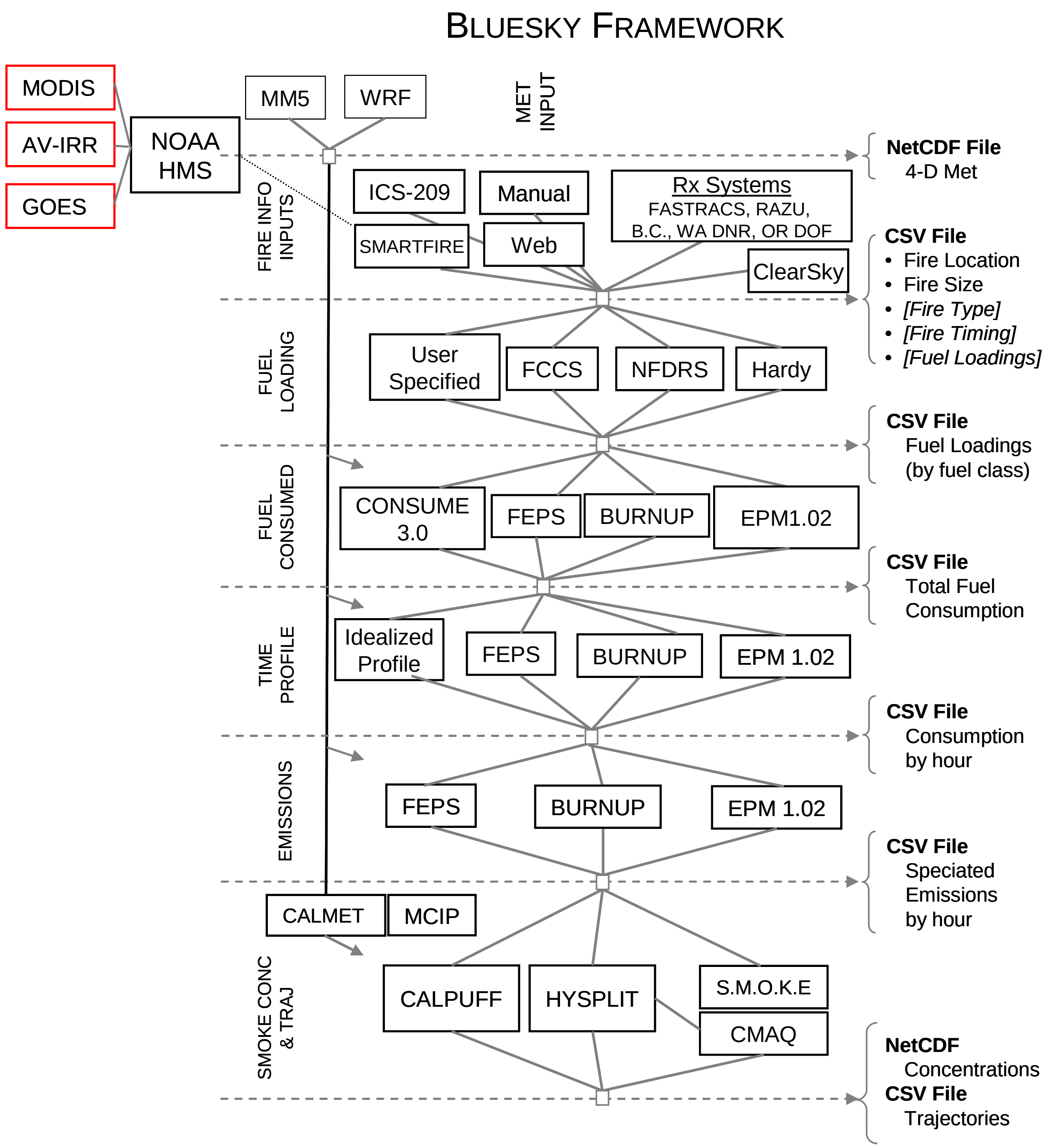
2.2 Implementation

The NASA-funded project involved implementation in two major areas: (1) systems development and/or re-engineering, and (2) outreach to user communities and/or support of novel applications. Major systems development tasks included the re-engineering of the BlueSky Framework; design and creation of SMARTFIRE; and the configuration and setup of ongoing systems based on the newly implemented tools. Outreach and support activities included the setup of systems for distributing information, technical contributions to novel BlueSky-enabled smoke impacts assessment tools, and announcement of newly available information and services and conferences, publications, and regular fire management training seminars. In brief, the NASA-funded project made possible exceptional expansions in the BlueSky user community and in the suite of purposes for which BlueSky systems are being applied now and in the future.

2.2.1 Systems Development and Re-engineering

As a result of the NASA-funded project, the BlueSky Framework progressed from a somewhat cumbersome in-house smoke prediction system to a streamlined and modular framework designed for ease of application by a community of users. The re-engineering of the BlueSky Framework addressed major issues raised by the BlueSkyRAINS-West 2005 project. The overhaul was a major achievement and has allowed uses of the Framework that were previously unattainable. Accomplishments included implementing modularity, supporting maintainability, broadening the array of built-in options and model choices, and facilitating system expandability or flexibility. To meet these goals, each model or data set was folded into a Python-language wrapper, so that each combination of model and Python wrapper behaves as a module within the Framework. The Python wrappers allow models and data sets to be added to the Framework or rearranged within it without changing the language of the code or data set. They also allow easy addition of new modules anywhere in the modeling pathway. The new Framework also provides a start, stop, and restart capability, to facilitate running different pathways through the Framework and comparing and contrasting the different choices at each modeling step. In addition, the array of built-in options and model choices was greatly increased. During the NASA-funded project, the number of functioning alternative modeling pathways available through the Framework (beginning to end) increased from one to over one thousand. Included in the overhaul was a standardization of input and output files such that the wrappers surrounding the models are designed to digest the appropriate data required to run the model and then output the data in the standardized format. This standardization allows easier user or system interfaces with the BlueSky Framework. The functioning of the re-engineered Framework is reported by Larkin et al. (2009) and illustrated in **Figure 2-3**.

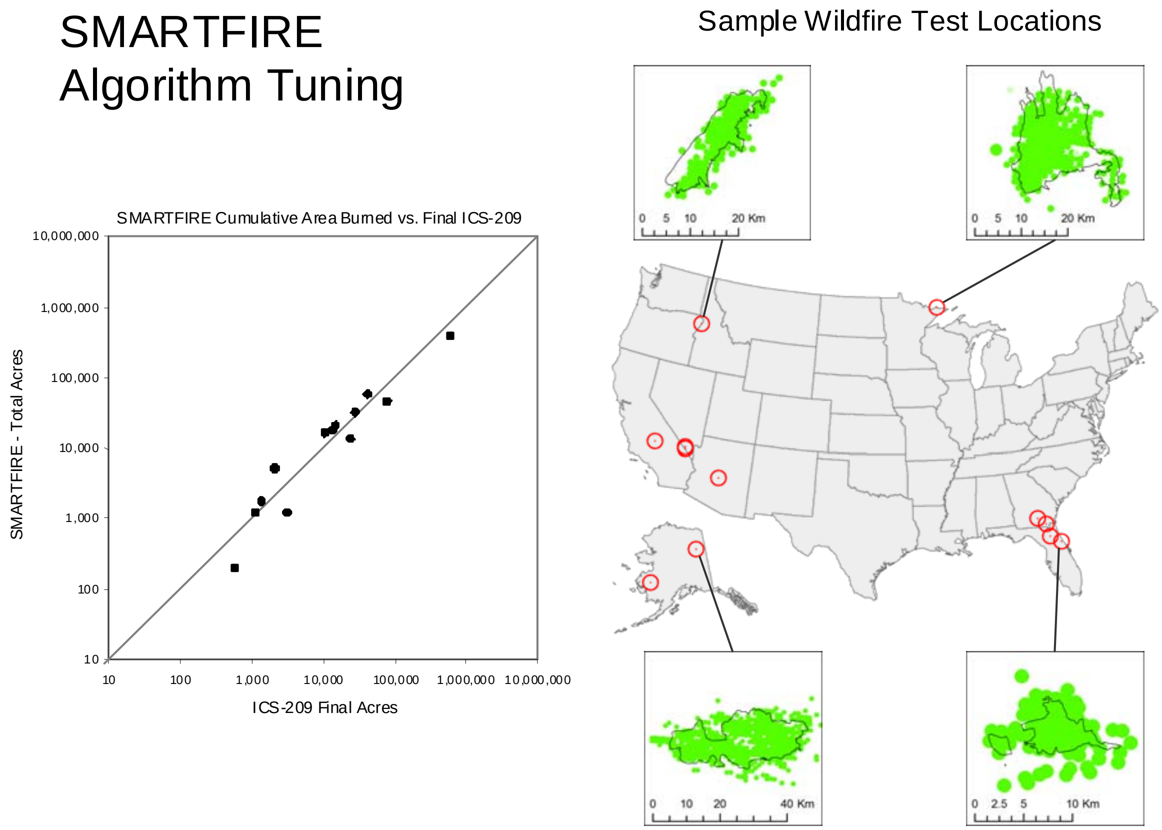
An exciting feature in the new Framework is the incorporation of real-time data, such as fire information from ground reports and satellite data. Bringing in and using real-time data is important for predicting smoke concentrations as accurately as current science and technology allow. In this area, development of SMARTFIRE was a major achievement of the NASA-funded project. SMARTFIRE processes and prepares fire information for input to the BlueSky Framework (or, potentially, any other system designed to accept fire information). SMARTFIRE integrates and reconciles satellite-detected fires with human-recorded events. Hence, SMARTFIRE harnesses the advantages of multiple data sets while minimizing double-counting. Its algorithms apply geographic information to associate proximate fires, define large events or fire complexes, and maintain the associations over time as fire events progress across the landscape or even divide into multiple fire fronts. SMARTFIRE also estimates the geographic extent of burned areas from satellite data.



Model progression is top to bottom, through the model steps listed on the left. Interface points where the framework can be started or stopped are shown by dashed lines, with the type of file and information contained listed to the right. Implemented models are shown and the data flow between them is indicated by lines. At each step, multiple model choices are implemented. Meteorological data local to the fire are utilized in several steps. Full meteorological grids are used for trajectory and dispersion calculations. Adapted from Larkin et al. (2009).

Figure 2-3. BlueSky component models and data flow.

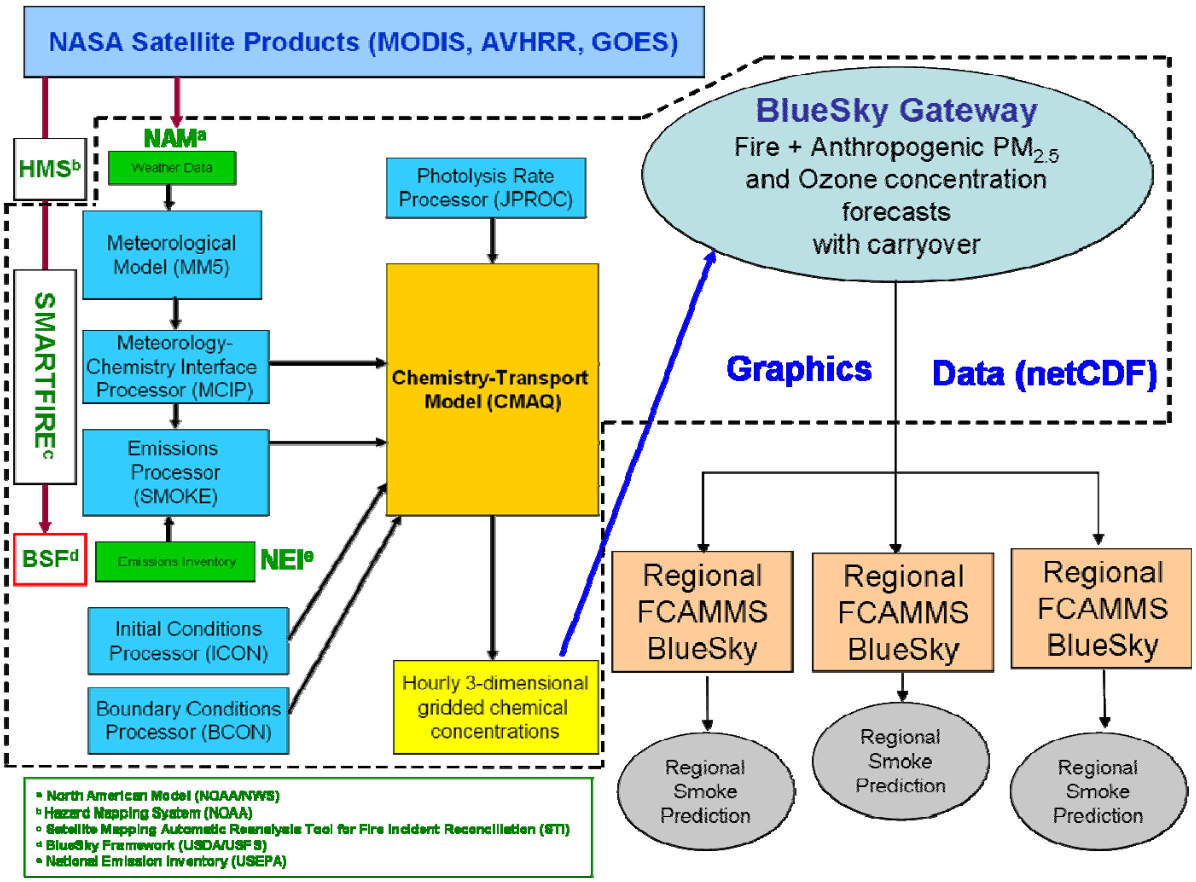
SMARTFIRE was built with the capability to ingest multiple disparate fire reporting data sets to produce a single unified data set. Currently, SMARTFIRE is configured to process two input data sources (though more can be added): (1) ICS-209 reports and (2) satellite data from the NOAA HMS. SMARTFIRE's algorithms were fine-tuned and its outputs validated using real-world data from a variety of sources (**Figure 2-4**). Its outputs are available on-line via web services, which may be called using a module of the BlueSky Framework, manually or by any system designed to access web services. The functioning of SMARTFIRE is documented in Appendix A, SMARTFIRE Algorithm Description.



SMARTFIRE's algorithm for estimating fire size from satellite fire detections (pixels) was initially tuned using the flown perimeters of 18 large fires distributed across the United States.

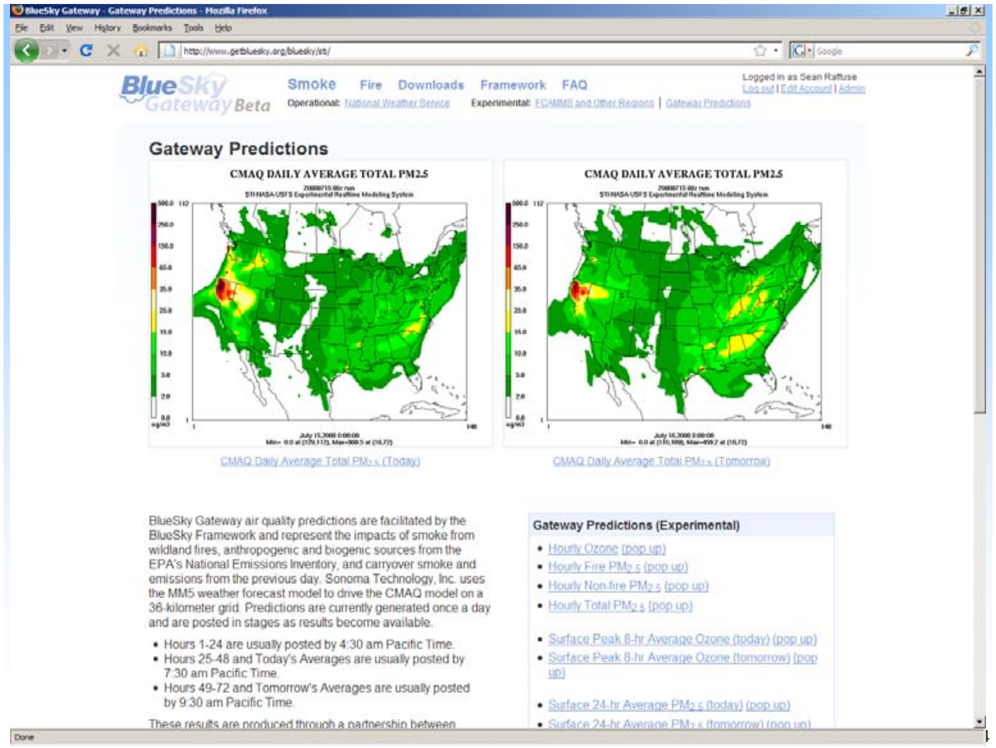
Figure 2-4. SMARTFIRE fire-size algorithm tuning with real-world data.

With the re-engineered Framework and the newly developed SMARTFIRE, a new configuration of systems was set up to produce daily smoke predictions, test functioning and reliability, demonstrate the value added with the use of satellite-based fire information, and offer experimental products to interested stakeholders (**Figure 2-5**). Predictions of $PM_{2.5}$ and ozone concentrations have been generated twice daily since summer 2007 with minimal human intervention (**Figure 2-6**). Results represent the impacts of smoke from wildland fires, anthropogenic and biogenic sources from the EPA's NEI, and carryover smoke and emissions from the previous day. The systems employ the NCAR/PSU Mesoscale Model version 5 (MM5) weather forecast model to drive the Community Multiscale Air Quality (CMAQ) model on a 36-kilometer grid. Predictions are automatically made available on the BlueSky Gateway web portal (www.getbluesky.org) in stages as results become available. The system configuration is listed in Appendix B.



The linkage to the BlueSky Framework is at the emissions processing step, where emissions from the NEI and the Framework are ingested by SMOKE (as illustrated in Figure 2-3). The NEI is referenced for non-fire emissions. The BlueSky Framework modeling pathway used for the BlueSky Gateway predictions is documented in Appendix B.

Figure 2-5. Workflow of BlueSky-enabled systems configured to produce twice-daily predictions of air quality for the BlueSky Gateway (dashed line shows features implemented during this project; BlueSky components outside this line pre-existed).



Experimental-grade $PM_{2.5}$ predictions for current day, next day, and third day were made available on the BlueSky Gateway web portal. The illustrations shown are predictions for July 15 and 16, 2008, during the severe fire season in northern California.

Figure 2-6. Automated twice-daily $PM_{2.5}$ predictions facilitated with BlueSky systems.

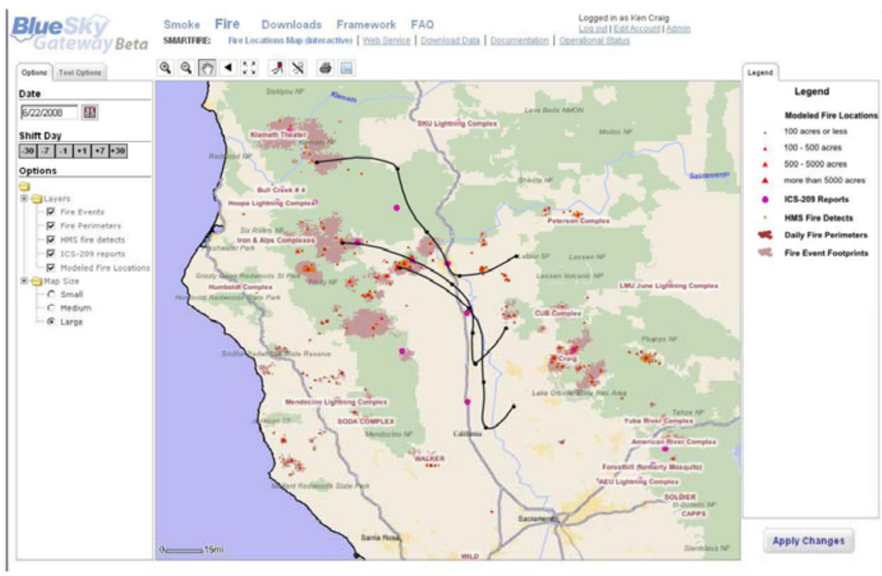
2.2.2 Community Outreach and Applications Support

Providing support for novel and expanded applications that use the BlueSky Framework and SMARTFIRE was a third major achievement of the NASA-funded project. Community outreach and applications support began with the opening of the **BlueSky Gateway** (www.getbluesky.org), a web portal providing access to daily air quality predictions, SMARTFIRE outputs, other BlueSky-related tools, and direction to external resources (such as the NWS operational-grade smoke forecasts). Information visualization tools, such as the interactive geo-navigable SMARTFIRE Viewer (**Figure 2-7**) and downloadable Google Earth-compatible files of smoke and fire information (**Figure 2-8**) were created and published. Also, guidance for acquiring the BlueSky Framework and its open-source code was provided. To date, nearly 200 new external users have registered for access to the Gateway. Examples of some of the purposes stated for requesting access include exceptional event analyses, support for emission inventory development, and air quality modeling research. A few examples of organizations requesting data access are Clark County, Nevada; California Air Resources Board (CARB); Bureau of Land Management; Tennessee Division of Air Pollution Control; and Texas A&M University. With the new attention garnered by the improved and expanded BlueSky systems, further opportunities to support novel applications began to arise. For example, after interest in the framework increased and more installations were done, a more technical web presence focused on modelers and not users was deemed necessary and was set up (www.blueskyframework.org).

One of these applications was an **Emergency Smoke Response Systems** (ESRS) prototype for the USFS Region 5 (California) (**Figure 2-9**). The severity of California's 2008 fire season was the result of unusual climate events interacting to cause the most geographically extensive, lengthy, and costly fire and smoke events to impact a single state to date. In response, USFS Region 5 launched the ESRS to offer information and support to the fire weather and air quality decision-support community in California and southern Oregon. The ESRS were also intended to serve as a demonstration prototype for similar applications in other USFS regions. Daily human-generated text and graphical three-day forecasts of smoke impacts for California and southern Oregon were produced for the decision-support community's reference by drawing on BlueSky systems and other information sources. Additionally, consulting forecasters were available during daily teleconference calls. Positive reactions were offered by the CARB and northern California organizations or agencies, and many specific requests and inquiries were received from other agencies throughout California. As an extension of this effort, USFS Region 5 is continuing to apply SMARTFIRE and BlueSky-enabled systems to conduct retrospective analyses of California's severe 2008 fire season and the associated air quality impacts. USFS Region 5 is also continuing to explore effective uses of ESRS in the future and to formulate associated recommendations.

SMARTFIRE Data Viewer

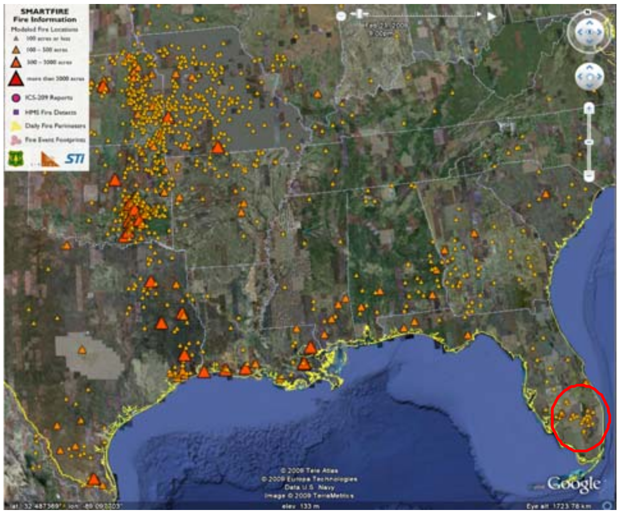
The interactive SMARTFIRE viewer provides graphical access to real-time and historical fire location information, with the ability to overlay trajectories from the NOAA HYSPLIT model. SMARTFIRE data are also available via FTP and web services technology.



Sample graphic generated from the BlueSky Gateway SMARTFIRE viewer for June, 22 2008. Fire events (grey shading) represent cumulative area burned as of September 22, 2008. Black lines are 24-hour HYSPLIT forward trajectories originating from various fire locations.

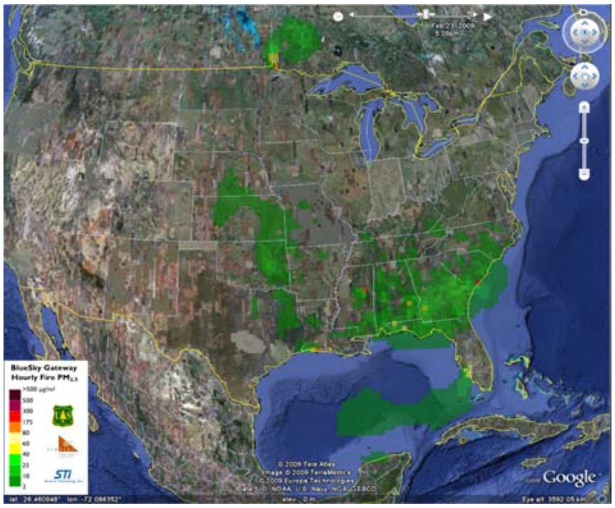
Figure 2-7. Illustration of the interactive, geo-navigable SMARTFIRE Viewer tool.

SMARTFIRE Daily Active Fires – February 21, 2009



South of Lake Okeechobee, FL – February 21, 2009

Predicted $PM_{2.5}$ from Fires, February 23 at 5:00 PM PST

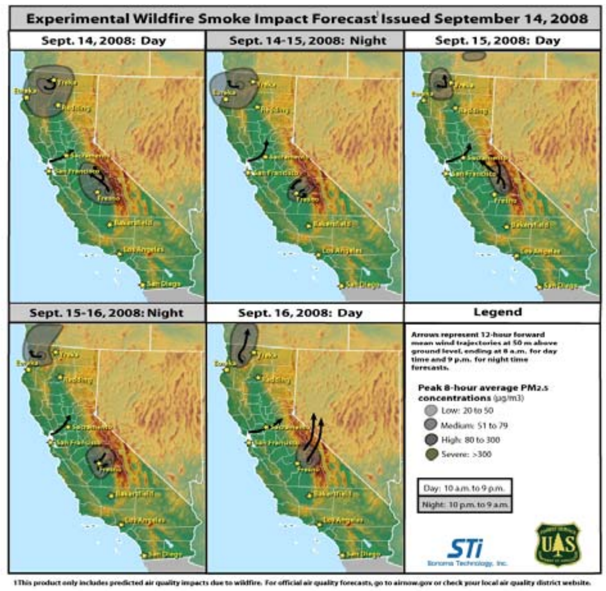


Fire activity data in the southeastern United States (upper left) showing active fires on February 21, 2009, with a close-up of the Lake Okeechobee, Florida, area showing active fires and the recent historical footprint of the active fires. Predicted $PM_{2.5}$ concentrations from fires are illustrated for the United States (lower left) on February 23, 2009, at 5:00 p.m. PST.

Figure 2-8. Visualizations of fire information and modeled $PM_{2.5}$ concentrations using Google Earth.

Forecasts

Daily smoke impact forecasts for California were generated by professional meteorologists. The styles and formats of the products were refined over the course of the fire season by working jointly and iteratively with USFS staff and stake-holders. The final version of the forecast product converged on a text discussion accompanied by a 5-panel graphic illustrating expected smoke conditions for the coming 3 days and 2 nights. These forecast products were consulted and discussed during a daily conference call held with stakeholder agencies in California.



Model Predictions

Existing experimental smoke modeling operations were modified and customized for application in California. Routine CALPUFF modeling by the California and Nevada Smoke and Air Committee (CANSAC) was customized to adjust the domain and bring systems up-to-date with the latest modeling tools. Experimental CMAQ modeling for the BlueSky Gateway was modified similarly. CANSAC's operations provided predictions of smoke dispersion at finer-scale resolution (e.g., 4-km and 1.3-km), while those from the BlueSky Gateway offered a perspective on the effects of photochemistry (using the CMAQ model).

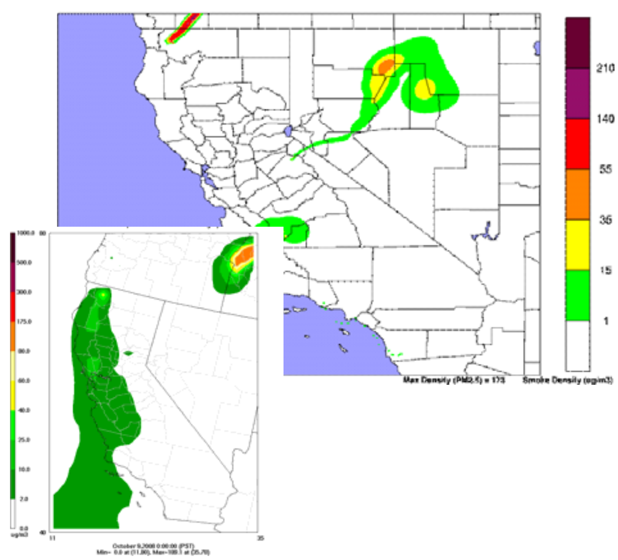


Figure 2-9. Illustrations of Emergency Smoke Response Systems deployed for California's 2008 fire season.

EPA used SMARTFIRE and the BlueSky Framework to prepare emission inventories for wildland and agricultural fires for its 2003-2008 **National Emission Inventories** (**Figure 2-10**). In addition, the EPA has announced plans to continue to use and further develop these systems to support future NEI projects. Emissions estimates from the NEI are often used as starting blocks of SIPs for air quality attainment. The value afforded to the EPA by the use of BlueSky systems is especially noteworthy. The EPA's efforts to develop the 2002 NEI alone—which produced results comparable to those generated by the BlueSky systems, but relied solely on ground-based fire reports and manual processes (no satellite data)—required a budget of approximately $1 million. The 2003-2006 emission inventories were prepared using BlueSky systems for a total budget of less than $50,000. This budget value was recently repeated with the preparation of the 2006-2008 emission inventories.

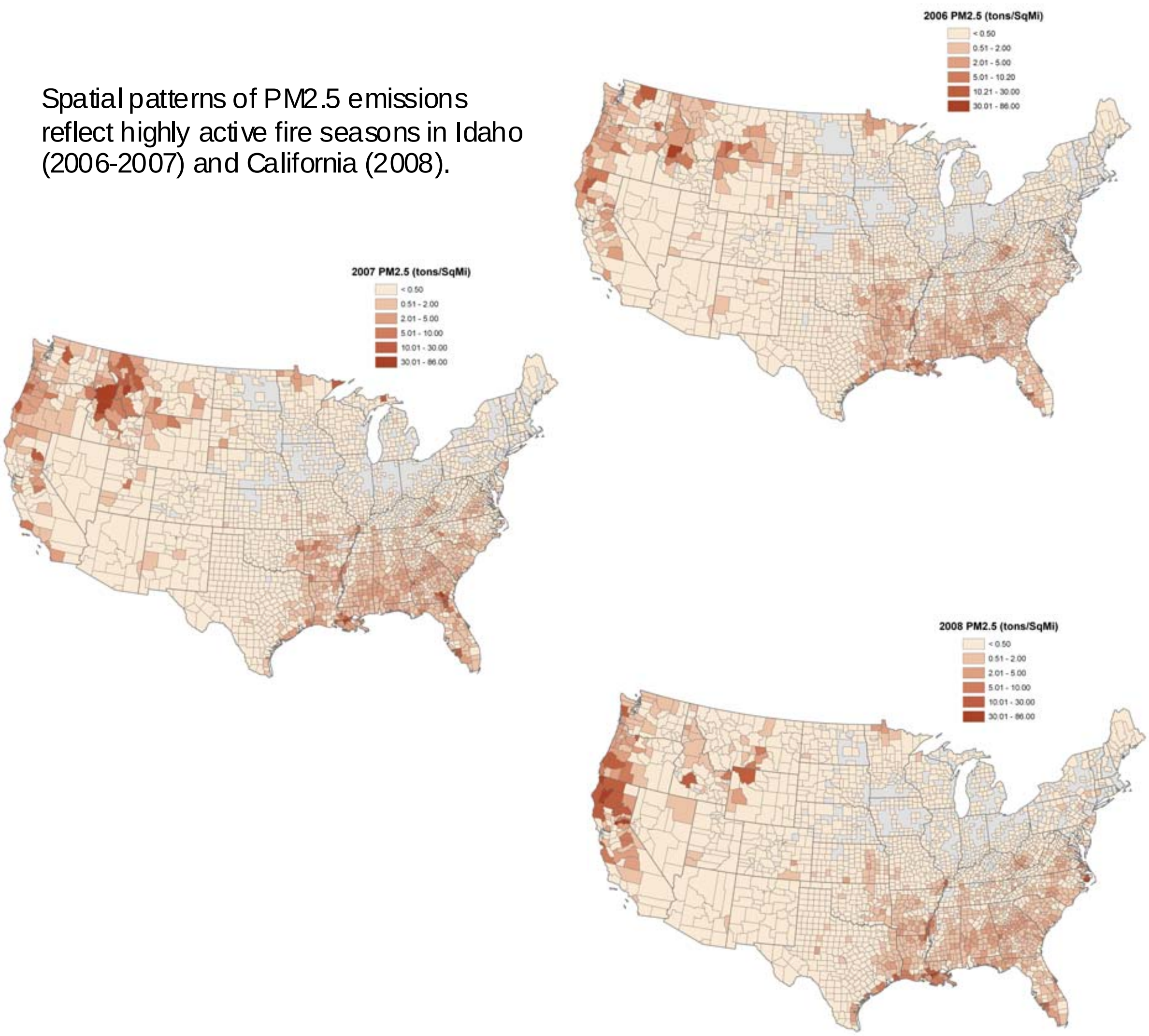


Figure 2-10. Illustrations of the spatial distributions of wildland fire emissions in EPA's 2006-2008 NEI.

A climate version of the BlueSky smoke modeling system, the **Air Quality Impacts Planning Tool** (AQUIPT), was created through USDA Cooperative State Research Education Extension Service (CSREES) funding to provide a probabilistic impact analysis from user-specified emissions sources. AQUIPT, which is enabled by the BlueSky Framework, produces probabilistic air quality impact analyses from user-specified emissions sources. It is being used by smoke and fire managers for the purposes of long-range program planning. A long-term (27-year) meteorological data set was prepared and connected to the BlueSky Framework. The Framework and these data were used to develop a climatology-type analysis of the expected impacts for a fire that might happen during a specific period. The results from multiple simulations (over ranges of days and years) are aggregated to provide statistical analyses of likely impacts from planned fires. A web-based interface to the AQUIPT allows outside users to submit analysis requests and review results online (**Figures 2-11 and 2-12**). Statistics produced by AQUIPT include average impact (the average concentration calculated from all hours contained in the concentration files), maximum impact (the maximum concentration contained in the concentration files at each grid cell), threshold impact (percentage of time the concentration exceeds a threshold value), percentage of time impact (concentration at and above which a given percentage of time is spent), and probability of impact (the probability that a given impact level will be achieved).

BlueSky Playground, another tool recently developed through JFSP funding, represents a full-fledged interactive scenario building (or, "game-playing") application for use by the smoke modeling community. BlueSky Playground allows users to dynamically link different models and adjust parameters on the fly to examine how model and parameter choices affect resulting smoke emission predictions. The Framework was ported to a web-service architecture and made available across the Internet for public use (**Figure 2-13**). An interactive web application showcases the services within the Framework and offers rapid visualization of modeling outputs. Not only has the need for examining "what-if" scenarios often been voiced in user feedback, but the BlueSky Playground also meets one of the JFSP's current objectives of demonstrating tools with service-oriented architectures (SOA). BlueSky as an SOA is able to support tailored user interfaces for specific user communities and is available for connection to other major decision-support tools currently in use or actively under development by the fire science community (i.e., the Wildland Fire Decision Support System and the Interagency Fuels Treatment Decision Support System). The USFS Region 6 is currently adapting the BlueSky Playground interface for its fire emissions and smoke management needs.

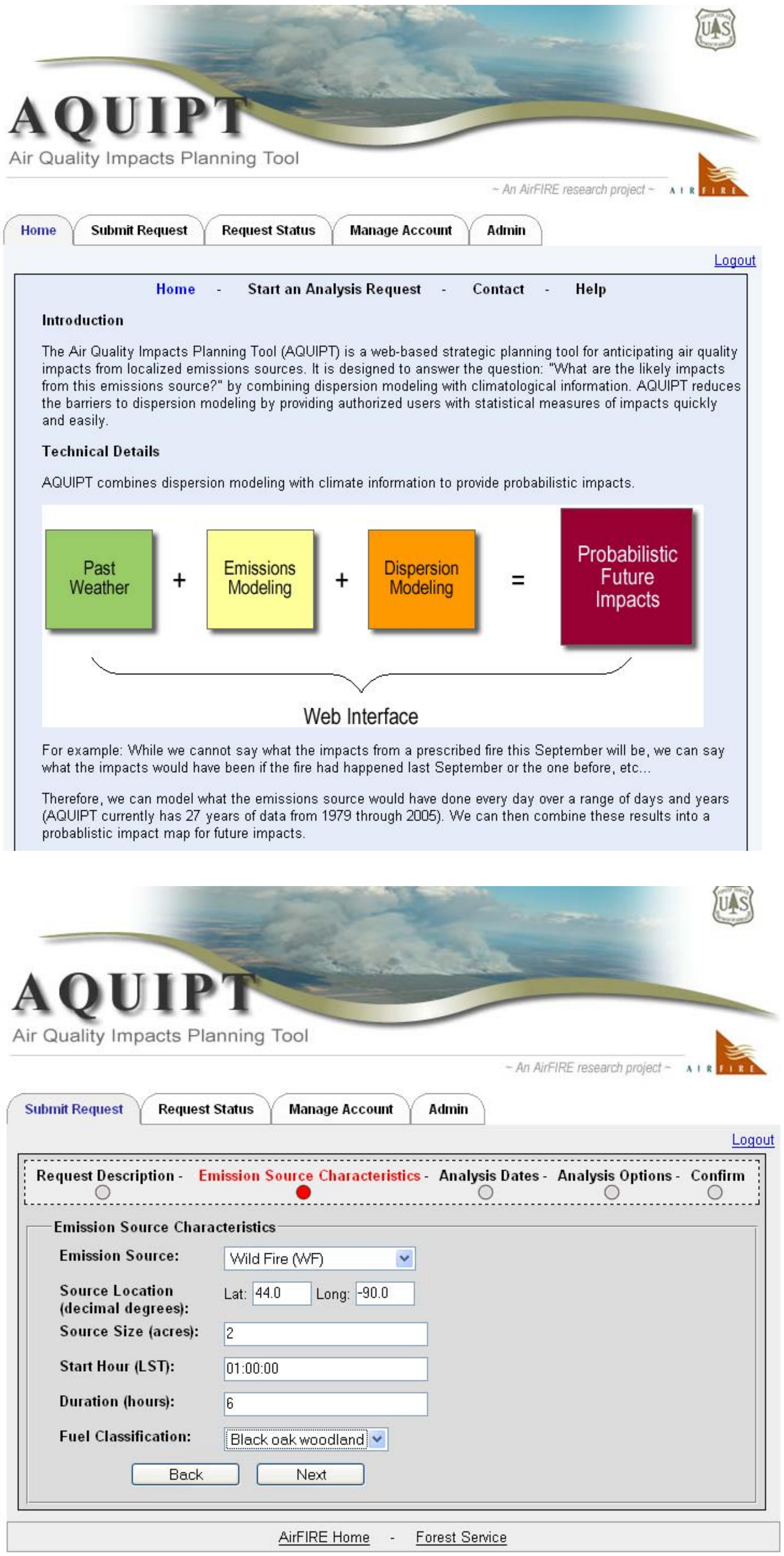
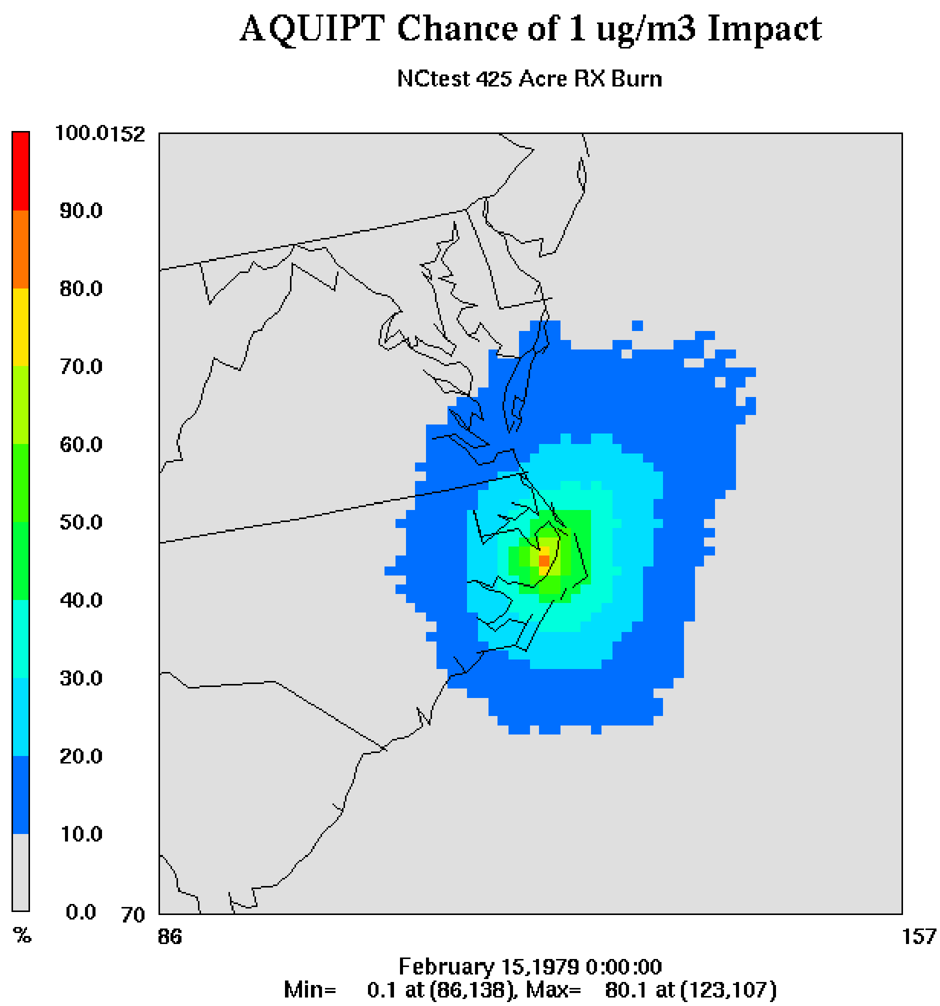
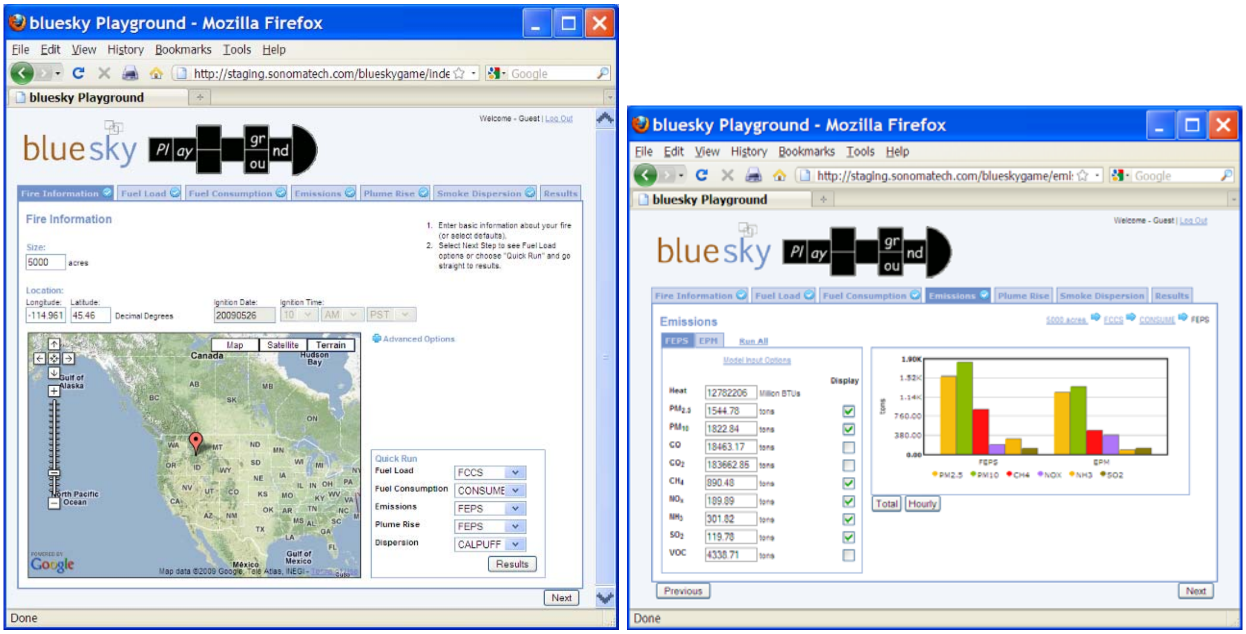


Figure 2-11. Excerpts from the AQUIPT user interface for submitting an analysis request.



The probability of impact statistic describes the probability that a given impact level will be achieved. In source modeling, this statistic describes the probability of impact from a particular fire. This statistic is determined by calculating the percentage of simulations in the ensemble in which a given impact level is exceeded for one or more hours.

Figure 2-12. Example plot of AQUIPT output.



Excerpts from the BlueSky Playground interface illustrate how users can interactively define fire information and overall modeling pathway (left), and view a range of emissions outputs depending on the particular emissions model selected (right).

Figure 2-13. Illustrations of the interactive user interface for BlueSky Playground.

Finally, one of the most potentially significant and far-reaching projects being supported by BlueSky systems is the **Smoke and Emission Model Intercomparison Project** (SEMIP). Just established in October 2008, SEMIP will be an ongoing community effort to intercompare and evaluate the growing number of fire- and smoke-related models. SEMIP will cover the modeling steps illustrated in **Figure 2-14**, each of which may comprise one or more of several different models. Specifically, SEMIP has established an open standard (including a sequence of standard case studies) for comparing smoke and emissions models against one another and/or against real-world observations. In the near future, a first round of rigorous evaluations of selected publicly available models will be completed. These evaluations will include model-to-model intercomparisons and model-to-observations performance assessments for 22 component models. These efforts will be completed with the collaboration of multiple researchers and stakeholders, many of whom will leverage the newly engineered modularity and interoperability of BlueSky systems to participate. SEMIP's results are intended for use by scientific and management communities, who are in need of model performance evaluations to better focus research efforts and better utilize existing models. Results will be translated into user-accessible guidance and training to identify which models perform best under which circumstances.

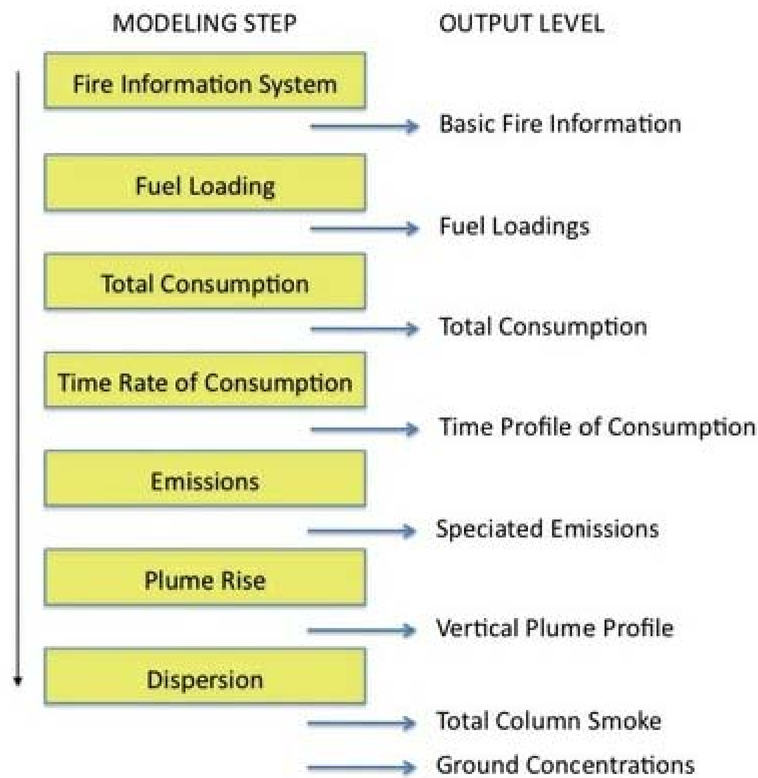


Figure 2-14. Modeling steps included in SEMIP.

2.2.3 Summary

The BlueSky user community and the suite of purposes for which BlueSky systems are being applied have greatly expanded as an outcome of the NASA-funded project activities. BlueSky-enabled systems are now referenced across the United States by both air quality agencies and forestland managers. In addition, the restructuring and wider acceptance of BlueSky systems and related tools are motivating sea changes in related fields of research. SEMIP is expected to rapidly further the understanding of the science of smoke impacts modeling and provide a basis for developing research priorities. In addition, BlueSky serves as a model and an information access point for development decision support systems in the areas of fuels management (the Interagency Fuels Treatment Decision Support System) and wildland fire management operations (the Wildland Fire Decision Support System). BlueSky's modularity, interoperability, standardization, availability as web-services applications, and national-scale attention—attained largely or in part through the NASA-funded project—have made these outcomes possible.

2.3 Validation and Verification

Validation and verification of BlueSky systems involved (1) testing, monitoring, and re-configuration of BlueSky systems to produce automated daily products with minimal levels of maintenance (as available on BlueSky Gateway); and (2) intercomparisons of Gateway modeling outputs with ground observations to demonstrate the achievability of predictive-mode model performance.

2.3.1 Verification of Systems Functioning for Routine Operations

BlueSky Gateway systems have been deployed to process fire information and to generate predictions of $PM_{2.5}$ and ozone concentrations twice daily since summer 2007. Products are automatically posted to the BlueSky Gateway web portal in stages as they become available. Systems stability and fail-safe measures were engineered from the outset; and systems statuses have been automatically and manually monitored since inception as summarized in Appendix B. Current systems statuses are made available on the BlueSky Gateway as shown in **Figure 2-15**. Improvements to systems monitoring, optimization, and stability are deployed continuously as problems or risks are identified. Thus far in 2009, SMARTFIRE has successfully completed its processing on all but one day (99.7% uptime); two-day CMAQ forecasts have completed with a 99.0% success rate; and three-day CMAQ forecasts have completed with a 96.6% success rate.

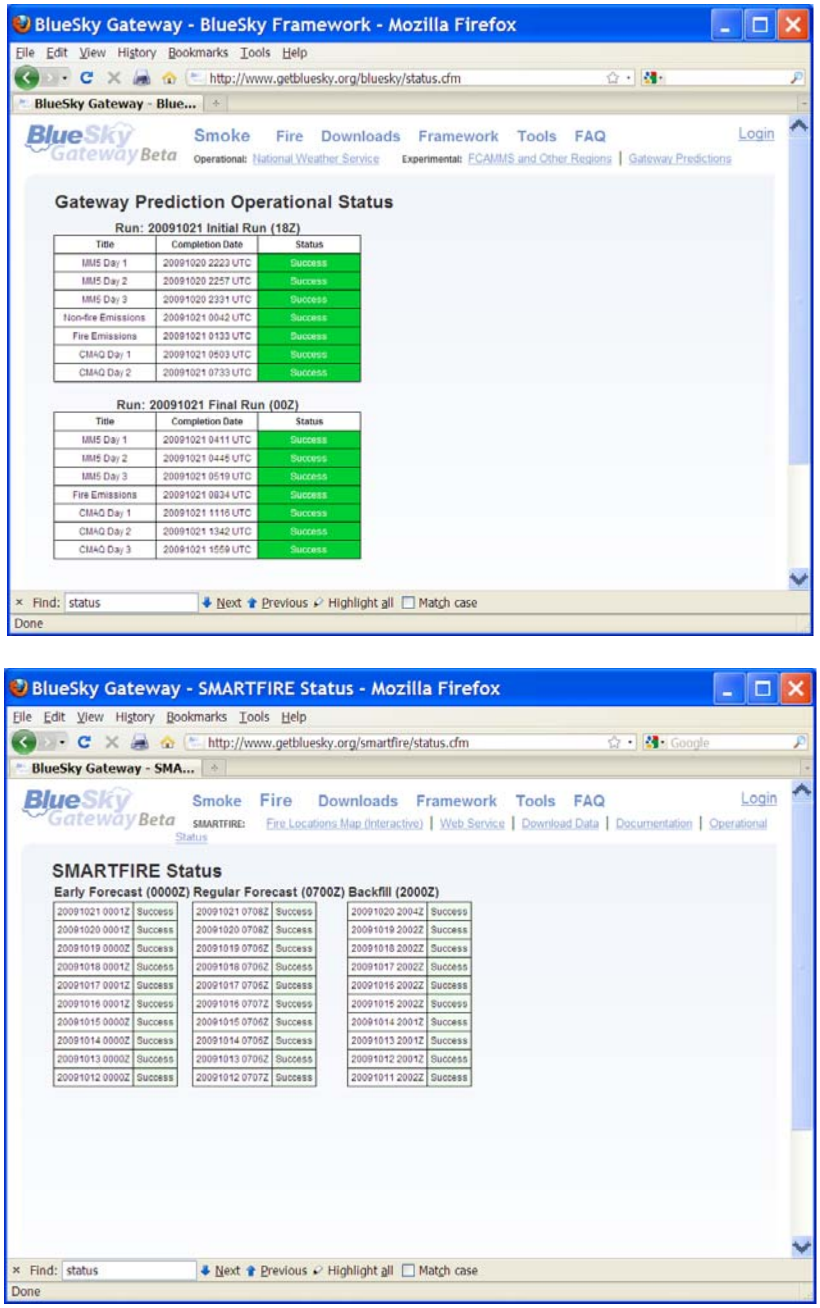
2.3.2 Validation of Model Performance

Predictive performance and capabilities of the Gateway modeling systems were evaluated by comparing observed smoke concentration data to model predictions for major wildfire events in southern (2007) and northern (2008) California. The Gateway systems use the BlueSky Framework to generate emissions data from fire; the modeling pathway steps through the framework are illustrated in **Figure 2-16**. The resultant smoke emissions data and smoke plume top and bottom are then fed into the CMAQ model. Other details of the Gateway configuration are documented in Appendix B.

For evaluation of the Gateway predictions, we used the 0-23 forecast hours from each run to create continuous time series of predicted concentration outputs for comparisons with in-situ observations. Highlights of the findings include the following:

- Unpaired analyses show the model performing well for a predictive system over space and time.
- Paired analysis results range from fair to good; most of the paired results are unsurprising.
- The predicted concentrations are within a factor of 2 for most of the observed $PM_{2.5}$ surface concentration range (low-high).
- For the 2007 event, the predicted results miss the observed ground concentration peaks, particularly during the offshore flow part of the wildfire event and improve when the conditions turn to onshore flow.

- For the 2008 event, the predicted results generally under-predict the observed peaks; however for six sites impacted heavily with smoke, the predicted results tend to over-predict rather then under-predict (but are very close to the observations).



Current systems statuses for CMAQ-based air quality predictions (top) and SMARTFIRE operations (bottom) are made accessible on the BlueSky Gateway.

Figure 2-15. Illustrations of automated systems monitoring information for the BlueSky Gateway.

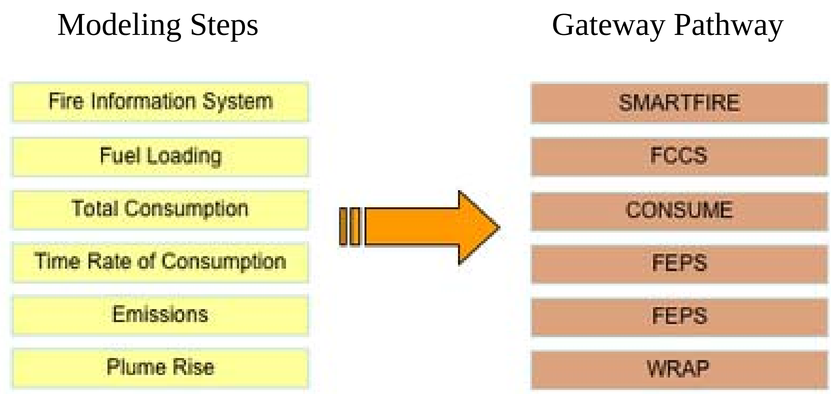


Figure 2-16. BlueSky modeling pathway employed for fire emissions modeling in the Gateway modeling systems.

We note that the expected results for a *predictive* smoke modeling system should differ from typical, retrospective model performance evaluations. Several factors influence the results of predictive modeling, particularly for fire events:

- Tomorrow's fire behavior (growth, size, location) cannot easily be determined; therefore, an assumption of persistent fire behavior is applied. (However, the assumption that today's fire growth will carry over to the next day represents an inherent uncertainty in the fire input).
- The fire growth curve used by the system (the static Western Regional Air Partnership [WRAP] time profile in this case) reflects an "average" wildfire growth curve. It does not reflect the specific hourly fire growth of the fires modeled. This mismatch is likely to affect timing of the peak modeled pollutant concentrations and potentially (through the covariation with wind shifts) the locations of modeled peaks compared with observations.
- Fuels information, particularly for the southern California fires, is a known issue because of the close proximity of the fires to urban centers and problems with the 1-km grid cell fuel maps, which assume a zero fuel loading in urban locations.
- Given the inherent uncertainties at each modeling step, we recognize the phenomenon of compounding error propagation as the modeling pathway becomes longer. These errors introduced by uncertainties may magnify or cancel each other out, so an in-depth analysis at each modeling step is required in order to characterize the magnitude and sign of potential errors. (This is being done as part of an ongoing JFSP-funded project; see http://www.semip.org).

Hence, we expect predictive model results to have systematic biases larger (and potentially significantly larger) than those typical of retrospective model performance evaluations. We expect this issue to particularly affect paired statistics model performance and metrics analyses. Smoke predictive model results are considered exceptional when the paired (predicted and observed) results show good agreement. In the unpaired portion of the analyses, we strive to achieve an overall performance of acceptable/good.

Gateway predictive performance for smoke was evaluated against the $PM_{2.5}$ observation data collected at 15 sites during the 2007 southern California wildfires and 134 sites during the 2008 wildfires in northern California. Observation data were collected through the AIRNow data system. Data from the 2007 event were selected from sites in the Los Angeles–San Diego corridor, which was influenced by smoke from the wildfire event. Data from the 2008 event were selected from AIRNow sites in Washington, Oregon, and California. Selecting sites from a wider geographic area ensured that the analysis of the 2008 event would cover sites heavily and moderately impacted by smoke, as well as sites primarily influenced only by urban anthropogenic emissions. Additional analyses of the 2008 event referenced data from six mobile monitors deployed by the USFS AirFire team along the Interstate-5 and Highway 3 corridors in northern California from sites heavily impacted by smoke.

Unpaired and paired results were both used to evaluate overall model performance, with unpaired data (i.e., modeled and observed data compared without regard to spatiotemporal matching) allowing evaluation on the total distribution of the data. (Portions of these analyses are discussed in Appendix C) This type of analysis answers the questions, (1) did the model predict the range and frequency of $PM_{2.5}$ concentrations observed during the events; and (2) are the $PM_{2.5}$ predictions too high, too low, or within an acceptable range during the space-time of interest? Analyses of quantile-quantile (Q-Q) plots are useful in addressing these questions.

The Q-Q plots (**Figures 2-17 and 2-18**) were used to examine the unpaired data and determine if the distribution of the modeled data was similar to that of the observed data during the overall space-time of interest. For this analysis, the data are arranged independently from low to high values. If the modeled distribution of data exactly matches the observed distribution, then the data fall along the 1:1 line (center line). Data falling between the 2:1 (upper) and 0.5:1 (lower) lines are within a factor of 2 of the observed data. Overall, the modeled data for 2007 and 2008 are generally within a factor of 2 of the observed data. However, the modeled $PM_{2.5}$ concentrations in the 2007 event were generally under-predicted (Figure 2-17), while the modeled concentrations during the 2008 northern California event are over-predicted (i.e., the modeled data is above the 1:1 line). For the 2008 modeled data, the over-estimation is greatest in the observed concentration range of 400-600 $\mu g/m^3$.

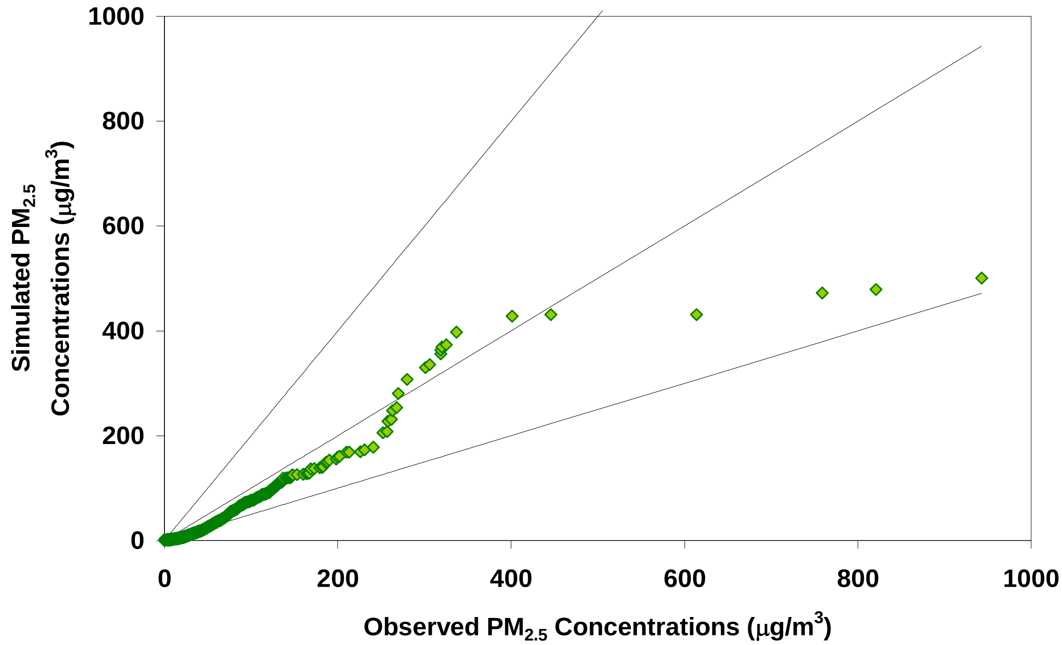


Figure 2-17. Quantile-quantile plot of modeled $PM_{2.5}$ concentrations (y-axis) compared to observations (x-axis). Observation data came from 15 AIRNow sites located in the Los Angeles–San Diego urban corridor. These sites were heavily impacted by smoke from the 2007 southern California wildfires.

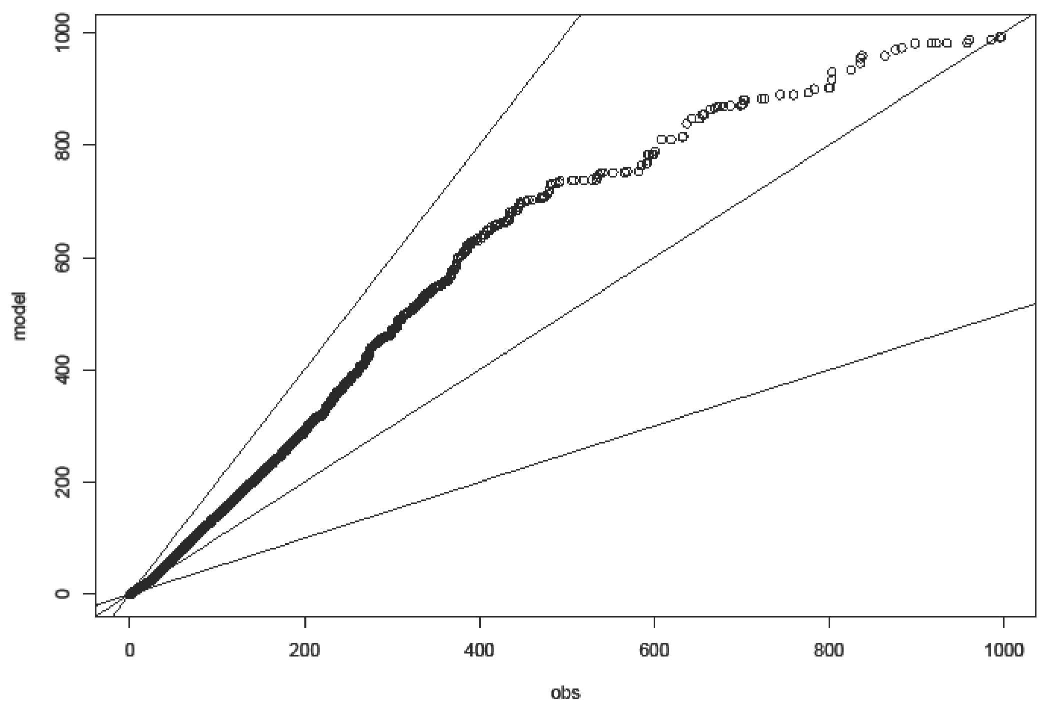


Figure 2-18. Quantile-quantile plot of modeled $PM_{2.5}$ concentrations (y-axis) compared to observations (x-axis). Observation data came from 134 AIRNow sites located in the states of Washington, Oregon, and California during the 2008 wildfire event in northern California. These sites included locations heavily and moderately impacted by smoke, as well as sites primarily influenced only by anthropogenic emissions.

Paired results were used to compare modeled data to observation data in space and time. Paired data evaluation attempts to answer the question, how well do the modeled data represent the observations in space (at the observation station) and time (hour by hour)? Though many standard model performance metrics may be used to evaluate paired data (observed, modeled), we chose the mean fractional bias (MFB) and error (MFE)—relatively basic statistics used to determine modeled data bias and error through data pairs. MFB and MFE are calculated as follows:

$$MFB = \frac{1}{N}\sum_{1}^{N}\frac{(C_m - C_o)}{\left(\frac{(C_m + C_o)}{2}\right)} \qquad MFE = \frac{1}{N}\sum_{1}^{N}\frac{\left|C_m - C_o\right|}{\left(\frac{(C_m + C_o)}{2}\right)} \tag{2-1}$$

where C_m and C_o are the modeled and observed values, respectively, and N is the total number of data in the sample size. *MFB* and *MFE* are normalized by both the modeled and observation data, ranging from ±200% and 0-200%, respectively. Both give equal weight to an over- and under-estimation (Seigneur et al., 2000). Boylan and Russell (2006) propose a standard of goals and criteria for MFB for modeled $PM_{2.5}$ concentrations when used to evaluate historical analyses. If the MFB results are within the goal standard (±30%), then predictive performance is considered good. If the MFB results are outside the goal but are within the criteria (±60%), then performance is considered acceptable. For mean fractional error (MFE), goals and criteria are proposed as +50% and +75%, respectively (U.S. Environmental Protection Agency, 2007; Boylan and Russell, 2006).

As expected, the results from the paired analyses demonstrated less agreement between predictions and observations than the unpaired analyses. The MFB (columns) for the 2007 southern California wildfire event showed a negative bias in the predictions for all monitoring sites **(Figure 2-19)**. At six sites, the MFB falls within the criteria range, and several more sites are close to the criteria (within 25%). While this analysis demonstrates that further improvement is required, model performance is acceptable, especially for a *predictive* model.

During the 2007 southern California wildfire event, a strong Santa Ana wind initially transported smoke from the fire locations to the Los Angeles–San Diego corridor, impacting the urban AIRNow sites. The $PM_{2.5}$ predictions do not compare well to observations during the strong Santa Ana winds; however, once the winds switched from offshore to onshore, the comparisons improved (**Figure 2-20**).

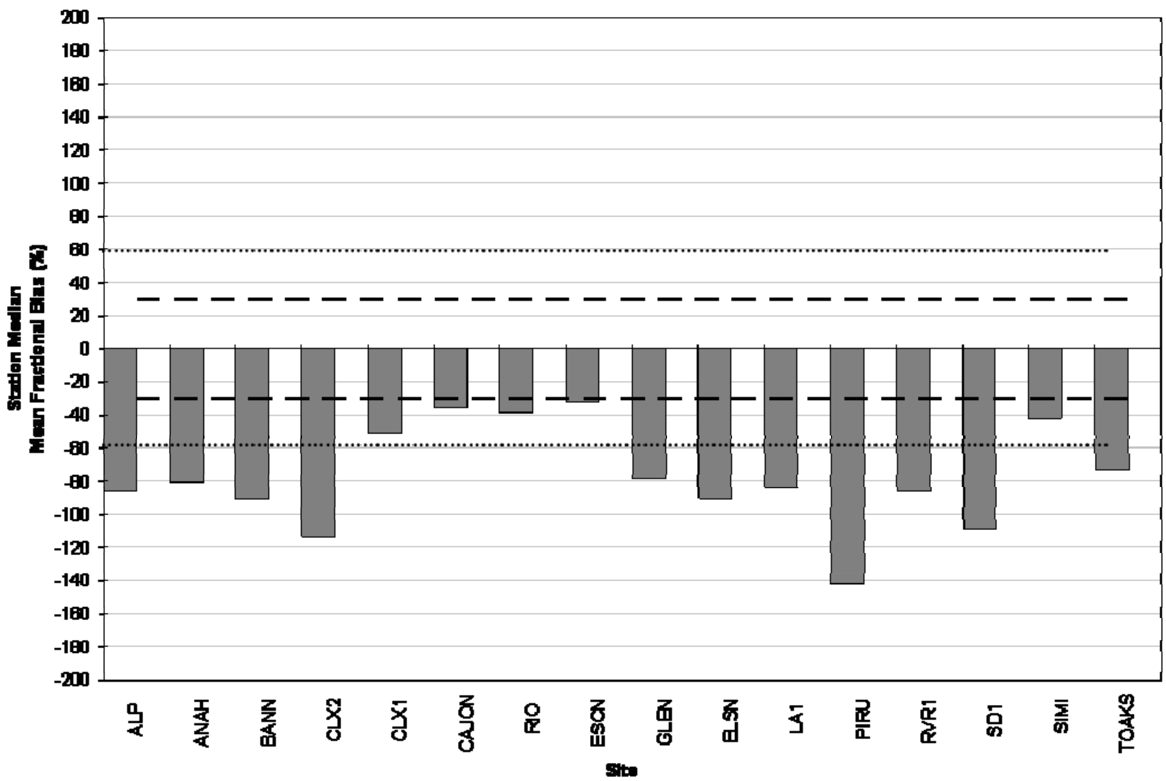


Figure 2-19. Station median (N = 9 days) mean fractional bias (MFB; N = 24 hours) calculated for 16 monitoring sites located in the Los Angeles–San Diego corridor during the 2007 wildfire event. The dashed lines indicate the goal (±30%) and the dotted lines the criteria (±60%) proposed by Boylan and Russell (2006).

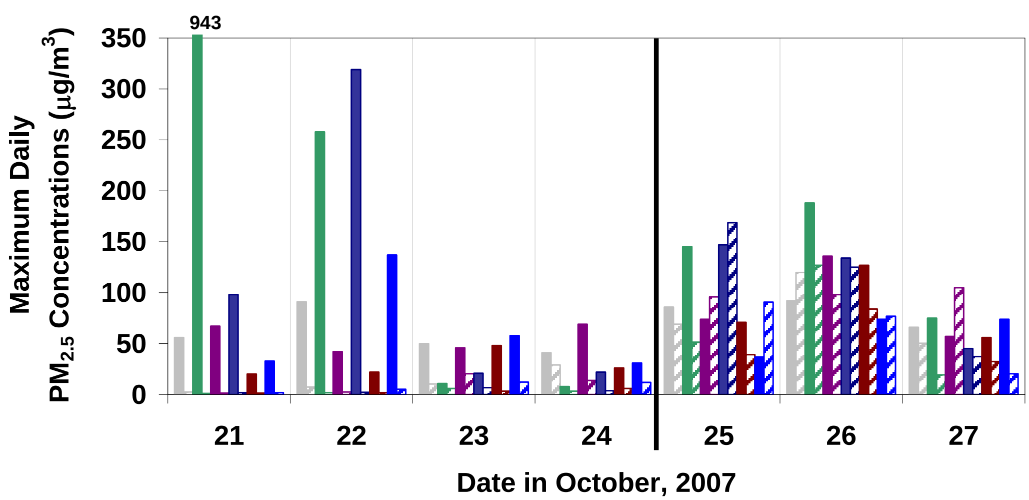


Figure 2-20. Observed (solid bars) and predicted (striped bars) maximum daily $PM_{2.5}$ concentrations ($\mu g/m^3$) for six AIRNow sites located in Los Angeles. Strong offshore flow funneled smoke from the interior toward the coast on October 21-24, 2007; predicted results did not compare well to observations during this period. On October 25, 2007, the flow switched from offshore to onshore, and the predictive performance improved markedly.

$PM_{2.5}$ observations from six AirFire rapid-response sites (deployed through JFSP funding) were used to further evaluate the predictions at sites impacted heavily by smoke. These sites were located in northern California in two parallel valleys: the Interstate-5 corridor (a wide valley) and the Highway 3 corridor (a very narrow valley). A Q-Q plot (**Figure 2-21**), a whisker plot (**Figure 2-22**), and MFB and MFE (**Figures 2-23 and 2-24**) were used to evaluate predictive performance at these sites.

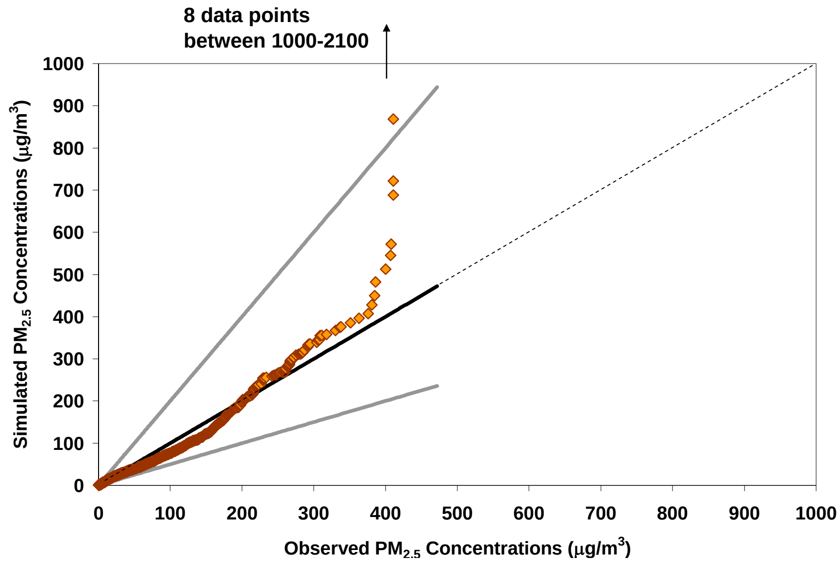


Figure 2-21. Quantile-quantile plot of modeled $PM_{2.5}$ concentrations (y-axis) compared to observations (x-axis). Observation data came from six sites heavily impacted by smoke during the 2008 northern California wildfire event. These sites were not apart of the 134 sites used in the analysis described above.

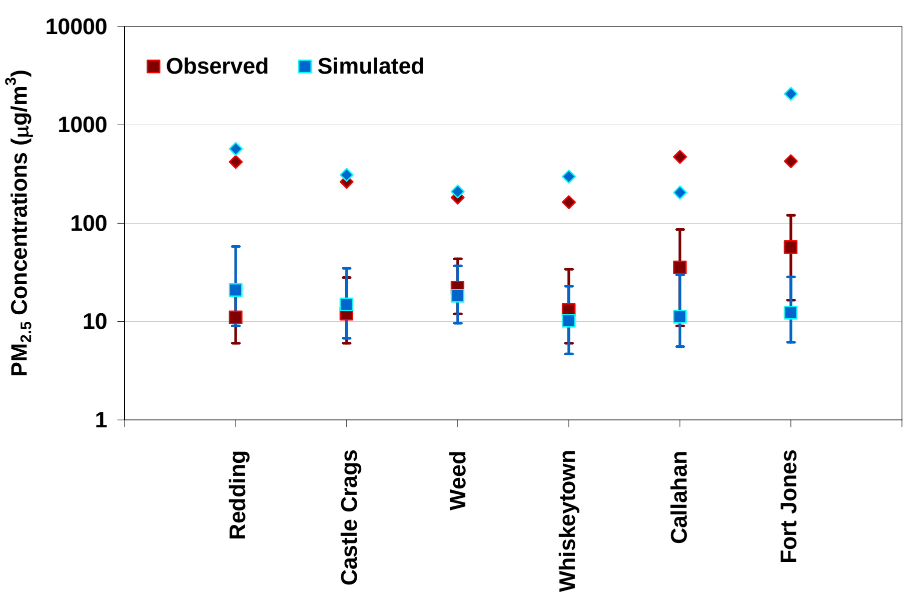


Figure 2-22. Whisker plot showing modeled (blue) and observed (red) medians (squares) and 1st and 3rd quartiles (whiskers) and peak concentrations (diamonds) for the six sites heavily impacted by smoke during the 2008 wildfire event in northern California.

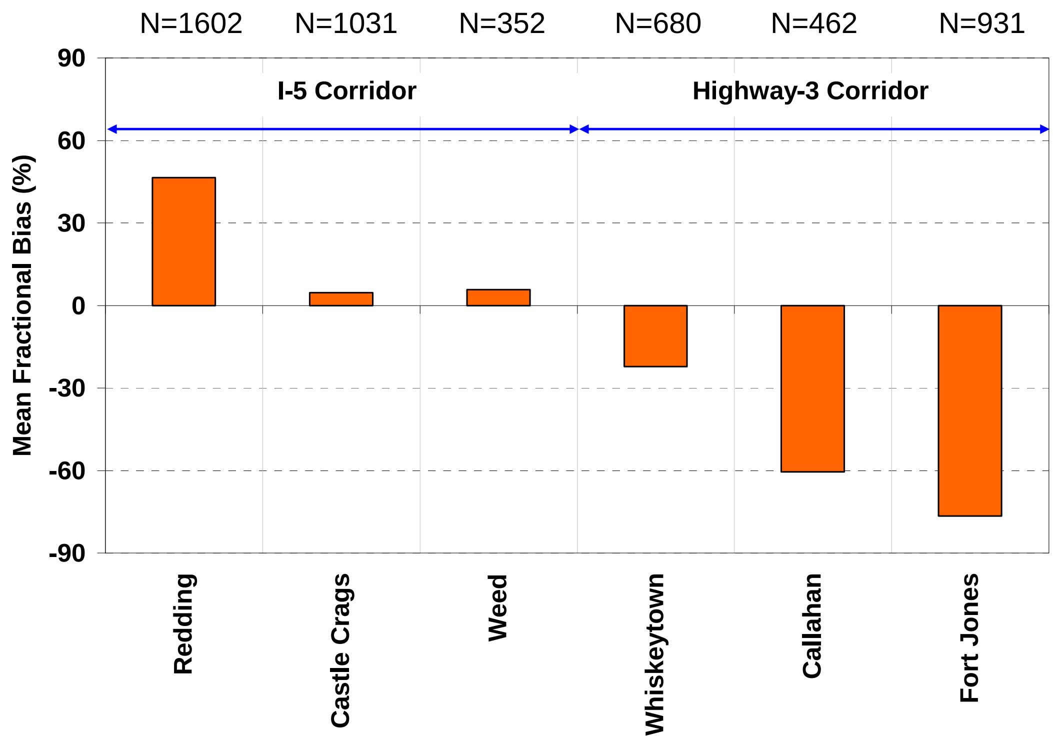


Figure 2-23. MFB for the smoke-impacted sites during the 2008 northern California event and the corresponding number of data pairs (N) used in the computation. N varied depending on the amount of observation data collected during the event. A positive MFB was observed for monitors located along the I-5 corridor (a wide valley), while a negative MFB was observed for monitors along the Highway 3 corridor (a narrow valley).

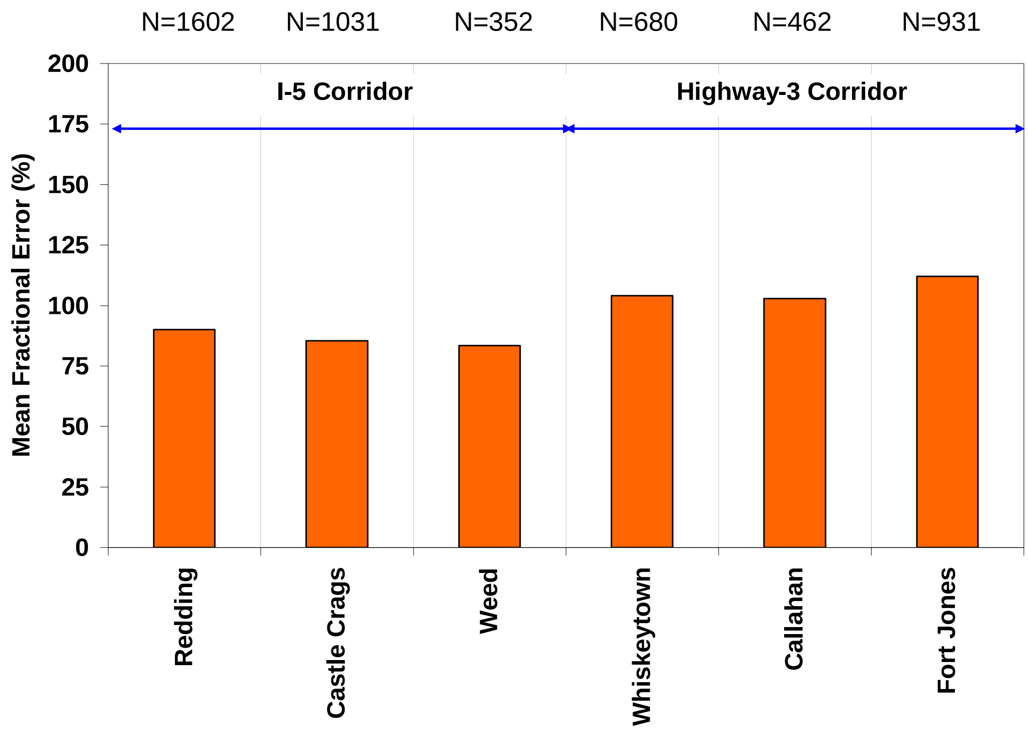


Figure 2-24. MFE for the heavily smoke-impacted sites during the 2008 northern California event and the corresponding number of data pairs (N) used in the computation. N varied depending on the amount of observation data collected during the event. There is little difference between the monitors located along the I-5 corridor, a wide valley, and the Highway 3 corridor, a narrow valley.

In summary, our model performance evaluation demonstrated that BlueSky Gateway results were sufficiently good to be useful for predictive purposes during the 2007 and 2008 California wildfire events. (This finding was corroborated anecdotally by STI air quality forecasters using the model results during those events.) Further evaluations are needed to investigate model performance under various conditions (i.e., for different areas of the United States, vegetation types, fire intensities, meteorology, etc.) and for different modeling pathways (other than those pictured in Figure 2-16). Addressing this need is a major undertaking of the SEMIP project, currently underway.

3. Benchmarking

Benchmarking goals were developed in consideration of the original project objectives, which were to (1) provide near real-time predictions of the emissions and air quality impacts of existing fires or planned fires across the United States; (2) improve and validate the accuracy of BlueSky-enabled predictions; and (3) expand the system's capabilities to meet the decision support needs of air quality agencies beyond the traditional user base of smoke and fire managers in the Pacific Northwest. Hence, we set out to benchmark predictive accuracy and emission inventory completeness (through quantitative measures); as well as system usability and user satisfaction; and system effectiveness at meeting decision-support activities (through user surveys).

3.1 Predictive Accuracy and Data Completeness

Predictive accuracy and data completeness were characterized by considering model-to-observation comparisons and emission inventory completeness. In Section 2.3.2, we showed that reasonably good predictive-mode model performance is currently achievable, at least for the 2007 and 2008 California fire case studies we examined. (Analogous analyses for both predictive- and retrospective-mode applications are currently being launched through the SEMIP.) However, in considering model-to-observation comparisons such as these (whether predictive or retrospective), we must bear in mind that BlueSky is *not* itself a model. It is a modeling framework, or a model-management system. It facilitates the ease of use and interoperability of varied, independently developed models commonly used to assess the air quality impacts of wildland fires. As such, results depend on the specific chain of model choices selected for use in the BlueSky modeling steps, as well as the inputs. BlueSky cannot be directly credited (nor blamed) for the scientific quality of the models operating within its structure. However, because of its modular structure and model interoperability, BlueSky presents new opportunities to easily investigate and intercompare the effects of various model choices or alternative inputs on predictive accuracies. Presently, no *a priori* guidance exists favoring any specific combination of models or model settings; however, some significant sources of uncertainty associated with model choices and inputs have been identified through recent intercomparison case studies. The intent of the SEMIP is to further this area of research and establish findings that ultimately can be translated into practical modeling guidance. However, prior case studies examining predictive accuracy provide a starting point for setting research priorities.

Two BlueSky-facilitated retrospective case studies of model performance and sources of uncertainties for large wildfires in the western United States were recently reported by Larkein et al. (2009) studying the 2005 Frank Church fire in Idaho and the 2001 Rex Creek fire in Washington.[7] For these case studies, long-range transport of pollutants compared well with the

[7] Fire information was collected as flown perimeters from the Incident Command Teams where possible, ICS-209 reports otherwise. Model pathways were set up by varying the fuel loading, consumption, and emissions models, while holding constant all other model choices and inputs (e.g., the CALPUFF dispersion model, fire information, and meteorology from the FCAMMS).

extents of plumes observed via satellites, indicating that long-range meteorology and dispersion were modeled realistically (with MM5/CALMET and CALPUFF). However, near-field concentrations of $PM_{2.5}$ were generally under-predicted. Investigating potential causes of the under-predictions, the investigators offered the following major findings:

- Quality of inputs—i.e., fire information and meteorology—is critical.
- Making different choices about which fuel loading and consumption models to apply can cause emissions estimates to vary by more than a factor of 10. This variance also affects estimates of plume rise, which in turn, directly influence near-field predictions of $PM_{2.5}$ concentrations.
- Plume rise is also impacted by assumptions concerning fire behavior. Treating a large fire as a single flaming core versus multiple cores alters outputs significantly. Generally, better model performance was observed when multiple cores were modeled.

The modifications and enhancements made to BlueSky systems through the NASA-funded project either directly address or will support further investigation and reduction of each of these sources of uncertainty. The newly available model interoperability is already facilitating rapid and cost-effective intercomparison studies of the effects of model choices and plume rise calculations (through the SEMIP). Within the next three to five years, accurate assessments of these effects are expected to yield practical modeling guidance and research priorities for technically improved models, hence better predictive accuracy among the array of models applied in the fields of fire science and smoke modeling.

In addition, the use of SMARTFIRE coupled with BlueSky has produced a clear improvement in the completeness of the fire emission inventories available for real-time, predictive modeling across the United States. We performed an intercomparison of emission inventories developed using SMARTFIRE (reconciling HMS data and ICS-209 reports), MODIS alone (which is one of several instruments used for compiling the HMS data), and ICS-209 reports alone as fire information inputs (Sullivan et al., 2008) for the period from 2003 through 2006. **Figure 3-1** shows the annual average area burned by state for the three fire information sources. In the West, the totals are similar for all three data sources. (The exception is Nevada, where an incorrect ICS-209 value is much larger than the others and was the result of a typographical error committed in a single daily report. The error was corrected on subsequent daily reports, but this example highlights the type of human error that commonly occurs in ICS-209 data.)

Note that total burned area in the West is dominated by wildfires, which is captured well both by ground reports (ICS-209s) and satellite (MODIS). The agreement suggests that SMARTFIRE is successfully achieving its goal of reconciling ground reports and satellite data while minimizing double-counting. The fires in the southeastern United States are largely prescribed burns, the vast majority of which are not subject to reporting in the ICS-209 system. Both MODIS and SMARTFIRE report area burned for the Southeast, but SMARTFIRE estimates over twice the total area throughout the region. A reason for this difference is illustrated in **Figure 3-2**, which shows the density of fire hot-spot pixels detected by MODIS and HMS for 2004 in the Southeast. SMARTFIRE uses NOAA HMS as its source of satellite-derived fire detects. HMS gathers fire detects from several instruments, including MODIS.

Although MODIS is the most sensitive and sophisticated instrument referenced by HMS, MODIS data are typically only available twice a day over the lower 48 states. Thus, small, short-lived fires, or fires burning during cloudy conditions (such as many prescribed fires in the Southeast) are easily missed by the MODIS instrument. However, HMS also incorporates fire detects from GOES and AVHRR. GOES is particularly useful for detecting short-lived fires because, as a geostationary instrument, it detects fire every 30 minutes. Another key advantage of HMS over other satellite-derived data products is the human quality control that is applied to the data set. The results of this can also be seen in Figure 3-2. Certain very hot industrial sources often result in false positives in fire detection algorithms. The standard MODIS product, for example, often shows fires in Detroit, Michigan; Cleveland, Ohio; and the northern tip of West Virginia, which are known industrial sources. These false detects are generally culled by the human-mediated quality assurance process of HMS data.

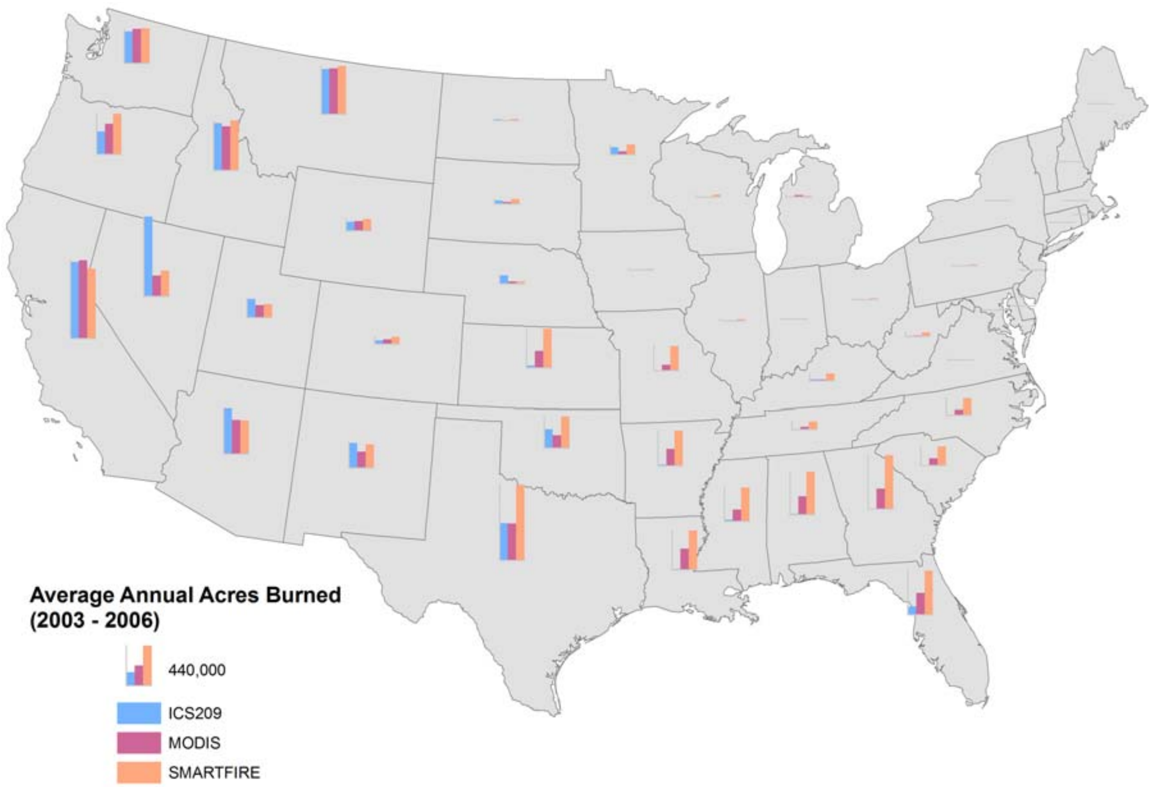


Figure 3-1. Annual average area burned by state for ICS-209 reports, MODIS fire detects, and SMARTFIRE.

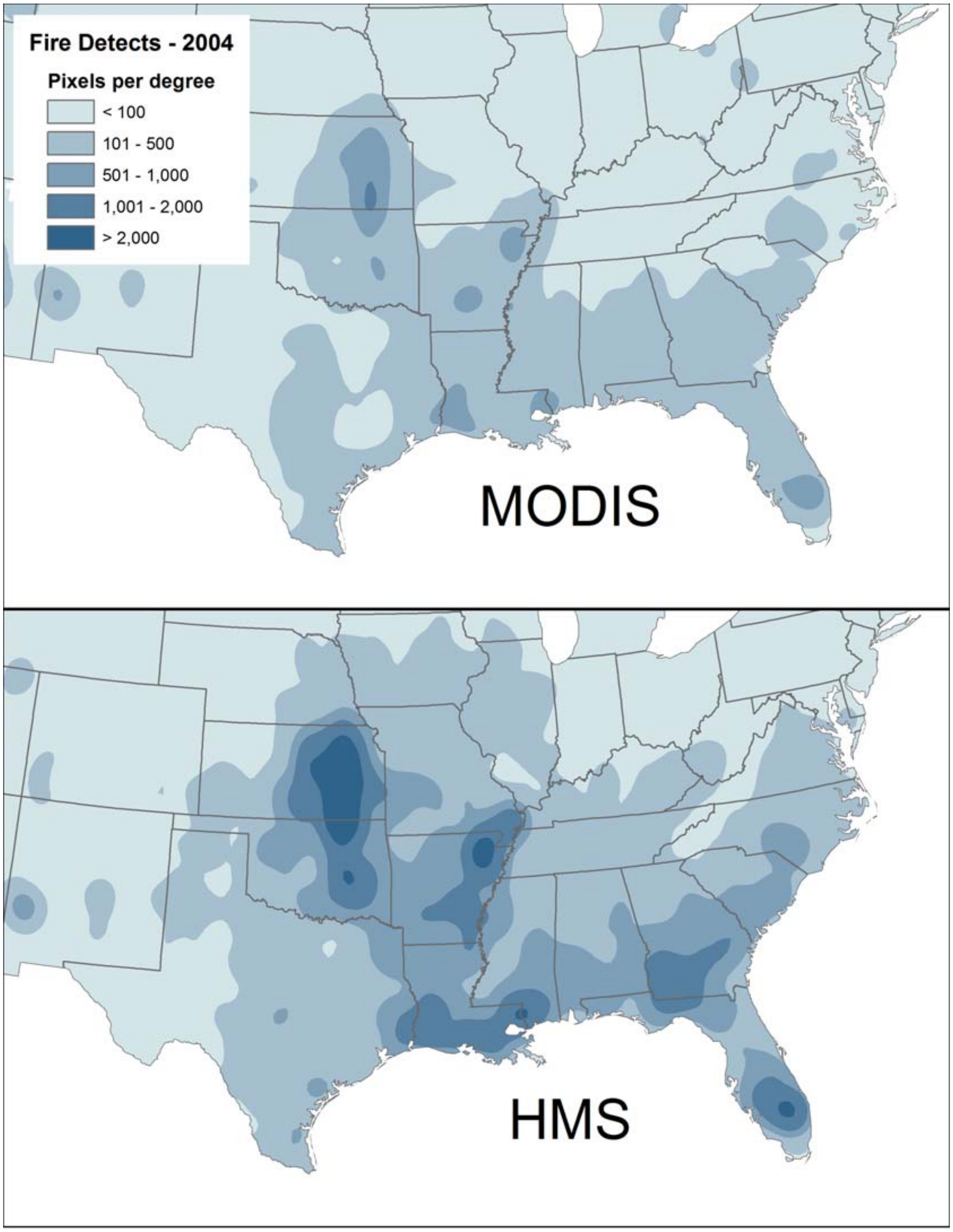


Figure 3-2. Fire pixel hot-spot density for MODIS and HMS for 2004.

Satellite-derived fire information, with its improved spatial and temporal resolutions (when compared to ICS-209 reports—i.e., the only other source of real-time, national-scale fire information), effectively enables the BlueSky modeling chain to treat fire behavior more realistically. Fires are spread out geographically and migrate from day to day appropriately across the landscape (rather than being assigned to a single, fixed coordinate), which in effect, splits each large, ICS-209-reported fire more appropriately into multiple cores (likely improving plume rise performance, as suggested by Larkin et al. (2009). This improved spatial representation also produces better mapping to fuel loadings and more refined emission estimates. **Figure 3-3** shows the B&B Complex fire, which burned in Oregon in 2003, as detected by several sources. The black outline is the final perimeter of the fire as determined by helicopter over-flights after the fire had stopped growing. The MODIS hot-spot fire pixels and SMARTFIRE fire points for the entire time period of the fire are plotted along with the ICS-209 report location. Although the final fire perimeter is over 20 miles wide, the ICS-209 location is only reported as the ignition point. Thus, for emissions modeling, the fuel loading and resultant consumption and emissions estimates do not vary throughout the life of the fire. The background of Figure 3-3 shows the total fuel loading from the FCCS fuel map. The fire ignited in a region of relatively low fuel loading, but spread to areas with heavier fuel loadings. The satellite-based data are able to capture and model that difference. In the case of the B&B Complex fire, the modeled emissions from SMARTFIRE are about four times greater than the emissions using ICS-209s only, despite a similar estimate in the total area burned.

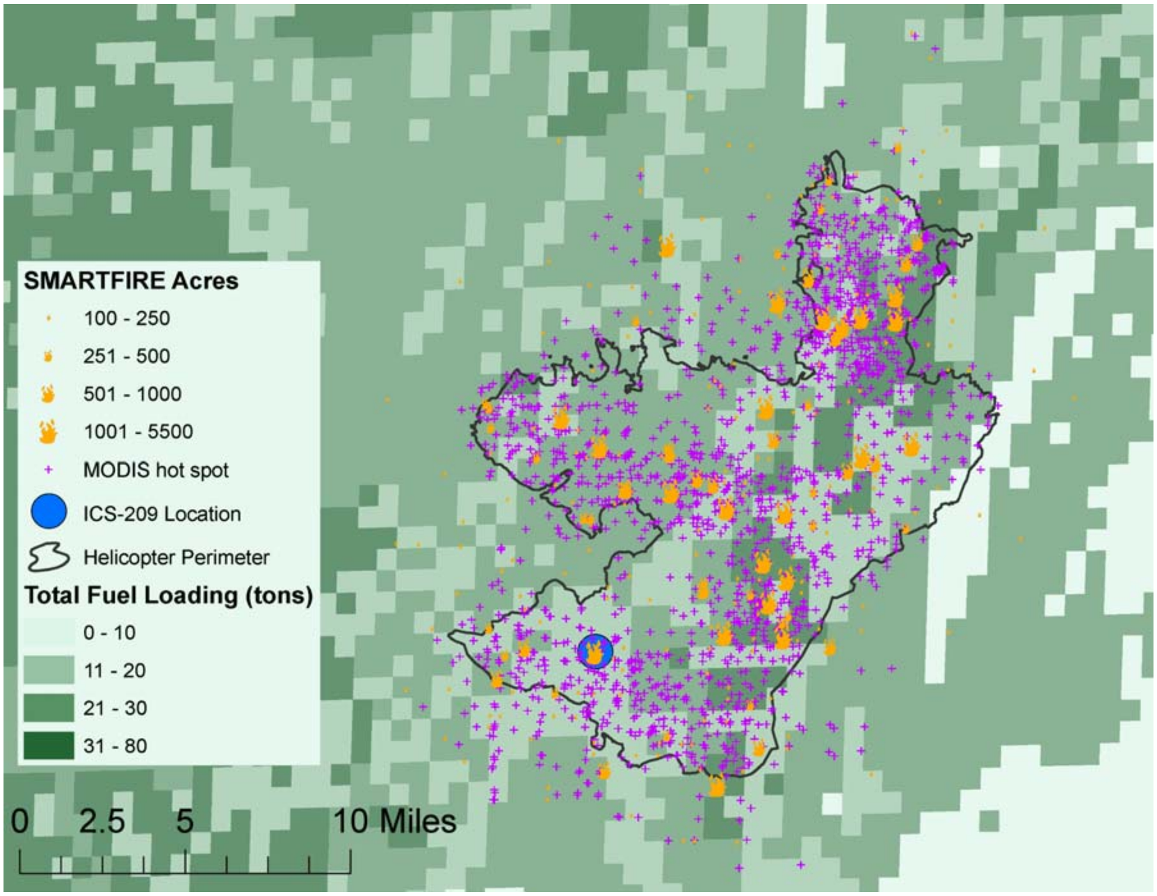


Figure 3-3. Illustration of fire information data and fuel loading data for the 2003 B&B Complex fire in Oregon.

In summary, the addition of satellite-derived fire information has quantifiably improved the completeness of data inputs to the models available in the BlueSky Framework, particularly when operating in a predictive mode or when studying remote or unreported fires across the United States. The potential improvements to retrospective modeling accuracy are not yet fully realized, but are now possible and are moving forward as a result of SEMIP and the BlueSky systems' capabilities made possible by the NASA-funded project.

3.2 System Usability and User Satisfaction

System usability and user satisfaction were considered by measuring changes over time in the numbers of users and web traffic statistics (e.g., "hits", IP sources, help requests). In addition, registered BlueSky Gateway users were queried for feedback using a web-based survey.

Traffic at the BlueSky Gateway website has been observed to consistently double every six months since its inception. Currently (October 2009), 50 to 100 unique IP addresses visit the site daily, primarily to access the SMARTFIRE data viewer and Gateway predictions of $PM_{2.5}$ concentrations. The distribution of site visitors is national in scope as illustrated in **Figure 3-4.**

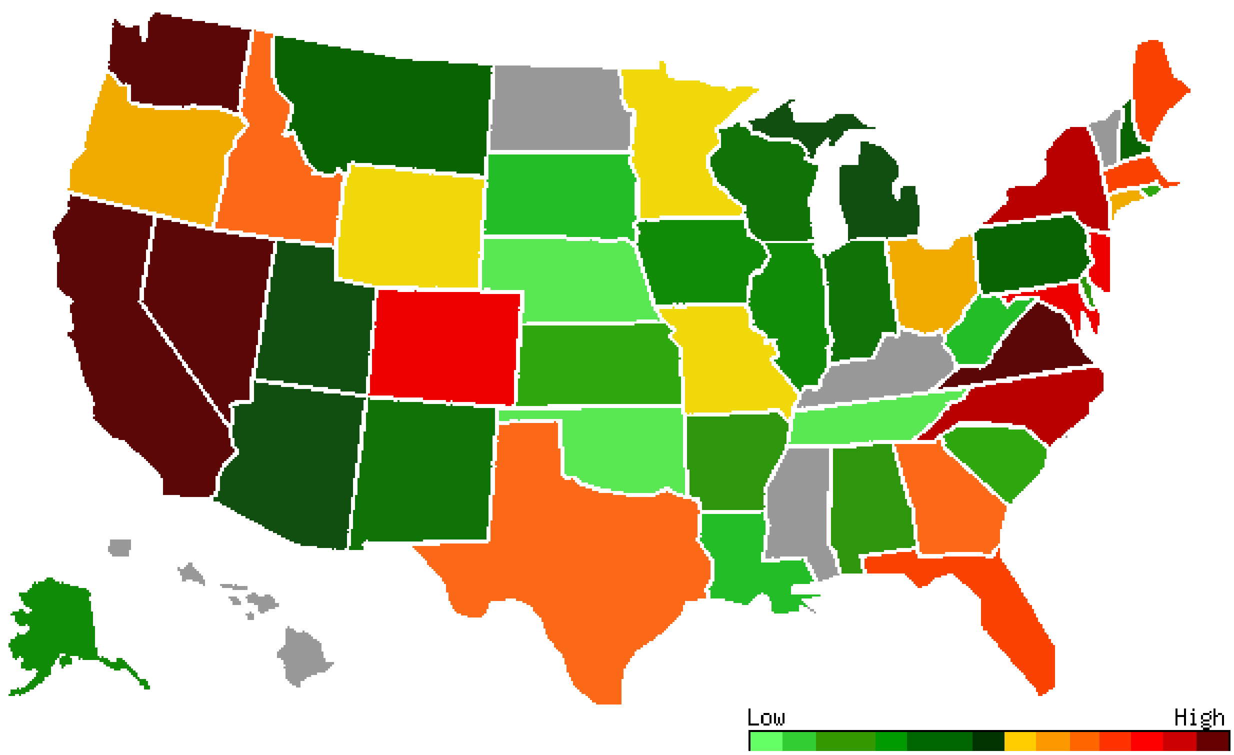


Figure 3-4. Geographic distribution of site visitors to the BlueSky Gateway across the United States.

In the summer of 2009, 116 registered BlueSky Gateway users were invited to participate in a web survey. Of those invited, 36 participated, corresponding to a 31% response rate (see Appendix D)—a fairly high participation rate for voluntary, web-based surveys. Most respondents (80%) reported using the site to access fire information, meteorological model predictions, or smoke or air quality predictions. In addition, most respondents (76%) felt the available information was very useful or useful; 15% felt it was somewhat useful; and only 9% felt it was not at all useful. Roughly half the respondents reported using the information to facilitate operational or policy-related decisions made by their organization. Examples of such decisions included calling air quality alerts, performing exceptional/natural event assessments, making prescribed burn decisions, and developing emission inventories for SIPs. Some users cited areas of desired improvements, including a return to better addressing the needs of prescribed-burn decision makers and better technical support and training. These needs are in the process of being addressed through, for example, the BlueSky Playground tool, publications, and technical documentation.

3.3 System Effectiveness

System effectiveness was considered by addressing whether adverse health effects from smoke conditions were avoided, the geographic extent of the jurisdictions of system users, and the frequency with which users state their intentions to incorporate the emission inventories or predictions into state local, or federal emission inventories or SIPs.

The clearest examples of health effects mitigation occurred during the 2008 California wildfires when multiple agencies and tribes in California and Oregon directly referenced the ESRS in calling air quality alerts and health advisories. CARB reproduced the forecast graphics in a public health advisory; Lane Regional Air Protection Agency (Eugene, Oregon) used the forecasts to notify the Olympic Committee of potential smoke impacts during the Olympic Trials in Eugene; and several local California agencies and tribes indicated using the forecasts to inform public health advisories during the 2008 wildfires.

In addition, about half of BlueSky Gateway survey respondents reported prior or future use of BlueSky systems for operational or policy-related decision support (such as supporting air quality forecasts or health advisories, developing SIPs, or calling burn/no-burn decisions). These respondents distributed all over the United States, from California, Nevada, Oregon, Washington, Montana, the Midwest (the nine-state Central Regional Air Planning Association region), Mississippi, North Carolina, Georgia, and Connecticut. Most of these states became part of the BlueSky user community as a result of the products of the NASA-funded project. The use of BlueSky systems by EPA for supporting NEI development also represents a major geographic expansion of the applicability of BlueSky systems for decision support. Many states rely on the NEI for air quality planning purposes.

3.4 Benchmarking Gaps

The accuracy and uncertainty of SMARTFIRE's algorithm for estimating the sizes of burned areas from satellite data is an area in need of some further research. Additional existing data should be assembled and applied to (a) improve algorithm tuning (e.g., Figure 2-4) and/or (b) characterize performance by comparing to real-world observations. This need is particularly important for better understanding small fires at or near the limit of satellite detection in size (roughly 100 acres or less). This research area is currently being considered for funding by EPA's Emission Inventory Group.

Decisions such as air quality alerts, health advisories, or burn/no-burn decisions translate into air quality and health benefits as the result of voluntary changes in behavior. Thus, the frequency and extent of changes in behavior resulting from operational or policy-related decisions is another area of research interest. Investigating this issue would involve expanding user surveys or performing random public surveys to characterize whether and how often changes in behavior occur as a result of decisions that have been assisted by BlueSky-enabled systems.

4. Transition Plan

The BlueSky-SMARTFIRE system relies on several NASA and non-NASA products for daily fire location information, including MODIS, GOES, and AVHRR instruments onboard multiple platforms. Each instrument type has its own algorithm, acquisition method, and expected lifetime. New missions that are expected to replace or improve current products include the Visible Infrared Imaging-spectro Radiometer Suite (VIIRS) and the GOES-R ABI.

Rather than acquire data from each of the instruments directly from various data warehouses, the BlueSky team leveraged the work of the NOAA HMS. The HMS is an operational program run by the NOAA Satellite Services Division that collects fire information from available NASA and NOAA sensors, applies human quality control, and provides the data in near real time every day. As new NASA and NOAA missions go online, HMS will incorporate the new products into its processing stream. Because of this insulation between BlueSky and the satellite products, transitions to new NASA missions will require minimal work. No changes will need to be made to data acquisition processes; however, new products may behave differently, in terms of sensitivity, accuracy, and precision. The algorithms developed to estimate area burned from active fire detection will likely need to be re-tuned in the future.

5. Lessons Learned and Recommendations

Over the course of the NASA-funded project, the team learned several valuable lessons. Re-engineering the BlueSky system to have a modular, open-source architecture opened unexpected pathways to its future longevity and general use in novel applications. Modularizing the BlueSky Framework allows efficient intermodel comparisons, which in turn, permits rigorous examination of variability due to model choice. It also enables quick development of different customized output products for different classes of users, whose needs may range from complex model intercomparison analyses to graphical visualizations of smoke to simple text reports. These abilities, as well as the open-source nature of the code, make end users more comfortable using the BlueSky products. And partly as a result of these developments, strong support for BlueSky systems came from programs that were not immediately foreseen at the beginning of the project. Most notably, support from the JFSP to leverage and further develop BlueSky systems to support the SEMIP and the BlueSky Playground application was an unanticipated success. These JFSP-funded projects highlight how BlueSky systems are being referenced as a standard or a paradigm for integrative modeling in the fields of fire sciences and smoke impacts. Acknowledging this unexpected but gratifying trajectory, the project team recommends a degree of fluidity in the benchmarking processes for decision-support systems. This flexibility would help highlight outcomes that may not have been predicted at the beginning of a project.

In addition, the project team noted some useful lessons that were practical in nature with respect to project execution. We found that applying stable, pre-existing operational systems (such as the HMS) greatly reduced technical challenges and risks to project success. We recommend this approach whenever the opportunity is available. In fact, we are applying this thinking to future BlueSky systems developments that will leverage existing satellite-observation products produced by the EastFire group at George Mason University and the MISR group at NASA.

We also acknowledge that issues troubleshooting inaccessible problems in commercially vended software were, at one point, a significant risk to the overall project success. The project team resolved these issues with significant difficulty. Using *mature*, open-source tools for systems development would have offered greater under-the-hood access for systems troubleshooting and control. However, during project planning, we also had to recognize and weigh the benefits of full access to open-source software code against the risks of the code's suspected instabilities due to its relatively immature, untested stage of development. (Further, the decision—commercial tools versus equivalent open-source tools—had to be considered with some urgency given the existing needs for improved BlueSky systems at the time. We could not simply wait an unknowable period of time for available open-source tools to reach a mature development cycle. But by a similar token, vendor warranties and technical support are not necessarily up to the required standards for timeliness and quality.) By the end of the three-year NASA project (at the time of this writing), the development cycle of the relevant open-source code has reached a more mature stage of development. Thus, we are currently porting key functions from a commercially vended tool to an open-source equivalent to gain further access and control. In light of our experience, we urge careful consideration of the risks that may arise when applying software tools that restrict access and control of the underlying code.

Finally, the redevelopment of the BlueSky framework into a modular system has been key to its continued success. In making BlueSky modular, we found that it was most useful to define interfaces at each point where modeled data changes dimensionality, for example, the addition of a time component. To support modularity, it is critical to use physical (measureable) units without resorting to the use of magic index values or other hidden tables. Finally, it us very helpful to use the simplest possible standards, such as comma separated text files, that the community can easily access and understand using basic tools.

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Appendix A

SMARTFIRE Algorithm Description

SMARTFIRE Algorithm Description

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INTRODUCTION

For large wildfires and wildland fire use (WFU) fires for which there is a federal response, Incident Command Summary reports (known as ICS-209 reports) are created on a near-daily basis. ICS-209 reports contain useful information about particular fires or fire complexes from the incident command team on the ground, such as descriptions of the fuel loading, growth potential, and type of fire. However, ICS-209 reports also have several limitations. Daily estimates of actively burning areas are required, but ICS-209 reports provide only the ignition point of the fire and an estimate of the total area burned over the lifetime of the fire. For large fires, active flame fronts can move dozens of kilometers from the original ignition point of the burn. More importantly, ICS-209 reports are only created for a small subset of fires. Fires that are not tracked with ICS-209 reports include prescribed burns, agricultural burns, and wildfires for which there is no federal response. Taken together, these missing fires represent a large fraction of the total area burned and resulting smoke emissions. The National Interagency Fire Center (NIFC) reports that at least 9000 km^2 of prescribed burning has been accomplished each year since 2001 in the US, representing up to 40% of the total area burned (http://www.nifc.gov/fire_info/fire_stats.htm).

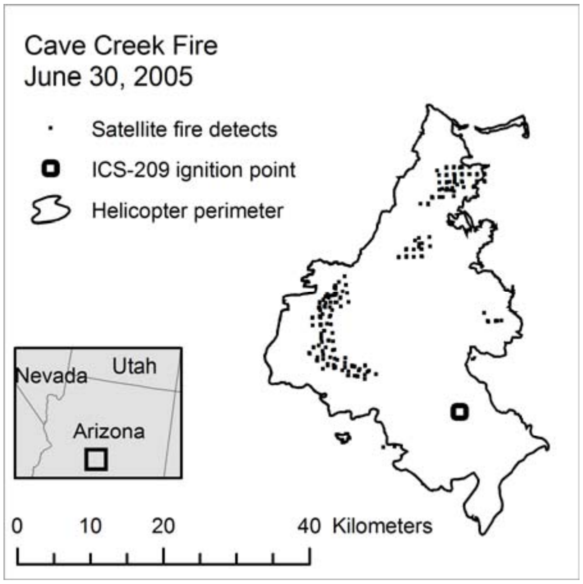
Numerous jurisdictions have burn authorization and reporting systems that provide information on prescribed fires. These data systems are the primary source of information for prescribed fires. Unfortunately, these individual systems were not developed to be interoperable which introduces difficulty in synthesizing their information in a regional- or national-scale system. For example, formats are inconsistent, contain different burn information, are difficult to acquire, and include information on potential prescribed burns that may never occur. Some of these issues are currently being addressed with the Fire Emissions Tracking System (FETS), which will provide a unified burn reporting system for the western United States (http://www.wrapfets.org/).

Near real-time fire information is also available from satellite-derived measurements (e.g., Dozier, 1981; Justice et al., 2002; Prins and Menzel, 1994; Li et al., 2000). Fire information from current space-borne instruments provides many advantages over ground-based reporting systems, including daily or better temporal resolution, the ability to detect relatively small fires, and consistency across jurisdictions. However, satellite-derived fire observations are limited by false positive detections, interference from clouds, and limited information about the total area burned. Total area burned can be derived from analysis of burn scars from satellite data (Li et al., 2004), but satellite burn scar data are not currently available in near real-time (i.e., data available on the day of detection). In the absence of burn scar data, other studies have used the sensor's nominal resolution (e.g., 1 km^2 for MODIS) as an upper limit of the total area burned by the fire (Wiedinmyer et al., 2006), sensor-based calculations of Fire Radiative Power to estimate the instantaneous burning area (Wooster et al., 2005), or used regression tree analysis to develop area-per-pixel relationships dependant on forest cover, region, and pixel cluster size (Giglio et al., 2006).

The Satellite Services Division (SSD) of NOAA’s National Satellite and Data Information Service (NESDIS) produces a daily quality controlled fire and smoke analysis for the United States using the Hazard Mapping System (HMS) (Ruminski et al., 2006). The HMS integrates satellite data from three instrument types (Geostationary Operation Environmental Satellite (GOES), Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced High Resolution Radiometer (AVHRR)) onboard seven different satellite platforms. Trained NOAA satellite analysts use the output from automated fire detection algorithms as well as various ancillary data layers. The automated fire detection algorithms produce false detections, especially in areas of high surface reflectance, sun glint, or high surface temperature (Hoelzemann et al., 2004; Giglio, 2005). The analysts review fire detects from the algorithms to reduce false detects and scan the satellite imagery and add fires that the algorithms have not detected (i.e., if a smoke plume detected in visible imagery has no associated fire detect, it will be added). The analysis is updated at http://www.ssd.noaa.gov/PS/FIRE/hms.html several times a day. The HMS is described by Ruminski et al. (2006),

Ideally, a daily, operational fire reporting system would take advantage of all available data sets to produce the most complete picture of daily area burned; however, simple summation of all data sets will result in double counting of some fires due to information overlaps. Multiple data sets can be combined if the data overlaps can be identified and rectified. Identifying data overlaps is difficult due to both the differences in the data sources and the fact that a fire can move many kilometers from its original ignition point over the course of its lifetime. For example, Figure 1 shows a June 30, 2005 snapshot of information for the Cave Creek wildfire, which burned over 800 km^2 of Arizona wildland in 2005. This fire ignited on June 22, 2005. The reported burn perimeter derived from a helicopter overflight shows the approximate final shape of the Cave Creek fire. Hot-spot points detected by satellite show the actively burning flame fronts for the June 30, 2005. From the helicopter perimeter, (which we do not have reliable access to in an operational time frame), it is obvious that all of the clusters of satellite fire points are actively burning sections of the same wildfire event. The ground-reported (ICS-209) fire ignition point is 50 km from some of the satellite points. To use multiple overlapping data sets, an algorithm for reconciliation must be developed. In this manuscript, we describe the SMARTFIRE algorithm and database system that combines disparate data on fires into a unified datasets. SMARTFIRE was developed specifically for use in the BlueSky smoke modeling framework (Larkin et al., 2009)) although, in principle, it should be portable to other modeling and emission inventory applications.

Figure 1. An illustration of the single-day satellite fire detection pixels for the day of June 30, 2005, the ICS-209 helicopter-flown final burn area perimeter, and ICS-209 ignition point for the Cave Creek Fire in Arizona.



METHODS

Data Sources

SMARTFIRE is an algorithm and database system developed and built within a geographic information system (GIS) framework that combines multiple sources of fire information and reconciles them into a unified data set. It was developed to take advantage of multiple data sources while avoiding double counting. The BlueSky system, developed by the US Forest Service, is a framework that attempts to serve these needs by connecting several submodels to produce predictions of emissions and resulting concentrations of smoke pollution from fires, both in near-real-time and retrospectively (Larkin et al., 2009).

SMARTFIRE was built with the capability to ingest multiple disparate fire reporting data sets to produce a single unified data set. Currently, two input data sources have been implemented within SMARTFIRE: (1) ICS-209 reports and (2) satellite data from the NOAA Hazard Mapping System (HMS).

Development of the SMARTFIRE Algorithm

The SMARTFIRE algorithm consists of four general steps, outlined for a small area in Figure 2 a-d:

a. Daily input data are loaded into the geodatabase.
b. Individual data points are associated together by proximity into Fire Perimeters representing contiguous burning regions.

c. Fire Perimeters are associated to Fire Events by proximity in time and space. Fire Events grow over time as long as the fire continues to be detected and represent the history and progression of the fire.

d. Fire Perimeter polygons are converted to point data for modeling by calculating centroids. For each model point, an area burned is estimated.

(a) Input Data

Daily input data are loaded into a geographic information system database (geodatabase). The currently implemented data sets, ICS-209 ignition points and HMS fire pixels, are both point data sets (i.e., they have a coordinate location but no associated shape); however, the algorithm could also incorporate line or polygon sources. The data for a small area on a single day are shown in panel (a). The region shown contains a single ICS-209 reported fire and many HMS fire pixels.

(b) Create Fire Perimeters

Data are converted from points to polygons by drawing circles of a specific radius centered on each point and then dissolving all intersecting circles into a set of disjoint polygons called Fire Perimeters (b). This is done to associate nearby data into contiguous burning areas (clusters) and to minimize double counting from multiple data sources detecting the same burning area. The radius varies by data source. For HMS, the value is an adjustable parameter set at 750 m, which assures that adjacent pixels are associated (HMS data are on a 1-km resolution grid). ICS-209 reports provide cumulative instead of daily area burned. To create a Fire Perimeter for an ICS-209 report, an estimate of the daily area burned is made by subtracting the cumulative area of the current report from the cumulative area of the previous report of the same name.

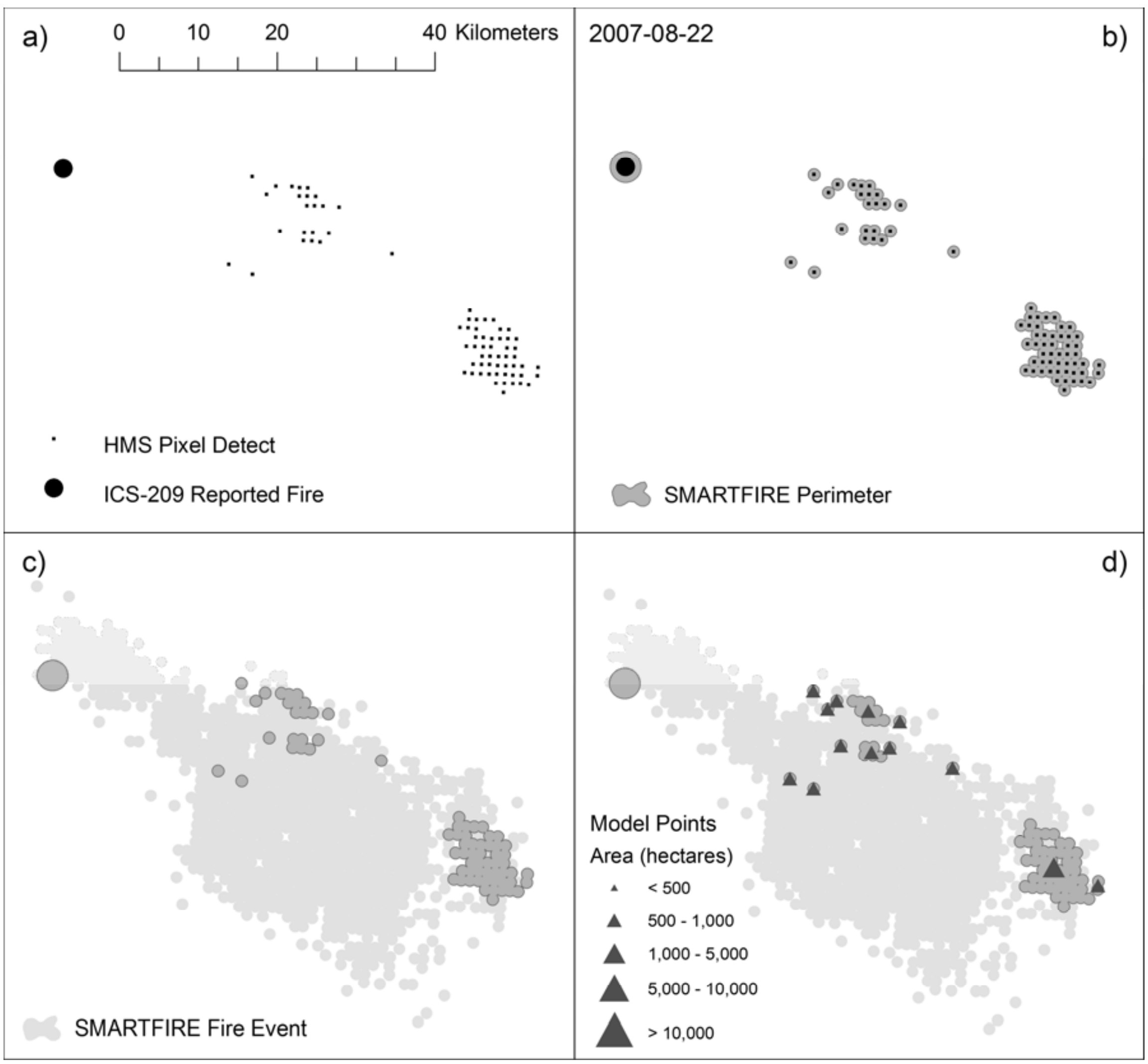
(c) Associate Fire Perimeters to Fire Events

The next step in the algorithm is to associate Fire Perimeters to active Fire Events in the SMARTFIRE geodatabase by proximity. A Fire Event is a collection of fire information that has been associated together. The Fire Event groups information into collections that resemble the way fires are understood in the fire management community. For example, all detection information from a single named fire should be associated into a single Fire Event. Fire Events can span multiple days. Fire Perimeters are associated with Fire Events by drawing a buffer around the Perimeters and intersecting them with active Fire Events. Buffer distance is a function of the Perimeter area (500 m for Perimeters less than 1.77 km^2; 1500 m for larger Perimeters). Buffer distances were selected by examining several wildfires and wildfire complexes and determining the distances which minimized false associations while maximizing positive associations. If no active Fire Event is found within the buffer distance, one is created. After four days without new data, Fire Events become inactive and are no longer considered in the algorithm (i.e., additional Fire Perimeters will be assigned to new Fire Events). Four days was chosen to account for gaps in the data stream, such as when clouds obscure satellite detections or no ICS-209 reports are produced.

(d) Create Model Points

The SMARTFIRE geodatabase provides activity data for predictive and historical modeling of air quality impacts from fires, such as the BlueSky smoke modeling framework. BlueSky requires burning point locations identified as latitude/longitude pairs and an associated estimate of area burned. Fire Perimeter polygons cannot be used as inputs for BlueSky and must be converted into point locations with area estimates. Points are created by calculating centroids from HMS Fire Perimeters (d). ICS-209 based perimeters are used if no HMS perimeters are available for the Fire Event on the specific date. Area burned estimates for each model point are not equal to their parent Fire Perimeter areas, but are scaled to them. The development of area estimates for model points is detailed below.

Figure 2. SMARTFIRE reconciliation algorithm illustration. (a) One day of input data (ICS-209 report and HMS pixels for the Zaca Fire on 2007-08-22, (b) SMARTFIRE Perimeters added to each data source, (c) the Perimeters overlaid on the active SMARTFIRE FireEvent from the previous day, (d) The SMARTFIRE Model Points at the centroid of each HMS-based Perimeter.



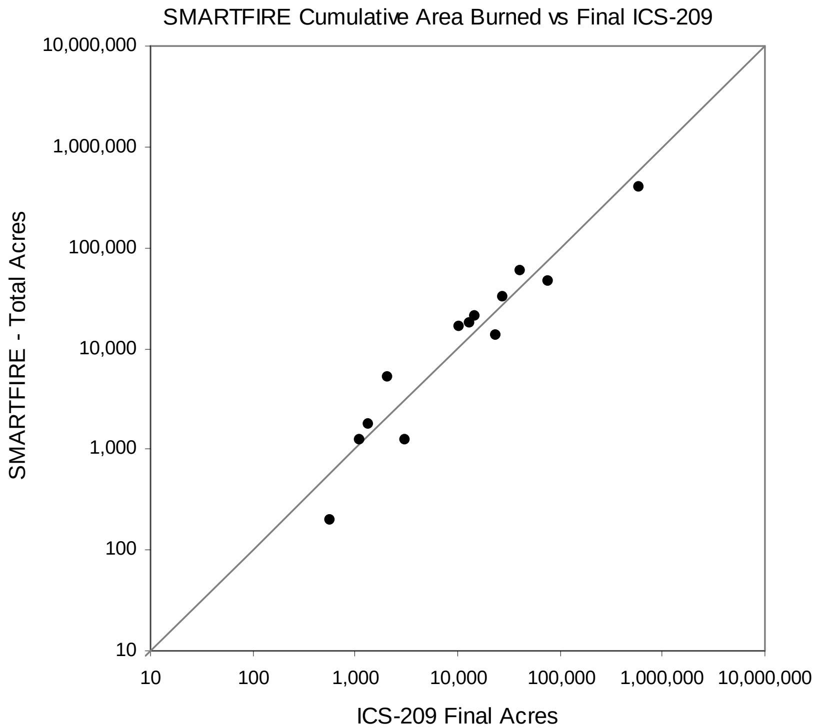
(e) Area Estimation

Satellite-derived hot-spots from HMS do not provide information about the area burned. SMARTFIRE area burned estimates for HMS data are estimated using one technique for large, multi-pixel fires and a second technique for small, single-pixel fires.

Large wildfire burn area estimates were derived by comparing HMS pixel perimeters to ICS-209 burned area polygons. For large wildfires, the responsible incident command team produces burned area polygons produced by helicopters equipped with GPS data loggers flying around the perimeter of the fire. The area within the last flown perimeter represents an estimate of the total area burned. The area per pixel in SMARTFIRE was determined by correlating final helicopter perimeter areas to total cumulative HMS pixel perimeters for 14 large fires (Figure 3). The fires ranged from about 2 to 2500 km^2 in size over various parts of the United States. The resulting area per pixel is 0.6 km^2. However, not all of the area encompassed by a helicopter-flown perimeter will have burned in a typical wildfire. Thus the actual burned area (sometimes called the blackened area) will be some fraction of the perimeter area. Based on past research, we estimated this fraction as 0.8 (Tom Pace, EPA, personal communication). Accounting for the estimate of only 80% of the helicopter perimeter area burned results in a per pixel area of 0.49 km^2.

Small single-pixel fire burn area estimates were derived by a comparison of a silvicultural prescribed burns database with HMS fire detects. The multi-pixel burn area estimate does not apply to small fires, which may be detected by only a single satellite pixel. To estimate the per pixel area burned by these fires, we used a silviculture database provided by the state of Georgia. The database provides information on the number and total acreage of fires by month and county for the year 2002. According to the database, about 20,000 prescribed fires burned a total of over 3100 km^2 in 2002. Unfortunately, HMS data do not exist for the full year in 2002. The prescribed fire count and total area were compared to HMS pixel counts for Georgia for 2004, 2005, and 2006. Pixel counts for these years ranged from 6,700 to 8,700 and averaged 7,723. The fires in the Georgia database were mostly small in size (< 0.4 km^2) so the vast majority of fires were detected by a single HMS pixel. Thus, HMS detects approximately 40% of the small fires in Georgia. Many fires are either too small to be detected or obscured by cloud cover or canopy. To account for the total reported acreage, we divide the annual average HMS pixel count by the total reported acreage in the database. The resulting area per pixel for single pixel fires is 0.4 km^2. Note that this value is much smaller than the nominal pixel resolutions for any of the instruments that HMS uses.

Figure 3. Scatter plot of SMARTFIRE total burn area estimates with ICS-209 helicopter burn perimeter areas.



Limitations

Four years (2003-2006) of daily area estimates across the continental US have been processed. Robust validation of the SMARTFIRE algorithm and its parameters is currently underway. The data used to tune the algorithm parameters were limited, especially for small fires. For example, area estimates for fires detected by a single HMS pixel are based on a prescribed fire database from the state of Georgia. This estimate needs to be corroborated with other data sources in other regions. The buffer distance parameters that dictate which ICS-209 reports and satellite pixels get reconciled have not been rigorously tested. False associations and non-associations sometimes occur.

Because SMARTFIRE was originally designed primarily to support predictions on a near-real-time basis, the possible input sources are limited. ICS-209 data are created by hand input and sometimes contain typographical errors. The most common errors are incorrect cumulative area burned from adding an extra zero to the value and transposed latitude and longitude. HMS data are currently produced on a 1-km grid that is lower resolution than some of the satellite input sources. Also, HMS does not report potentially useful values such as the fire radiative power, which could be used to calculate total emissions (Jordan et al., 2008). More refined and potentially more accurate data sources, such as satellite-derived burn scars, are available for retrospective studies. Future work will explore the incorporation of these high quality but time lagged data sets for retrospective analyses such as emission inventories.

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Appendix B

Gateway Modeling Configuration and Real-Time System

B.1 Modeling Configuration for Gateway Air Quality Predictions

Meteorological Predictions

- Pennsylvania State University/NCAR Mesoscale Model (MM5) Version 3.7
- Initial and boundary conditions from NCEP North American Model (NAM) 40-km forecast
- 129x165 Lambert Conformal grid with 36-km horizontal grid spacing and 29 vertical layers
- Simple Ice explicit moisture
- Mellor-Yamada planetary boundary layer scheme (from the Eta model)
- Kain-Fritsch cumulus parameterization
- Rapid Radiative Transfer Model (RRTM) radiation
- 5-layer soil model
- Meteorology-Chemistry Interface Processor (MCIP) version 3.1 post-processing

Anthropogenic and Biogenic Emissions

- SMOKE processing system version 2.3
- MOBILE6 for on-road mobile source emissions
- 2002 National Emission Inventory (NEI) version 3 projected to the current year using Economic Growth Analysis System (EGAS) version 4.0
- Biogenic Emissions Inventory System (BEIS) version 3.09 for biogenic emissions
- MM5 temperature predictions used in emission estimates for on-road mobile and biogenic sources.

Fire Emissions

- BlueSky Framework v3.0.0
- Fire inputs from the Satellite Mapping Automatic Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE)
- Fuel Characteristic Classification System (FCCS) fuel loading
- CONSUME fuel consumption
- Fire Emission Production Simulator (FEPS) emissions
- FEPS time profile
- Western Regional Air Partnership (WRAP) plume split
- Separate flaming and smoldering emission profiles
- Persistence modeling of future day fire emissions

Air Quality Predictions

- Community Multiscale Air Quality (CMAQ) model version 4.5.1 with modifications to support
  fire-related $PM_{2.5}$ tracer species
- 112x148 Lambert Conformal grid with 36 km horizontal grid spacing and 17 vertical layers
- Carbon Bond-IV gas-phase chemistry with Euler Backward Iterative (EBI) solver

- AERO3 aerosol chemistry mechanism for secondary aerosol formation
- Aqueous and cloud chemistry invoked
- RADM cloud processor with asymmetric convective mixing (ACM)
- Yamartino advection scheme
- Multiscale horizontal diffusion scheme
- Vertical diffusion using eddy diffusivity theory

B.2 BlueSky Gateway Real-tIme System

Monitoring Capability

- The status of each major processing task is updated on the BlueSky Gateway Prediction Operational Status web page at http://www.getbluesky.org/bluesky/status.cfm. A status check is performed at the completion each task, and the success or failure status is reported.
- As tasks are completed, graphical products are posted in real-time on the BlueSky Gateway Predictions web page at http://www.getbluesky.org/bluesky/sti/. Monitoring this web page serves as both as an operational system status check, and as a product integrity check.
- The SMARTFIRE system sends email warnings to key personnel when a SMARTFIRE run fails, or when any input data sources are missing from a successful SMARTFIRE run.
- The operational system sends informational emails to key personnel regarding system progress.

System Redundancy/Fail-Safes

- If fire information data from the latest SMARTFIRE run are unavailable due to a SMARTFIRE failure, fire emissions data are calculated by the BlueSky Framework using fire information from the most recent SMARTFIRE run, if available, and the full CMAQ forecast will be completed. Otherwise, fire emissions data from the previous day are used in the CMAQ forecast, and a full CMAQ forecast will be completed, but with no fire emissions during the third forecast day.
- If the SMARTFIRE web service is unavailable, fire emissions data from the previous day are used in the CMAQ forecast. A full CMAQ forecast will be completed, but with no fire emissions during the third forecast day.
- If the BlueSky Framework encounters a failure and fire emissions data are not produced, fire emissions data from the previous day are used in the CMAQ forecast. A full CMAQ forecast will be completed, but with no fire emissions during the third forecast day.
- If carryover concentration data from the previous day’s CMAQ forecast are unavailable to initialize the current CMAQ forecast, the system will use carryover concentration data from the CMAQ forecast from two days ago, if available. Otherwise, the CMAQ forecast will be initialized from a default initial condition, without smoke carryover, and a full three-day CMAQ forecast will be completed.

- If the entire NAM meteorological forecast is unavailable to provide initial and boundary conditions for the MM5 forecast, the initial and boundary conditions from the previous MM5 forecast will be used. A two day MM5 and CMAQ forecast will be completed.
- If there are missing or incomplete (as determined by a file completeness test) NAM meteorological forecast files, data from those missing or incomplete files are filled by interpolation, and the full MM5 and CMAQ forecasts will be completed. If more than a minimum number of NAM data files are missing or incomplete, then the initial and boundary conditions from the previous forecast will be used, and a two day MM5 and CMAQ forecast will be completed.
- If the MM5 forecast run fails, a partial CMAQ forecast will be completed using MM5 data from a previous forecast.
- NAM data downloads are managed by the Unidata Local Data Manager (LDM). The LDM captures NAM data as they distributed by NCEP. Data transfer from the LDM server to the local realtime operational machines are handled by a task management system (DATAFLOW) that sends email warning to key personnel when the transfer fails.

Appendix C

Supplemental Analyses of Model Performance

This appendix provides additional supporting analyses of model performance (in addition to the discussion provided in Section 2.3.2).

Histograms facilitate an understanding of the distribution of simulated values with respect to the distribution of observation data. Values are binned and the frequencies with which observed and simulated points occur in each bin are plotted. The 2008 northern California simulations (red) display a similar frequency (y axis) to the observation data (columns) (**Figure C-1**). At lower $PM_{2.5}$ concentrations (x axis), the simulations do not match the observed data (approximately 10 $\mu g/m^3$ or less). Rather, the simulations are more evenly distributed with a higher number of data points falling into the bins located around 20 $\mu g/m^3$. Overall, the histograms show the simulated data matching the observed data in frequency, with a few exceptions at the lower end of the concentration scale.

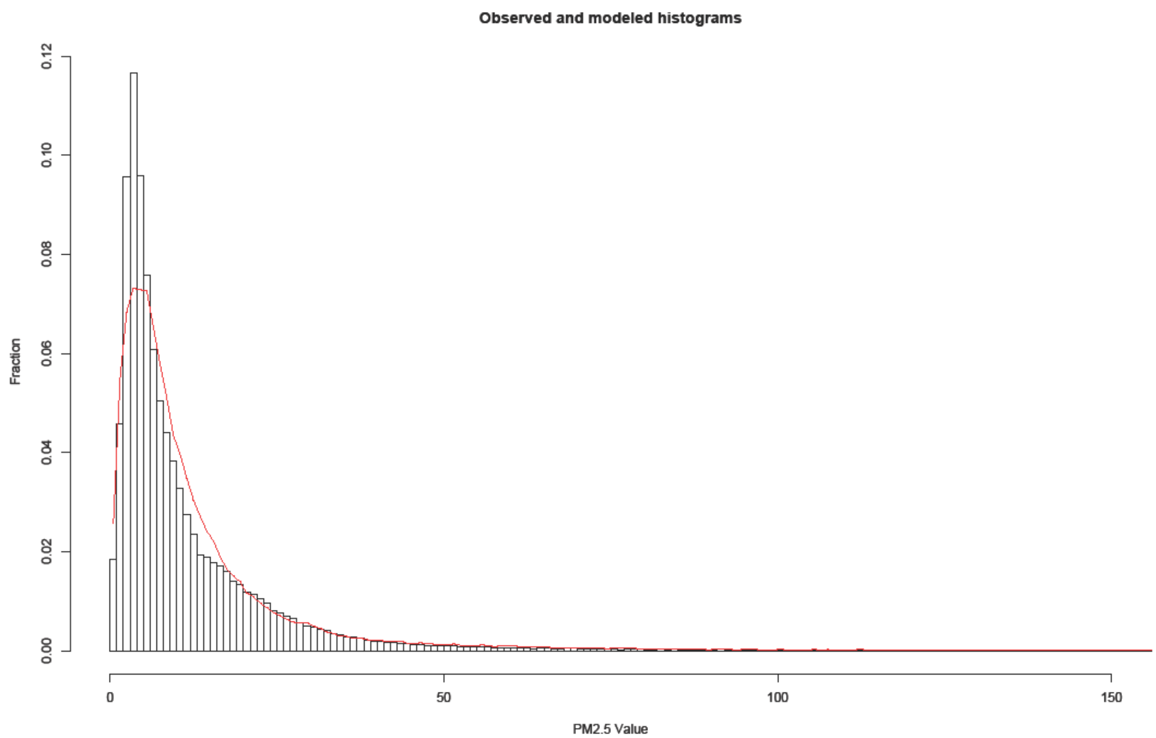

Figure C-1. Histogram plot of model results (red line) compared to binned observations (bars). $PM_{2.5}$ concentrations ($\mu g/m^3$, 0 to 150) are plotted on the x-axis; proportion of the total observations at each concentration bin is plotted on the y-axis.

The ratio of modeled to observed values data plotted against the observation data provides an easy way to quickly examine the paired data and determine performance trends. Scatter of the data at lower concentrations is expected. Ideally, the data should merge into a triangle-like shape with the peak centered on the ratio=1 line. For the 2008 northern California event, the ratio of the simulated data-to-observations (y axis) demonstrate a general under-estimation by the predictive data to the observed $PM_{2.5}$ concentrations (x axis), particularly at high concentrations (400+ $\mu g/m^3$) (see **Figure C-2**).

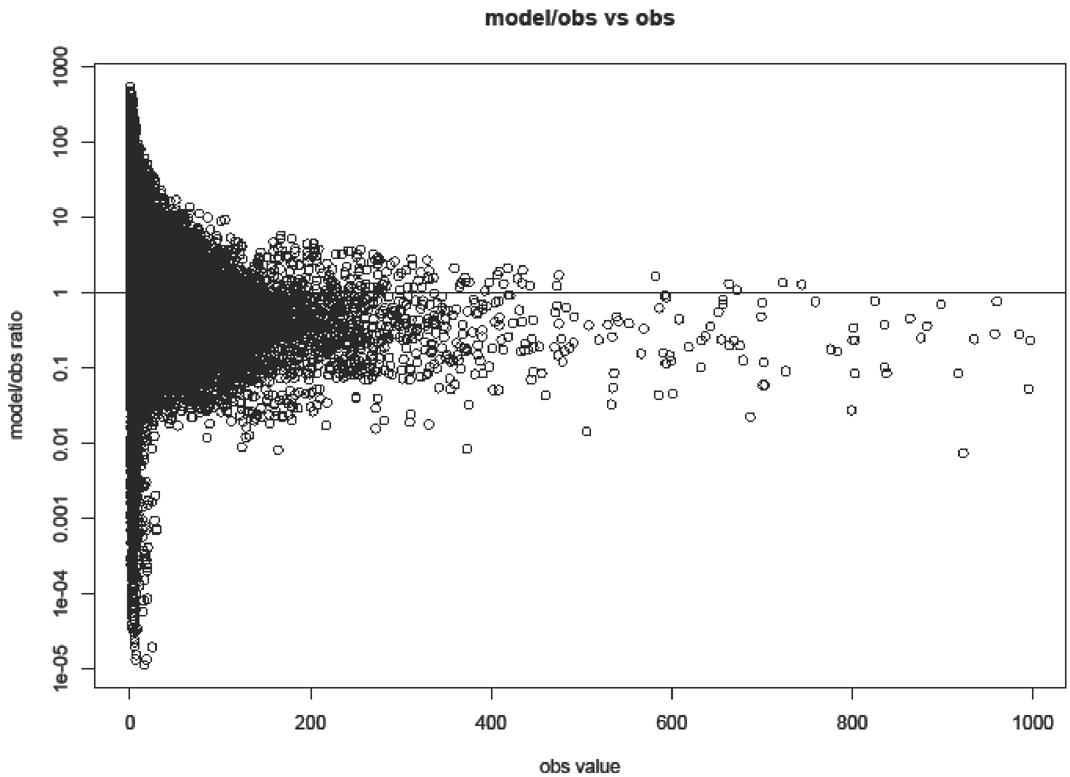

Figure C-2. Ratio of modeled to observed $PM_{2.5}$ concentrations (y-axis) plotted against the observed $PM_{2.5}$ concentration (µg/m^3, x-axis, from 0 to 1000).

To further investigate the timing of modeled peak concentrations, we examined ways of interpreting the model results to give useful information about the expected observations. We chose the simplest model—a categorical threshold forecast—where we looked for temporal relationships. If the model is predicting high concentrations, then we expect the observations to be high as well. This condition can be expressed as follows:

$$C_m \geq T_m \Rightarrow C_o \geq T_o$$

such that when the model value, C_m, reaches or exceeds a model threshold level, T_m, does the observed value, C_o, tend to reach or exceed some observational threshold level, T_o. Such relationships are determinable by examining the histogram of observed values under different model thresholds (T_m). **Figure C-3** highlights the observational values selected at varying levels of T_m. This threshold histogram for the 2007 southern California event displays $PM_{2.5}$ observed values (x axis) that occurred when the modeled value was greater than a given threshold, T_m, for T_m = 0, 5, and 10 µg/m^3. Ideally, as T_m increases the observed values selected would contain all observed values above some value. The histogram shows that for a given model threshold, many different observational values can occur though the median observational value does increase. This result indicates model skill.

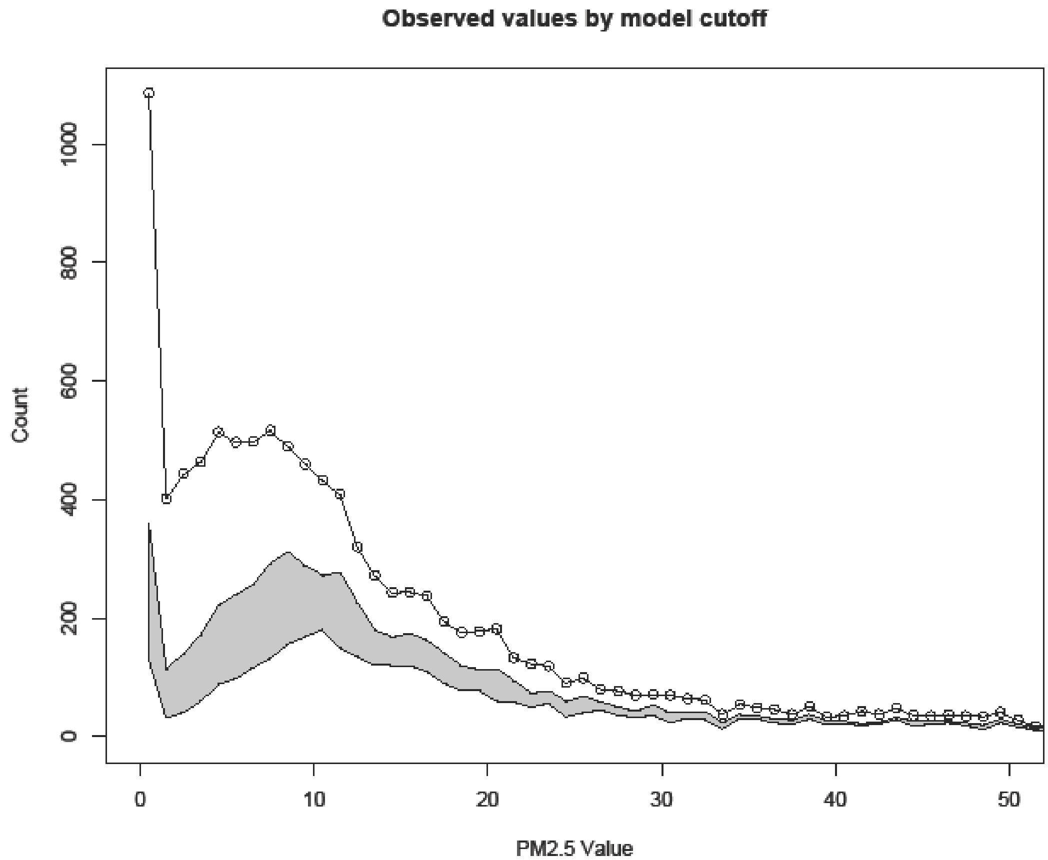

Figure C-3. Threshold histogram for the 2007 southern California event. Frequencies (count, y-axis, 0 to 1000) of observed $PM_{2.5}$ concentrations (μg/m^3, x-axis, 0 to 50) occurring when modeled value exceeds thresholds, 0, 5, and 10 μg/m^3. Each histogram is denoted by a line. Gray shading is applied between the T_m = 5 and T_m = 10 lines (such that the grey shaded area equals the difference between T_m=10 and T_m=5). Note that T_m=0 is equivalent to all observed values (open circles).

We have attempted to maximize model skill by examining all integer T_m values from 0 to 50 μg/m^3. The results suggest that the maximum skill for determining when observations exceed T_o = 35 μg/m^3 is a model threshold of approximately T_m ~ 12 μg/m^3. This balances the probability of detection (i.e., the assurance that observations above 35 μg/m^3 are detected) with the false alarm rate. However, the false alarm rate remains high for any T_m. The major reason for the high false alarm rate is the use of directly paired data in this analysis. If the model time and observation time are allowed to slightly differ, then the model performance improves significantly. That is, if the performance criteria changes from

The model predicts above T_m *at 2 p.m., so the 2 p.m. observations should be above* T_o

to a condition that would be more appropriate for predictive applications, such as

The model peaks above T_m *in the afternoon so some afternoon observations should peak above* T_o

then, the probability of detection and false alarm rates is evaluated much more favorably.

Appendix D

Survey Results

Response Summary

Total Started Survey: 38

Total Completed Survey: 36 (94.7%)

Show this Page Only

Page:

1. Identifying information:

Download

			Response Percent	Response Count
Show replies	Name:		100.0%	38
Hide replies	Organization:		100.0%	38

1.	San Joaquin Valley APCD	Mon, Jul 6, 2009 2:31 PM	Find...
2.	Environment Canada	Thu, Jun 11, 2009 2:06 PM	Find...
3.	USDA - Forest Service	Wed, Jun 10, 2009 2:34 PM	Find...
4.	environment canada	Wed, Jun 10, 2009 1:40 PM	Find...
5.	Ministry of Healthy Living and Sport	Tue, Jun 9, 2009 3:21 PM	Find...
6.	California Air Resources Board	Tue, Jun 9, 2009 9:47 AM	Find...
7.	NOAA	Tue, Jun 9, 2009 6:49 AM	Find...
8.	Monterey bay Unified APCD	Mon, Jun 8, 2009 4:13 PM	Find...
9.	NC Division Of Air Quality	Mon, Jun 8, 2009 1:13 PM	Find...

50 responses per page

answered question	38
skipped question	0

1. Identifying information: [Download]

10.	USFWS	Mon, Jun 8, 2009 12:54 PM	Find...
11.	Oregon State University	Mon, Jun 8, 2009 11:55 AM	Find...
12.	Texas Commission on Envirionmental Quality	Mon, Jun 8, 2009 11:39 AM	Find...
13.	Environment Canada	Mon, Jun 8, 2009 11:37 AM	Find...
14.	USDA Forest Service	Mon, Jun 8, 2009 11:37 AM	Find...
15.	USDA FS	Mon, Jun 8, 2009 11:32 AM	Find...
16.	USDA Forest Service	Mon, Jun 8, 2009 11:15 AM	Find...
17.	Maricopa Co. AQ Dept.	Mon, Jun 8, 2009 10:47 AM	Find...
18.	CT DEP	Mon, Jun 8, 2009 10:28 AM	Find...
19.	CenSARA/CENRAP	Fri, Jun 5, 2009 2:23 PM	Find...
20.	Washington State University	Fri, Jun 5, 2009 2:14 PM	Find...
21.	NC Division of Forest Resources	Fri, Jun 5, 2009 12:20 PM	Find...
22.	USDA Forest Service/USDI Bureau of Land Management	Fri, Jun 5, 2009 12:19 PM	Find...
23.	ruminski	Fri, Jun 5, 2009 11:08 AM	Find...
24.	Bureau of Land Management	Fri, Jun 5, 2009 7:21 AM	Find...
25.	Tall Timbers Research Station	Thu, Jun 4, 2009 12:03 PM	Find...
26.	Georgia Dept of Natural Resources	Thu, Jun 4, 2009 11:58 AM	Find...
27.	CA Air Reasources Board	Thu, Jun 4, 2009 11:15 AM	Find...
28.	US Forest Service	Thu, Jun 4, 2009 6:30 AM	Find...
29.	consultant	Wed, Jun 3, 2009 3:51 PM	Find...
30.	Oregon Dept of Forestry	Wed, Jun 3, 2009 1:30 PM	Find...
31.	Michigan Tech Research Institute	Wed, Jun 3, 2009 1:28 PM	Find...
32.	EPA	Wed, Jun 3, 2009 12:57 PM	Find...
33.	Clark County Department of Air Quality and Env Mgt.	Wed, Jun 3, 2009 12:44 PM	Find...
34.	Grayback Forestry Inc.	Wed, Jun 3, 2009 12:37 PM	Find...
35.	Missoula City County Health Department	Wed, Jun 3, 2009 12:31 PM	Find...

50 responses per page

answered question	**38**
skipped question	**0**

1. Identifying information: [Download]

36.	North Carolina Division of Air Quality	Wed, Jun 3, 2009 12:29 PM	Find...
37.	Environnement Canada	Wed, Jun 3, 2009 12:24 PM	Find...
38.	DAQEM	Wed, Jun 3, 2009 12:18 PM	Find...

50 responses per page

Show replies

Title:	**100.0%**	**38**
	answered question	**38**
	skipped question	**0**

2. Have you ever accessed or downloaded information from the BlueSky Gateway (http://www.getbluesky.org)? Create Chart Download

	Response Percent	Response Count
Yes	**89.5%**	**34**
No	10.5%	4
	answered question	**38**
	skipped question	**0**

Show this Page Only

Page:

1. Which elements of information have you accessed or downloaded? Create Chart Download

	Graphical Results	Data Download	Response Count
Meteorological Model Predictions	**100.0% (17)**	17.6% (3)	17
Smoke or Air Quality Model Predictions	**88.5% (23)**	23.1% (6)	26
Fire Information, Locations, or Sizes	**84.0% (21)**	32.0% (8)	25
		answered question	**31**
		skipped question	**7**

1. Which elements of information have you accessed or downloaded?

Create Chart Download

Hide replies Other (please specify):	2

1.	Information about the BlueSky program	Thu, Jun 11, 2009 2:19 PM	Find...
2.	Framework	Fri, Jun 5, 2009 2:37 PM	Find...

answered question	**31**
skipped question	**7**

2. Have you downloaded or requested a copy of the BlueSky Framework Application?

Create Chart Download

	Response Percent	Response Count
Yes	27.3%	9
No	**72.7%**	**24**
answered question		**33**
skipped question		**5**

3. How useful do you find the information available on the BlueSky Gateway?

Create Chart Download

	Response Percent	Response Count
Very useful	30.3%	10
Useful	**45.5%**	**15**
Somewhat useful	15.2%	5
Not at all useful	9.1%	3
Hide replies Please comment (optional):		11
answered question		**33**
skipped question		**5**

3. How useful do you find the information available on the BlueSky Gateway? Create Chart Download

1.	the smoke prediction links to the different FCAMMs don't work, so the information that I am interested in (smoke forecasts) is not available unless I have missed something.	Tue, Jun 9, 2009 3:26 PM	Find...
2.	I used the smoke forecasts inconjunction with other data (sat images, MM5, weather models) to get an idea of the changing smoke situation during the 2008 "fire siege" which saw over 300 sq mi of vegetation burn in our area. We were also impacted by long range smoke transport where the Bluesky model was helpful. The coarse resolution of the model, at least US level one I looked at, was somewhat of a concern and also hwo well it was capturing multi-day carryover which was a big factor during last year's extended smoke "siege". Anyway, thanks for making available the resources you have.	Mon, Jun 8, 2009 4:22 PM	Find...
3.	never did manage to figure out how to download historical (2008) data	Mon, Jun 8, 2009 10:49 AM	Find...
4.	Potentially useful, but right now we're still trying to get the framework running locally in a productive manner.	Fri, Jun 5, 2009 2:37 PM	Find...
5.	The two products I relied on in 2008 was the Dispersion Projection for the Northern California Fires and SMART Fire. By linking the Oregon Department of Environmental Quality and the Lane Regional Air Pollution to the smoke dispersion graphs enable effectively and timely communications with the affected publics in Southern Oregon through multiple media releases. The best example of the use of this tool was when LRAPA notified the Olympic Committee of potential smoke impacts during the Olympic Trials in Eugene. As a minimum the committtee advised athletics who had respiratory problems of the potential so they could minimize their exposure. The ease of which BLUESKY and Sonoma Tech extended the forecasts into Oregon also helped assure that the information was used. I used SMART Fire to get a feel for fire spread and burnout operations during the same episode. SMART Fire was also used effectively by our Fire Operations Staff to alert them to potential Wildfire Use Fires, as one example, in some of our most remote areas. Linking SMARTFire ignitions to FCCS fuel types would be helpful and give a better picture of the overall risk and hazard associated with any new ignitions.	Fri, Jun 5, 2009 1:13 PM	Find...
6.	I have just started to work with the data. I am sure that I will find it much more useful as time goes on.	Thu, Jun 4, 2009 12:04 PM	Find...
7.	More detailed traj info would be helpful	Thu, Jun 4, 2009 11:58 AM	Find...
8.	Many broken links to Air Fire and currently my password does not work.	Thu, Jun 4, 2009 11:16 AM	Find...
9.	Process is so convoluted, so many changing acronyms, and so many non-functional pieces I have basically given up on BlueSky.	Wed, Jun 3, 2009 1:31 PM	Find...
10.	SMARTFIRE is interesting for aggregating ICS-209 and HMS fire information. Documentation is lacking especially for SMOKE integration (SMOKE-ready ?). Documentation should be integrated to the framework to better understand exactly what comes out of the framework. Currently, understanding the output requires to look into each piece of the puzzle.	Wed, Jun 3, 2009 12:34 PM	Find...
11.	It used to be useful but since the predictive BlueSkyRains is now gone I find it less useful.	Wed, Jun 3, 2009 12:31 PM	Find...

25 responses per page

answered question	**33**
skipped question	**5**

Show this Page Only

Page:

1. Approximately when did you last refer to the BlueSky Gateway website? Create Chart Download

1. Approximately when did you last refer to the BlueSky Gateway website?	Response Percent	Response Count
Today	24.2%	8
Within the past week	12.1%	4
Within the past month	15.2%	5
Within the past six months	**33.3%**	**11**
More than six months ago	15.2%	5
	answered question	**33**
	skipped question	**5**

Create Chart Download

2. Do you tend to refer to the BlueSky Gateway website during specific seasons?	Response Percent	Response Count
Spring	36.4%	12
Summer	**48.5%**	**16**
Fall	45.5%	15
Winter	6.1%	2
No specific season	42.4%	14
	answered question	**33**
	skipped question	**5**

Create Chart Download

Show this Page Only

Page:

1. During the season(s) you just indicated (i.e., spring, summer, winter, fall), with what frequency do you tend to refer to the BlueSky Gateway website? Download

1. During the season(s) you just indicated (i.e., spring, summer, winter, fall), with what frequency do you tend to refer to the BlueSky Gateway website? Download

Number of Times

	0	1	2	3	4	5	6	7	8	9	10+	Response Count
Frequency:	0.0% (0)	5.9% (1)	5.9% (1)	**35.3% (6)**	11.8% (2)	11.8% (2)	0.0% (0)	5.9% (1)	5.9% (1)	0.0% (0)	17.6% (3)	17

Time Period

	per week	per month	number of times in total	Response Count
Frequency:	**43.8% (7)**	37.5% (6)	18.8% (3)	16

Hide replies Other frequency (please specify): 6

1.	depends on the fire and air quality situation, if the smoke is of concern, I may need to access it multiple times/week. However given that smoke predictions are not available, I link to other websites like the NOAA site	Tue, Jun 9, 2009 3:28 PM	Find...
2.	sporatic depending on events	Mon, Jun 8, 2009 4:24 PM	Find...
3.	more often when large fires or prescribed burns going on	Mon, Jun 8, 2009 11:39 AM	Find...
4.	during short periods of time it could be a lot more	Mon, Jun 8, 2009 11:33 AM	Find...
5.	But more frequent during air quality episodes	Thu, Jun 4, 2009 12:00 PM	Find...
6.	depending on burn contracts	Wed, Jun 3, 2009 3:52 PM	Find...

answered question **17**

skipped question **21**

Show this Page Only

Page:

1. With what frequency do you tend to refer to the BlueSky Gateway website? Download

Number of Times

answered question **12**

skipped question **26**

1. With what frequency do you tend to refer to the BlueSky Gateway website? [Download]

	0	1	2	3	4	5	6	7	8	9	10+	Response Count
Frequency:	0.0% (0)	16.7% (2)	0.0% (0)	25.0% (3)	0.0% (0)	**50.0% (6)**	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	8.3% (1)	12

Time Period

	per week	per month	per year	number of times in total	Response Count
Frequency:	33.3% (4)	8.3% (1)	**50.0% (6)**	8.3% (1)	12

Hide replies Other frequency (please specify): 2

1. I don't use it now. Tue, Jun 9, 2009 9:50 AM Find...
2. When we downloaded and tested the Bluesky Framework last fall (fall 2008), we accessed the site several times. Otherwise not much. Mon, Jun 8, 2009 11:41 AM Find...

answered question	**12**
skipped question	**26**

Show this Page Only

Page:

1. Have you used information from the BlueSky Gateway to facilitate operational or policy-related decisions made by your organization? [Create Chart] [Download]
Some examples of operational or policy decisions are listed below (but this list is not comprehensive): - Whether to conduct a prescribed fire - Whether to permit planned burns or call a no-burn day - Whether to call air quality alerts - Support of State Implementation Plan (SIP) development - Assessment of exceptional or natural events in determining compliance with the National Ambient Air Quality Standards (NAAQS) - Greenhouse gas emissions accounting

	Response Percent	Response Count
Yes	**53.1%**	**17**
No	37.5%	12
Not applicable - My organization is not involved with these types of	9.4%	3
answered question	**32**
skipped question	**6**

1. Have you used information from the BlueSky Gateway to facilitate operational or policy-related decisions made by your organization? Create Chart Download

Some examples of operational or policy decisions are listed below (but this list is not comprehensive): - Whether to conduct a prescribed fire - Whether to permit planned burns or call a no-burn day - Whether to call air quality alerts - Support of State Implementation Plan (SIP) development - Assessment of exceptional or natural events in determining compliance with the National Ambient Air Quality Standards (NAAQS) - Greenhouse gas emissions accounting

decisions.

answered question	**32**
skipped question	**6**

2. If you answered "yes" to the question above, please describe the decisions made or the circumstances. Download

	Response Count
Hide replies	18

1.	During severe wildfire events, our Forest provides information via an air quality information website to the public and other agencies about predicted smoke conditions that may impact public health and lead to posting an air quality alert which, in turn, may trigger a public health advisory by the county health dept.	Wed, Jun 10, 2009 2:42 PM	Find...
2.	would like to say yes to many of these questions, but unable to obtain smoke forecasts to the level of detail required.	Tue, Jun 9, 2009 3:30 PM	Find...
3.	For wildfire smoke advisories and assessment of natural event	Mon, Jun 8, 2009 4:26 PM	Find...
4.	We have used the information gain through the BlueSky Gateway to help support air quality forecasting activities during time of known smoke impacts from large fires. The graphical presentation of the forecast data is very helpful in assessing potential air quality impacts.	Mon, Jun 8, 2009 1:16 PM	Find...
5.	track where observed smoke on the forest was coming from. to check on who is burning and where in general	Mon, Jun 8, 2009 11:35 AM	Find...
6.	Prescribed Burning Decision Making	Mon, Jun 8, 2009 11:17 AM	Find...
7.	Registered with BlueSky in an attempt to get SMARTFIRE data	Mon, Jun 8, 2009 10:50 AM	Find...
8.	Air quality alerts	Mon, Jun 8, 2009 10:30 AM	Find...
9.	SIP Development and Exceptional events compliance	Fri, Jun 5, 2009 2:29 PM	Find...
10.	My agencies responsibility for public health protection is advisory, but fire fighter health assessments needs to be done with remote sensing. Smaller scale information would be needed to look at localized concentration with incident bases, stagging areas, and spike camps. General smoke conditions over larger incidents would help with aviation, burnout operations, and online fire fighter safety/health. For prescribed fire linking remote sensing to optical instruments, similar to what was done on the Tripod Fire in terms of distribution and development of trend analysis COULD facilitate issueance of permits, Go/NOGo decision, and determination of natural events criteria given an instrusion. The use would be limited to landscape level burning in order to detect the effects because of the frequency that the satellite passes overhead. Computer extrapolation by inputting planned acreage and ignition and burnout period may allow for its use on a smaller	Fri, Jun 5, 2009 1:24 PM	Find...

25 responses per page

answered question	**18**
skipped question	**20**

2. If you answered "yes" to the question above, please describe the decisions made or the circumstances. Download

	scale.		
11.	We are currently attempting to determine pm2.5 emissions from prescribed burning.	Thu, Jun 4, 2009 12:05 PM	Find...
12.	Yes, but this is only one of many tools used to help generate AQ forecasts for Metro Area, Macon and Columbus	Thu, Jun 4, 2009 12:02 PM	Find...
13.	Assistance in forecasting using Smoke function	Thu, Jun 4, 2009 11:18 AM	Find...
14.	go or no go for Rx burns	Wed, Jun 3, 2009 3:53 PM	Find...
15.	The needs are there, but we are currently exploring the framework in order to quantify its potential for future operations	Wed, Jun 3, 2009 12:36 PM	Find...
16.	Calling burn/no-burn days Calling air quality alerts	Wed, Jun 3, 2009 12:32 PM	Find...
17.	We consider the Blue Sky model as part of our model suite to determine the ozone and PM2.5 forecast	Wed, Jun 3, 2009 12:29 PM	Find...
18.	monitor any fire activities that might elevate ozone concentrations in Clark County	Wed, Jun 3, 2009 12:19 PM	Find...

25 responses per page

answered question	**18**
skipped question	**20**

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Page:

1. What roles or job functions in your organization are (or could be) aided by information from the BlueSky Gateway (http://www.getbluesky.org)? Download

	Response Count
Hide replies	28

1.	Information on current state of BlueSky. Tutorial on setting up BlueSky and carrying out a canned run with it. A LiveCD with a minimal Linux distribution on it, and all the software needed to do sample runs would be good. Preferred Linux distributions for use with BlueSky.	Thu, Jun 11, 2009 2:26 PM	Find...

50 responses per page

answered question	**28**
skipped question	**10**

1. What roles or job functions in your organization are (or could be) aided by information from the BlueSky Gateway (http://www.getbluesky.org)? Download

2.	Go-no go decisions based on the assesment of prescibed fire impacts to air quality.	Wed, Jun 10, 2009 2:45 PM	Find...
3.	at this time, with respect to forest fires, my role is to oversee air quality model development projects	Wed, Jun 10, 2009 1:43 PM	Find...
4.	public information, health alerts	Tue, Jun 9, 2009 3:31 PM	Find...
5.	link on our improved web-site, prescribed fire assessments	Mon, Jun 8, 2009 4:32 PM	Find...
6.	Air Quality Forecasting Burn Ban Issuance PM2.5 Exceptional Events Packages	Mon, Jun 8, 2009 1:43 PM	Find...
7.	It's helpful for getting the big picture but I really need a larger scale with reference points for decision making.	Mon, Jun 8, 2009 11:45 AM	Find...
8.	Too early to tell for us.	Mon, Jun 8, 2009 11:42 AM	Find...
9.	fire events and associated activity data.	Mon, Jun 8, 2009 11:41 AM	Find...
10.	all levels of fire mgmt. smke mgmgt, rec	Mon, Jun 8, 2009 11:37 AM	Find...
11.	Prescribed Burning, Smoke, Fog	Mon, Jun 8, 2009 11:18 AM	Find...
12.	Readily available historical fire data	Mon, Jun 8, 2009 10:51 AM	Find...
13.	Air quality forecasting	Mon, Jun 8, 2009 10:31 AM	Find...
14.	I think some of our grad students might benefit from info available from Bluesky Gatewayo ,n a proect by project basis.	Fri, Jun 5, 2009 3:18 PM	Find...
15.	Prescribed burns emission calculations.	Fri, Jun 5, 2009 2:30 PM	Find...
16.	Linking met data with SMARTFire and FCCS spread and emission data would benefit wild fire suppression and landscape level prescribed burning operations. It would also probably be the only available data we would have for using unplanned ignitions for resource benefit under the Federal Fire Policy.	Fri, Jun 5, 2009 1:30 PM	Find...
17.	information could aid in determining accuracy of fire analysis and aiding in smoke analysis. we need to investigate this more as a resource	Fri, Jun 5, 2009 11:12 AM	Find...
18.	Fuels planner, burn boss, long-term fire analyst, possibly fire behavior analyst	Fri, Jun 5, 2009 7:23 AM	Find...
19.	Prescribed burn planning Emissions modeling	Thu, Jun 4, 2009 12:07 PM	Find...
20.	I felt the direction Blue Sky went last summer with the USFS graphics in their final form were useful to assist in health messages.	Thu, Jun 4, 2009 11:20 AM	Find...
21.	air pollution meteorologist, modeler	Wed, Jun 3, 2009 3:54 PM	Find...
22.	We control and manage almost all forestry prescribed burning in the state of Oregon. Provide forecasts, burning instructions, and burn approvals.	Wed, Jun 3, 2009 1:37 PM	Find...
23.	Researchers.	Wed, Jun 3, 2009 1:30 PM	Find...
24.	operational planning for prescribed burning, contingency planning, etc.	Wed, Jun 3, 2009 12:44 PM	Find...

50 responses per page

answered question	**28**
skipped question	**10**

1. What roles or job functions in your organization are (or could be) aided by information from the BlueSky Gateway (http://www.getbluesky.org)? Download

25.	air quality developpers	Wed, Jun 3, 2009 12:39 PM	Find...
26.	We intend to incorporate the Blue Sky framework into our real-time CMAQ runs - This would allow us to incorporate real fires into our CMAQ runs.	Wed, Jun 3, 2009 12:35 PM	Find...
27.	Calling burn/no-burn days Calling Air Quality Alerts	Wed, Jun 3, 2009 12:33 PM	Find...
28.	the ozone team in the Planing Division possible predictions of smoke might trigger additional monitoring	Wed, Jun 3, 2009 12:23 PM	Find...

50 responses per page

answered question	**28**
skipped question	**10**

2. What modifications, new information, or new tools would be helpful to add to the BlueSky Gateway? Download

	Response Count
Hide replies	24

1.	Links to the possible components that have been or could be used in BlueSky, as well as repositories of data for practice runs.	Thu, Jun 11, 2009 2:26 PM	Find...
2.	any documentation with respect to any piece of bluesky - even a blog or discussion group for developers	Wed, Jun 10, 2009 1:43 PM	Find...
3.	working links to smoke predictions for FCAMM regions	Tue, Jun 9, 2009 3:31 PM	Find...
4.	Vertical plume profiles? Higher resolution graphics, if possible, hourly PM estimates for certain locations	Mon, Jun 8, 2009 4:32 PM	Find...
5.	Archived PM2.5 Forecast Information	Mon, Jun 8, 2009 1:43 PM	Find...
6.	Historic smoke predictions - that is, past smoke predictions from fires that occurred.	Mon, Jun 8, 2009 11:56 AM	Find...
7.	State level maps with cities and roads	Mon, Jun 8, 2009 11:45 AM	Find...
8.	finer resolution. the tools is a regional scale tool at this time. allow nested grids? allow custom fuel entries.	Mon, Jun 8, 2009 11:37 AM	Find...
9.	Not sure have not used it enough	Mon, Jun 8, 2009 11:18 AM	Find...
10.	user-friendly instructions; clearer explanations of what is/is not available from the site	Mon, Jun 8, 2009 10:51 AM	Find...
11.	Regional closeups of areas, such as the northeast U.S.	Mon, Jun 8, 2009 10:31 AM	Find...

25 responses per page

answered question	**24**
skipped question	**14**

2. What modifications, new information, or new tools would be helpful to add to the BlueSky Gateway? Download

12.	Not sure.	Fri, Jun 5, 2009 3:18 PM	Find...
13.	Will let you know.	Fri, Jun 5, 2009 2:30 PM	Find...
14.	See previous	Fri, Jun 5, 2009 1:30 PM	Find...
15.	Haven't had much chance to use BlueSky lately so don't know	Fri, Jun 5, 2009 7:23 AM	Find...
16.	Easier access to data sets.	Thu, Jun 4, 2009 12:07 PM	Find...
17.	More detailed information on trajectory analysis such as vert motion or isentropic options and other meteorological parameters such as 850mb streamlines would be useful. Also can't read heights or pressure levels of trajectories.	Thu, Jun 4, 2009 12:05 PM	Find...
18.	The Airfire links have been broken for some time. Our meteorologists can use a good information on the location and elevation of the fire to help make forecasts.	Thu, Jun 4, 2009 11:20 AM	Find...
19.	Cannot answer. MM5 file link to BlueSky failed (according to what I was told) some time ago and BlueSky was unable to provide forecasted smoke trajectories. To be useful for us, BlueSky would have to be able to model and predict smoke trajectories and impacts at least 48 hours in advance.	Wed, Jun 3, 2009 1:37 PM	Find...
20.	Haven't checked in awhile, but when I last downloaded the data, fields for individual emission species were blank.	Wed, Jun 3, 2009 1:30 PM	Find...
21.	3-5 day weather and smoke management forecasts	Wed, Jun 3, 2009 12:44 PM	Find...
22.	Generation and archival of daily PM2.5 contribution from fires - This would help in estimating impacts from fires for declaration of an Exceptional Event. Run model out another day - would help forecasting process.	Wed, Jun 3, 2009 12:35 PM	Find...
23.	Bring BlueSky Rains back!! The ventilation information and predictive prescribed fire smoke tracking.	Wed, Jun 3, 2009 12:33 PM	Find...
24.	cannot of any at this time	Wed, Jun 3, 2009 12:23 PM	Find...

25 responses per page

answered question	**24**
skipped question	**14**

3. How or for what purpose would these changes be useful? Download

	Response Count
Hide replies	18
answered question	**18**
skipped question	**20**

3. How or for what purpose would these changes be useful? Download

1.	Education, moving from neophyte rookie to being able to ask intelligent questions about Bluesky.	Thu, Jun 11, 2009 2:26 PM	Find...
2.	help development	Wed, Jun 10, 2009 1:43 PM	Find...
3.	Improved assessment of conditions and trends during wildfire and prescribed burn events.	Mon, Jun 8, 2009 4:32 PM	Find...
4.	The archived PM2.5 forecast information could be very useful in our preparations of PM2.5 exceptional events packages.	Mon, Jun 8, 2009 1:43 PM	Find...
5.	Research	Mon, Jun 8, 2009 11:56 AM	Find...
6.	Determining potential for smoke impact to a community and subsequent decision making.	Mon, Jun 8, 2009 11:45 AM	Find...
7.	Smoke Fog	Mon, Jun 8, 2009 11:18 AM	Find...
8.	More accurate analysis of air quality	Mon, Jun 8, 2009 10:31 AM	Find...
9.	N/A	Fri, Jun 5, 2009 2:30 PM	Find...
10.	For prescribed burning better projects of emission and trajectories under a state-wide smoke management plan. Allow for a regional scale view at both prescribed fire and wildfire and their anticipated effects on visibility, public health, and GHG distribution through the atmosphere.	Fri, Jun 5, 2009 1:30 PM	Find...
11.	data could aid us in performing operational near-real time analysis. fire locations could help in validation.	Fri, Jun 5, 2009 11:12 AM	Find...
12.	These changes would allow easier downloading of current and historical data sets.	Thu, Jun 4, 2009 12:07 PM	Find...
13.	Model input, forecast improvement, health messages.	Thu, Jun 4, 2009 11:20 AM	Find...
14.	We could use good, reliable smoke trajectory forecasts as an aid in the burn/no burn decisions for large or multi-day burns.	Wed, Jun 3, 2009 1:37 PM	Find...
15.	My organization is interested in wildfire emissions information, so increased granularity would be a plus.	Wed, Jun 3, 2009 1:30 PM	Find...
16.	operational planning for prescribed burning, contingency planning, etc.	Wed, Jun 3, 2009 12:44 PM	Find...
17.	Answered previously	Wed, Jun 3, 2009 12:35 PM	Find...
18.	na	Wed, Jun 3, 2009 12:23 PM	Find...

25 responses per page

answered question	**18**
skipped question	**20**

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Page:

1. Do you have any other remarks or feedback that you would like to add? Download

Response Count

1. Do you have any other remarks or feedback that you would like to add? [Download]

Hide replies 18

1.	BlueSky needs people who are the interface between the developers and the users. It is very hard to get in touch with the scientists and developers because they are overwhelmed and busy. There needs to be someone on the BlueSky team whose sole job it is to be the contact/documenter/trainer for the outside world.	Thu, Jun 11, 2009 2:28 PM	Find...
2.	availability of an on-line archive, if not already there	Mon, Jun 8, 2009 4:34 PM	Find...
3.	I have not logged on yet - I have limited feed back.	Mon, Jun 8, 2009 12:55 PM	Find...
4.	I can't seem to find my username and password so I can't get to the smartfire applications anymore. I've said it before and I'll say it again. Blue Sky RAINS was the right tool for the job and a National scale looped gif image is interesting but not really useful for the level of communication we need to do with decision makers.	Mon, Jun 8, 2009 11:47 AM	Find...
5.	great tool. how does this tool interface with hysplit? which tool has advanteges/disadvantages for what applications?	Mon, Jun 8, 2009 11:38 AM	Find...
6.	More stuff for the southeast	Mon, Jun 8, 2009 11:19 AM	Find...
7.	Your graphics always seem to be late. I would expect to see todays graphics by 7:30 am EST, but it has never been the case: Today's hourly predictions are usually posted by 4:30 a.m. Pacific Standard Time. Tomorrow's hourly predictions and Today's Averages are usually posted by 6:30 a.m. Pacific Standard Time.	Mon, Jun 8, 2009 10:34 AM	Find...
8.	Not at this time	Fri, Jun 5, 2009 3:19 PM	Find...
9.	None.	Fri, Jun 5, 2009 2:30 PM	Find...
10.	Products need to be developed collaboratively with NWCCG in support of WFDS (Decision Support) to assure the states that smoke considreations are a part of our use of unplanned ignitions.	Fri, Jun 5, 2009 1:34 PM	Find...
11.	I appreciate all of the help that the project manager (Dana Sullivan) has provided.	Thu, Jun 4, 2009 12:07 PM	Find...
12.	Seems to be a useful product for helping make AQ forecasts.	Thu, Jun 4, 2009 12:07 PM	Find...
13.	How are the SMOKE/NWS surface PM2.5 levels determined? Modeled or measured? How is fire PM2.5 parsed from total PM2.5 especially considering transport and generally high PM2.5.	Thu, Jun 4, 2009 11:22 AM	Find...
14.	The last time I was able to get smoke trajectory information it was late (the decision would have had to already been made before the forecast was available) and appeared to never disperse or dissipate the smoke. Smoke plumes appeared to carry on forever in a consolidated "blob".	Wed, Jun 3, 2009 1:39 PM	Find...
15.	No, thanks!	Wed, Jun 3, 2009 1:31 PM	Find...
16.	The site has been helpful in our forecast process, especially the PM2.5 predictions	Wed, Jun 3, 2009 12:36 PM	Find...
17.	Blue Sky Rains is an important tool which is sorely missed.	Wed, Jun 3, 2009 12:34 PM	Find...
18.	it is a great tool for us ... keep up the good work	Wed, Jun 3, 2009 12:23 PM	Find...

25 responses per page

answered question **18**

skipped question **20**

1. Do you have any other remarks or feedback that you would like to add?

Download

answered question	18
skipped question	20

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Page:

1. We wish to follow up with some survey participants via telephone, asking them to elaborate on their responses or discuss related areas of importance. If asked, would you be available and willing to participate in a 20-minute telephone interview?

Create Chart Download

	Response Percent	Response Count
Yes	77.8%	28
No	22.2%	8
answered question		36
skipped question		2

2. If you answered 'yes' to the question above, please complete all information below.

Download

		Response Percent	Response Count
Show replies	Phone #:	100.0%	28
Show replies	Your time zone:	100.0%	28
Show replies	Best time to call:	96.4%	27
	answered question		28
	skipped question		10