FINAL REPORT

TECHNICALLY ADVANCED SMOKE ESTIMATION TOOLS
(TASET)

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AND
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I. Executive Summary

The TASET project was funded by the Joint Fire Science Program to develop a structured analysis of smoke management and to recommend specific developments for advancing the state of science in this field.

We approached this problem by first developing a task-oriented breakdown of the smoke management issue. We did this by developing a structured analysis, using existing information from an assortment of sources, including the EPA interim Guidelines for Wildland Smoke, the Forest Service National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality, EPA regional haze regulations, and similar documents. The Forest Service's National Strategic Plan (Sandberg, 1999) lists over 45 strategies for work in smoke management. The TASET effort used these strategies while attempting to focus them for potential support by the Joint Fire Sciences Program.

The structured analysis was conducted by determining specific information needed to take actions required to manage smoke. Further, we asked what tools, primarily which models and data sets, are used to provide this information. The analysis resulted in the following breakdown of smoke management actions: *strategic planning, tactical planning and permitting, operations, and evaluation and monitoring*.

Following development of this task breakdown, we designed a survey focusing on the identified tools which asks respondents about the utility of these tools and their suggested priorities for improving them. The survey was provided to over 200 fire and air quality professionals by both conventional mail and e-mail. Further, the survey was published on the CIRA smoke & fire website. This process led to over 50 total responses.

Finally, based on the structured analysis and the results of the survey, a Workshop was held at Colorado State University in February 2000. The workshop provided 50 key players in the smoke management field the opportunity to interact and discuss development of technically advanced tools for smoke management.

A specific set of recommendations has developed as a result. These recommendations are presented in a format we believe will be helpful to the Joint Fire Sciences Program. This format is a short (one-page) description for each specific proposed activity, including the Subject, Need, Research and Development Question, Anticipated Cost, Anticipated Duration, Anticipated Product, and its linkage to National Strategic Plan. It is anticipated that the JFSP Board will find these results useful for discussion of potential funding opportunities.

Nine specific recommendations for research activities follow this page.

IA. TASET Project Recommendations

TASET Project Recommendation, #1
- Strategic Level -

Subject: Fire community participation in Regional Air Quality Modeling Consortia

Need: As air resources have become more highly regulated, the sophistication and complexity of models used for strategic planning (SIPS and land management planning) have increased. Specifically in support of current regulatory issues, regional haze, ozone, and PM2.5, air regulators and their publics have developed regionally oriented consortia to help cope with technical complexity and the interstate nature of many of these issues. For example, in the western United States, the Western Regional Air Partnership (WRAP) established a fire emissions subgroup and is in the process of initiating a regional modeling consortium. Models, such as EPA's Models3/CMAQ being used for the next round of SIP revisions, require super computer power and specialized inventories of emissions. Information, skills and costs needed to operate these models is greater than any land manager can possibly afford. Output from such models routinely requires skilled technical specialists not available to the fire community. In time, it will be clear that the fire community must participate with these regional consortia. Rather than having to accept the models being used at that time, we recommend initiating a research presence to assure final models are appropriate for dealing with fire and smoke. Additionally, fire managers will benefit from improved weather and smoke forecasts provided by next generation models. Skilled modelers with the correct modeling tools available to them may provide weather simulations for fire danger and behavior, perhaps providing fine scale forecasts days in advance. In the Pacific Northwest, a regional modeling consortium has been started for this purpose. Shared funding costs can reduce single party costs; joint-planning products will assure usefulness. Participants and benefactors of this current fledgling consortium include the USDA Forest Service, EPA, and the State of Washington.

Research and Development Question: The concept of regional modeling consortiums for meteorology and air quality appears both innovative and practical. It is suggested that support be provided through a system of competitive grants to develop such consortia as a proof of concept.

Anticipated Cost: $400,000 per year ($200,000 each for two consortia) for a two year period ($800,000 total).

Anticipated Duration: Two years, but on-going if concept is proved.

Anticipated Products: Two operating consortia, general technical report on consortium operations for evaluating value of concept.

Link to National Strategic Plan: This funding would implement six of the nine summary strategies. It would also support the following sub strategies P1:1,2,5; P2:2; P3:2,3;O1:1;O2:2,3; O3:1;M1:1, and M2:3.

TASET Project Recommendation, #2
- Strategic Level -

Subject: National Smoke and Visibility Conference

Need: Visibility as a scientific endeavor is technically complex, highly data reliant, intellectually challenging, populated with a very small group of scientific experts, and has undergone great change within the last decade. The new regional haze rules proposed by EPA will cause smoke managers to become increasingly involved in visibility issues. Smoke emissions will be regulated under this rule. Air quality regulators will be required to address smoke in state-level implementation of the regional haze rule. Unfortunately, however, there is sometimes little understanding between these communities. A single current reference document on smoke and visibility would be useful to all parties.

Research and Development Question: An up-to-date reference on visibility, science, and fire smoke could be produced through a national scientific conference on the issue. The reference would be a peer-reviewed formal conference proceeding document.

Anticipated Cost: $100,000

Anticipated Duration: 1 year

Anticipated Products: Peer-reviewed conference proceedings document.

Link to National Strategic Plan: This funding would support the following sub strategies: P2:1;P3:2,3; O1:5;O3:1;M1:1;M2:1,2,5; and M3:1,4.

TASET Project Recommendation, #3
- Strategic Level -

Subject: National Smoke Emissions Data Structure or Database System

Need: The new regulatory programs for PM2.5, ozone, and regional haze will require improved record keeping on fire emissions. These data will need to be accessible to many parties including the federal EPA, state air agencies, researchers, fire managers, and the interested public. Smoke emissions will also need to be available for use in regional scale modeling using such systems as the new EPA Models3/CMAQ. Data in such a system will need to be easy to up-date, provide for documentation of the sources of data, provide information on the quality of data, provide explicit geographic reference information, and allow data to be pre-processed for use in modeling.

Research and Development Question: A new smoke emissions inventory system is recommended for development. The system will incorporate all emissions species of relevance to air quality regulators and will be useful in modeling studies, state implementation plan (SIP) development, and regional planning. It will also be compatible with the EPA AIRS system but will be tailored for ease of use by fire practitioners.

Anticipated Cost: $150,000

Anticipated Duration: Three years

Anticipated Products: New data structure or database system for smoke emissions, user's documentation and training, program code documentation, implementation/life cycle management plan for the finished system.

Link to National Strategic Plan: This funding would implement one of the nine summary strategies, <u>National Fire and Air Quality Information Database.</u> It would also support the following sub strategies: P1:3,5; P2:2; P3:3,4; O1:1,3; O2:3; O3:2; M1:4; and M2:3

TASET Project Recommendation, # 4
- Strategic Level -

Subject: Remote Sensing for Fuels and Fire Area Emissions Inventories

Need: There is a recognized need for fuels inventory at state, regional, and national scales. Such information as amount of fuel loading, fuel temperature, and fuel moisture would be extremely useful in calculation of potential for fire. For emissions calculation, accurate estimates of fire area and fuel consumed are also needed. Meaningful spatial resolution for this information would be 100 meters or less. Time resolution for this information would be at several days to daily resolution. New multi-spectral sensor/platform combinations are becoming available in the near future with the potential to provide significantly enhanced information for fire managers.

Research and Development Question: Remote-sensing products, preferably from space-based platforms, could solve fuels inventory and classification needs if spectral, spatial and temporal resolution were high enough. This information when coupled with burn area estimates can give regional to national emissions estimates for all fires. To achieve this level of information, it will require new techniques for data collection, management, and analysis. Although technology may not exist at the present time to reach the level of spatial and temporal resolution we desire, work to develop the framework for methodologies/processes will allow both useful products now and improved technology management as remote sensing advances as a practice.

Anticipated Cost: $200,000 per year

Anticipated Duration: Five years

Anticipated Products: Improved remote sensing data analysis algorithms for fuel inventory and fire assessments, linkage of remote sensing information to emissions calculations.

Link to National Strategic Plan: This funding would implement one of the nine summary strategies, <u>National Fire and Air Quality Information Database.</u> It would also support the following sub strategies: P1:3,5; P2:2; P3:3,4; O1:1,3; O2:3; O3:2; M1:4; and M2:3.

TASET Project Recommendation, # 5
- Strategic and Tactical Level -

Subject: Fire Gaming System

Need: Air quality regulators need to know how much wildland and agricultural burning is being planned and to what extent this use of fire represents a trade-off of emissions from wildfire. They also need to keep track of which locations are planned for fire treatment, which locations actually were treated, and to what extent the planned parameters for the treatment were actually achieved.

Research and Development Question: A simple model is needed to estimate the emissions contribution made by alternative fire practices to ambient air quality, to quantify the differential emissions resulting from the use of alternative fire management practices, and the implications of each of these on ambient air quality. The functionality of the Models3/CMAQ system provides all of this capability but does it by using state of the science computer models that are very complex and require vast data resources. The proposed Fire Gaming System would include much of the Models3/CMAQ functionality but would utilize simpler models and less complex data inputs.

Anticipated Cost: $225,000

Anticipated Duration: Three years, $75,000/yr.

Anticipated Products: Fire Gaming Model for use by air quality regulators in development of SIPs as well as more refined planning documents.

Link to National Strategic Plan: This funding would implement two of the nine summary strategies, <u>Air quality impact assessment,</u> and <u>Emission tradeoffs and determination of natural visibility.</u> It would also support the following sub strategies: P2:2,4; M1:3,4; and M2:3.

TASET Project Recommendation, # 6
- Tactical Level -

Subject: CalMet/CalPuff Smoke Management Version

Need: Although some simple screening models such as SASEM are adequate for many smoke screening and permitting situations, there is a recognized need for models that address multiple fires and complex terrain. Two models, NSF Puff and TSARS Plus (among others) were developed to answer this need. NSF Puff, developed by USDA Forest Service, incorporates interesting approaches and an excellent user interface, but it does not represent the state of the science as it must for it to receive broader acceptance in the air quality community. TSARS Plus, developed by USDOI, although incorporating a complex terrain diagnostic wind-field model driving gaussian puffs for pollutant dispersion much like CalMet/CalPuff, has no user community and its user's interface is not state of the science. In the past several years many modelers, including the Interagency Working Group on Air Quality modeling (IWAQM) have come to view EPA's modeling system CalMet/CalPuff as being the most useful for air quality regulatory purposes in complex terrain. EPA, at their next Modeling Conference scheduled for early July 2000, will propose the system for approval as a 'guideline' model. Thus, it represents the most likely potential candidate for a nationally accepted smoke management model.

Research and Development Question: The CALMET/CALPUFF models are, for most intents and purposes, nationally accepted as regulatory tools, have been extensively peer-reviewed, use current dispersion techniques, and are capable of simulating smoke dispersion from multiple fires in complex terrain, and operate under MS Windows. These models are more complex than NSF Puff and other currently used smoke management tools, but they are also much more acceptable to air quality modelers and state regulators. A new user's interface needs to be developed for CalMet/CalPuff that will make it practical for use by fire managers and planners; building on the experience of NSF Puff, TSARS Plus and other efforts.

Anticipated Cost: $150,000

Anticipated Duration: Two years

Anticipated Products: New version CALMET/CALPUFF user's interface and results processor to make the system practical for smoke management (coping successful aspects of NSF Puff), programming code documentation, model user's training materials, and technical paper.

Link to National Strategic Plan: This funding would implement one of the nine summary strategies, <u>Air quality impact assessment.</u> It would also support the following sub strategies: P2:2,4; O2:2; O3:1; and M3:2,4.

TASET Project Recommendation, # 7
- Tactical and Operational Level -

Subject: Nationalized Screening Model / Simple Approach Smoke Estimation Model (SASEM) Upgrade

Need: There is a recognized need for a simple to use smoke dispersion model that can be used to plan and permit fires. The model must be easily usable by fire managers, requiring data that is readily at hand, and be operable on common computers. Additionally, the model must be understandable and approved by air quality regulators who see it as reliable to predict potential impacts to ambient air quality standards and visibility. At present, the model used by more states as a screening model than any other is the Simple Approach Smoke Estimation Model (SASEM). SASEM is accepted as a regulatory tool in Wyoming, Colorado, Arizona, New Mexico, and Idaho and has some usage in other states. Originally developed in 1986 by the Bureau of Land Management, the model now needs updating both in programming and technical approaches. It, or a successor-screening model, also needs to be formally reviewed and accepted through EPA's modeling clearinghouse to insure regulatory acceptance.

Research and Development Question: Develop a newer generation screening tool for single and multiple fires that requires input readily available to fire managers and planners and results in conservative (but believable) estimates of ground level particulate concentrations and visibility impacts at selected sites. Functionality of existing SASEM should be incorporated into the product and expanded.

Anticipated Cost: $85,000

Anticipated Duration: 1 to 1.5 year projects.

Anticipated Products: New generation SASEM or successor screening model, using manual, code documentation, technical paper and materials to submit model to EPA clearinghouse process.

Link to National Strategic Plan: This funding would implement one of the nine summary strategies, <u>Air quality impact assessment.</u> It would also support the following sub strategies: P1:1; P2:2; P3:4,5; O1:1,3; O2:1,2,4,5; and M3:1,4.

TASET Project Recommendation, # 8
- Operations/Evaluation Level -

Subject: On-Site Fire Emissions Verification

Need: Although fire emissions can be modeled, it is now impossible to accurately measure emissions at the fire site to verify model results. Accurate measurements of emissions at fire sites will become important for regional haze assessments and determining compliance with mitigation plans for non-attainment areas. For example, one extremely useful measurement would be the total amount of PM2.5 emitted during the course of the fire. Currently, some fire managers are attempting to measure particulate concentrations at fires and near fires using portable nephelometers. The limitations of these devices are well known; inability to provide accurate measurements at high concentrations and point, rather than spatial, measurements being two often cited. New techniques and technologies need to be explored to meet this need.

Research and Development Question: LIDARS and short-band radar are technologies that could be investigated to produce fire emission species concentrations and plume volume measurements to calculate total emissions from fires. Advances in electronics and data processing would allow such devices to be made field rugged and portable. The activity would be to develop a new generation of on-site fire emissions measurement devices whose information output could be used, perhaps in conjunction with a new generation of emissions models, to accurately measure total fire emissions in a manner that will be acceptable to air quality regulators.

Anticipated Cost: $250,000 per year

Anticipated Duration: Three years

Anticipated Products: Research/production prototype instrument for on-site fire emissions measurements, technical papers on instrument theory and performance, detailed design specifications, guidelines for instrument usage.

Link to National Strategic Plan: This funding would support the following sub strategies: M1:3; M2:5; and M3:4,5.

TASET Project Recommendation, # 9
-Evaluation Level -

Subject: Back-Trajectory Modeling and Filter Analysis for Fire Smoke Contributions for Non-Attainment Areas

Need: In situations where it is uncertain as to the extent of the contribution of a source to exceed an air quality standard or guideline, back-trajectory models have been used to understand how much pollution has come from the source. Routine measurements of ambient air quality are taken at the site of concern and a chemical/physical profile of the atmospheric contamination developed. Models, which then "back calculate" where such pollution is most likely to have come from, are then applied. The results of such back-trajectory analysis are often insightful and surprising. In areas of non-attainment for PM, such techniques would allow an objective assessment of the contribution from fires at a particular location.

Research and Development Question: Back-trajectory modeling techniques previously employed by the USDOI National Park service could be adapted for use in fire situations. A method of carbon species analysis of air monitoring filters, that would be affordable (about $50 per analysis), will need to be developed (initial investigation by NPS already has begun on this issue) and applied. Using the filter analysis techniques and back-trajectory modeling techniques developed by NPS, it will be possible to objectively assess the contributions of wildland fire to non-attainment areas.

Anticipated Cost: $100,000 per year

Anticipated Duration: Three years

Anticipated Products: New generation back-trajectory models specialized for use in wildland fire assessments, new filter analysis techniques to analyze for fire contributions to ambient air quality, technical reference for wildland fire back-trajectory analysis in non-attainment areas.

Link to National Strategic Plan: This funding would support the following sub strategies: P2:1; O1:1; O3:1; M2:2,5; and M3:4,5.

II. Introduction & Background

The Smoke Management Issue

In the early years of this next century, the United States Environmental Protection Agency (EPA) will implement new regulations for the management of atmospheric particulate matter 2.5 microns and less in diameter (PM2.5), tropospheric ozone, and regional haze. These three air quality issues relate directly to forest and agriculture burning. Fire generates PM2.5 and other ozone precursor gases that reduce visibility. Hence, wild and agricultural land managers will be subject to these new regulations as much as industrial and mobile sources have been for the past 25 years. In addition, these new regulations come at a time when private as well as public land managers throughout the United States are developing plans to increase their application of fire as a management tool. Prescribed fire will remain viable as a tool for land managers with these new regulations but only under a new paradigm of smoke management. This paradigm will include formal "state-approved" Smoke Management Programs and will of necessity require use of new technologies subject to the same public scrutiny as any air pollution source. These programs will acknowledge wildland fire as being different from the more conventional human caused air pollution sources. They will recognize that the managed use of fire is a superior option to wildfire from public safety and health perspectives. In circumstances where fire is used for primarily economic rather than ecological reasons, procedures to steadily reduce emissions will likely be required.

How shall these new technically advanced smoke management tools be developed? They will require roughly equal acceptance between fire managers, fire scientists, air quality regulators, and air quality scientists. They will need to pass public review, especially by other stakeholders (industrial pollution generators) to the clean air process. Increasingly, emissions limitations will be imposed through a Clean Air Act process know as State Implementation Plans (SIP.) Thus, the development of the next generation of smoke management tools needs to be collaborative between fire and air quality communities.

At the present time, there are a wide variety of tools being used for smoke management. Many of these tools have been developed and are applied regionally. With the emergence of national regulations and the increasing significance accorded to fire, there is a growing demand for nationally recognized tools.

The Joint Fire Sciences Program is in a position to advance the development of this next generation tool set. This project is designed to advise the JFSP about priorities and investment opportunities in the development of technically advanced smoke estimation tools.

The Overall TASET Project Plan

Technically Advanced Smoke Estimation Tools (TASET): Needs Assessment and Feasibility Investigation is designed to identify activities, or tasks, that land managers and air quality managers need to undertake in order to practice smoke management. Associated with each task, we identify information needs and the tools (models) and other information sources (data sets) used to provide that information. Users, actual land and air quality managers, were polled regarding their use of these tools and their priority for improving them. A Workshop was conducted allowing practitioners to discuss the tools and to comment on the conceptual Smoke Estimation Tool Set. The final product is a set of recommendations to the Joint Fire Science Program about which aspects of smoke management should receive additional funding from that Program.

The scope of the needs assessment and feasibility investigation included consideration of the current state of the science and emerging technologies anticipated to be available in three to five years. Specifically, the term “tool” describes models and data sets that provide information to the user.

III. Methodology

The specific steps along with their associated objectives are listed below:

1. Utilize the ***results of existing efforts****, including the EXPRESS Team and others.*

First, the project's principal investigators conducted a detailed review of the EXPRESS Team's results (National Strategic Plan: Modeling and Data Systems for Wildland Fire and Air Quality (Sandberg, et al., 1999) and built on them for this project. Further, we developed the Express Team's recommendations into a form that was provided to additional users for their critical evaluation and comment in our survey.

Second, we critically reviewed the EPA Interim Air Quality Policy on Wildland and Prescribed Burning (EPA, 1998). This document identifies minimum requirements for Smoke Management Programs identified in the EPA Regional Haze Regulations.

Finally, we reviewed the Work Plan of the Fire Emissions Joint Forum (1999). FEJF is charged to make recommendations to the Western Regional Air Partnership (1997) on policies and methodologies for:

a) Estimating air pollution emissions and their effects on air quality and visibility due to smoke from various natural and human-caused fires;
b) Developing a data set and associated tracking system for those emissions in, at least, the geographical areas associated with the Grand Canyon Visibility Transport Commission; and
c) Recommending strategies and methods to manage emissions from these sources.

Along with existing literature on smoke management tools, these three documents formed the background for our structured analysis.

2. Develop a ***Needs Assessment***

2.1 Activity or "Task" Breakdown

As the first step in developing the needs assessment, we analyzed specific activities or "tasks" associated with managing smoke. We considered the task breakdown for land managers and for air quality managers. At the highest level the tasks identified are:

a) Long-Range or Strategic Planning;
b) Shorter Range or Tactical Planning and Permitting;
c) Operations; and
d) Monitoring and Evaluation.

For each task, we asked what information is required to perform the task and what source(s) of information or tool(s) are used to provide this information.

2.2 User Survey

The Task breakdown was used to design a user survey to develop the following information:

a) Identify and verify the tasks performed by individuals in managing smoke;

b) Identify the tools or other information sources used to manage smoke;
c) Identify positive and negative aspects of using the tool;
d) Determine user-based priorities for improving the focus and coordination of research and development of future tools; and
e) Evaluate tool development priorities identified in the National Strategic Plan in view of used identified tasks and their tool needs.

After pre-testing the survey on a selected set of users (about 20 people), the survey was distributed by electronic mail to 200 fire and air quality workers. The survey was also sent in hard copy format to an additional 80 people, and it was installed on the CIRA website for direct internet access.

3. Develop a ***Structured Smoke Management System***

We proposed a set of **Smoke Estimation Tools Sets (SETS),** based on integrating survey results with the task breakdown and existing documents. These SETS are linked to tasks and include a set of currently available technologies. Recommendations to the JFSP result from a gap analysis between the need for and availability of required tools within specific SETS.

4. Conduct a ***Smoke Tools Workshop***

We propose to conduct a Workshop that critically reviews the conceptual SETS developed above as well as other tools and their utility. The report of this workshop will include recommendations from leading smoke modelers and associated experts from a wide variety of backgrounds as to the feasibility and likely costs of improving the tools identified as needing to be improved and of implementing SETS on a national basis.

5. ***SSMP Development proposal***

A final product of this project will be the development of a proposal to the JFSP suggesting how to approach the next generation structured smoke management system and what it is likely to cost. It will be designed so that the JFSP has a clear outline of what to develop, the skills needed to develop proposed technologies, and estimated time requirements. This proposal has been presented in a set of nine specific recommendations.

IV. Structured Analysis of Smoke Management

This work was done using a software tool known as Inspiration http://www.inspiration.com. Results can be viewed at the CIRA website http://www.cira.colostate.edu/smoke/taskflow/default.htm

V. Survey Results

Survey methods and yield

The survey used three different methods. We sent e-mail versions to approximately 200 individuals. We obtained about 26 responses at a 13% response rate. We placed the survey on the world wide web at the CIRA website. We have no record of how many people saw the survey through this route, but we obtained an additional 20 responses through this tool. Finally, in order to supplement this sparse survey, we mailed it to an additional 80 individuals. The mailing yielded another 14 returns for an approximate 18% return rate. Thus the total number of surveys we obtained for analysis was about 60.

Tools: Most frequently used

The results from the survey identify the most frequently used tools, in ranked order, as:
BEHAVE, FARSITE, FOFEM, FBPS, NFDRS, CONSUME, EPM, NFSPUFF, SASEM, MM5; Forest Plan; Fire Management Handbooks; Prescribed Fire; Smoke Management Guide; Fire Mgt. Preparedness and Planning Handbook; FEIS; Natl. Interagency Incident Management System; NWCG Smoke Management Guidelines; Southern Forestry Smoke Management Guidebook; SIP; Spot Weather Forecasts; Relative Greenness Maps; WIMS; Internet weather sites; National Weather Service; PM10 & PM2.5 Samplers; RAWS.

Tools: Most "Important" to Job

BEHAVE; FOFEM; FBPS; NFDRS; CONSUME; EPM; NFSPUFF; MM5; SASEM; TSARS/TSARS-PLUS; VSMOKE; Fire Management Handbooks; NIIMS; NWCG; Smoke Management Guidelines; Prescribed Fire Smoke Mgt. Guide; SIP; Spot Weather Forecasts; IMPROVE; Relative Greenness Maps; NWS; Internet Weather; PM10 & PM2.5 Samplers; RAWS; FRM's.

Tools: Most "Able" to do What Needed to Do

BEHAVE; FARSITE; FBPS; MM5; SASEM; TSARS/TSARS-PLUS; VSMOKE; SPOT WEATHER FORECASTS; IMPROVE; Relative Greenness Maps; Internet Weather; NWS; PM2.5 & PM10 Samplers; RAWS.

Tools: Most in "Need" of Further Development

BEHAVE; FOFEM; FBPS; CONSUME; EPM; NFSPUFF; MM5; SASEM; TSARS-PLUS; VSMOKE; FOREST PLAN; NFMAS; NIFMID; NIIMS; Prescribed Fire Smoke Management Guide; SIP; NEPA; EPA Interim Guide; WIIMS; Visual Weather Checks; FRM's.

National Strategic Plan Strategies endorsed by the respondents of the survey

Strategies: Planning

Source Strength

- Develop a nationally applicable wildland fuel classification system, inventory and database to monitor fuel conditions, fuel treatments, and changes in fuel characteristics over time, which would include spatial attributes and a method for reporting between land and air managers.
- Provide training programs for using available methods for determining fuel conditions and estimating emissions.

Ambient Air Quality

- Determine the “natural” visibility conditions for regional haze evaluations for all areas of the country; develop a modeling system that would evaluate trade-offs between prescribed fires, wildfires, and other treatments; conduct long-term research on emissions trade-offs from treatment vs. wildfires.
- Develop emission factors for all vegetation types.

Effects on Receptors

- Establish a national fire database (wildland and prescribed fire) that contains the minimum data needed by air resource managers.
- Hold a series of workshops with stakeholders to agree on interagency model coordination for consistent model development, use guidance and evaluation; decide which models to use and how: an assessment of existing models; display modeling results, graphically or visually, at a level appropriate for the general public.

Strategies: Operations

Sources Strength

- Develop a comprehensive fire and smoke management system that links behavior, fuel consumption, emissions, and dispersion models. This system must be user-friendly and must accurately represent the full array of fuel types and conditions.

Ambient Air Quality

- Update and develop wildland emission factors and fuel moisture nomograms; develop nomograms that are applicable to all parts of the country (currently only address the West); update emission factors for all fuel types.
- Develop an interagency task force to coordinate, develop/approve of an operations level smoke management modeling system to address air quality, emission production, and dispersion for varying types of fires and complexity.
- Develop a uniform, linked, air quality, fire and meteorological database that supplies sufficient data for operational decision-makers to use models developed by inter-agency task force.

Effects on Receptors

- An easy-to-use dispersion model that uses current data to predict air pollutant impacts 3, 6, and 12 hours into the future.
- Develop a real-time analytical tool (computerized data display system) linked to GIS and easily communicable that integrates current meteorology (fine scale meteorological data fields) and air quality data to provide a complete picture of the near and far field impacts of emission from an ongoing burn.
- Develop criteria to determine when a receptor impact becomes unacceptable and determine the practicality of receptor mitigation strategies (e.g., a matrix of impacts and mitigation techniques).

Strategies: Monitoring

Source Strength

- Facilitate a forum where land managers and air resource managers will form partnerships to establish common standards and guides for monitoring and modeling source strength of fires and publish in a nationally accepted guidebook. Synthesize existing knowledge of fuel loading, fuel consumption, and emissions models for all ecosystems. Publish a national fuels inventory sampling guidebook that covers all sampling methods.
- Use fuels photo series and expert field knowledge to develop and expand fuel characteristic classes to represent other fuel types not currently available.
- Establish an integrated and consistent approach for collecting input variable to estimate daily emissions from fires (e.g., wildland fire recording form).

Ambient Air Quality

- Develop air quality, visibility, and meteorological monitoring protocols to support, assess, and evaluate wildland fire impacts. Protocols should include siting, operation and maintenance, quality assurance and quality control, system design, etc; cover both temporal and spatial scales; public notification; as well as the differences between wildfires and prescribed fires.
- Develop training programs, or identify existing programs to address needed skills for air quality, visibility and meteorological monitoring operations, data use, interpretation, and analyses.
- Conduct air quality, visibility, meteorological monitoring to provide data to assess wildfire and prescribed fire impacts.

Effects on Receptors

- Develop information needs for short-and long-term impacts (e.g., economic, medical, ecological, social, political, and public safety).
- Develop a centralized information management system for smoke levels and receptor impacts.

A Summary of additional comments made by respondents

- Vegetation dynamics models need to be linked to activities to generate fuel loading in dynamic fashion.
- Emissions production models are fine, no problem with emission factors, but need better characterization of combustion.
- Tools need to be linked to other GIS tools used for forest inventory, etc.
- Need a good tool for complex terrain, multiple fires, longer time periods.
- Need a consistent, nationally applicable guidance document.
- Need a tool for State Implementation Planning
- Need better instrumentation to monitor smoke in real time.
- Need national scale databases where information about fire and specific fires can be aggregated together to yield a national assessment.
- Need improved NWS forecast models.
- Need better temperature profile and wind field data at various heights.
- Need better communication/information-sharing with state, local agencies and public.

VI. Workshop Report

WORKSHOP BACKGROUND

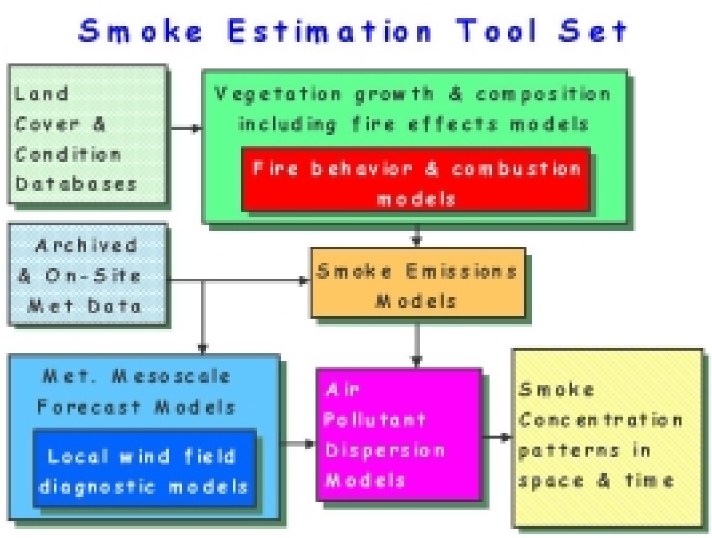
This workshop was intended to provide participating smoke management experts an opportunity to design and evaluate "technically advanced smoke estimation tools" and recommend priorities for further development of these tools. The workshop built on work previously done for the Joint Fire Sciences Program that:

- Identified smoke management tasks performed by land managers and air quality regulators;
- Identified, for each task, both the information needed and the tools used to provide that information;
- Polled fire practitioners regarding use of tools and priority for improving them, and,
- Developed a conceptual structured smoke management system including suggested priorities for further development of system components.

WORKSHOP PROCESS

The workshop's central structure was based on a conceptual design of an overall framework of smoke estimation tools consisting of data sources and models linked together to provide a logical information flow. Figure 1 depicts this framework.

Figure 1 Conceptual framework



This workshop consisted of four key components:

1. In order to prepare a uniform set of information for Workshop participants, we created a web site linking TASET's conceptualization of necessary modeling (figure 1), the Smoke Estimation Tool Set with available (as of February2000)

web references to detailed information about commonly available models in each of the identified model components. The reader will find a wide array of information about existing models by accessing this site and then following links to each model components.
2. Participation by a mix of modelers/tool developers, land managers, regulators, and smoke management program managers. A list of attendees is provided in Appendix B.
3. Presentations by tool developers and program managers on a variety of smoke management tools and their uses. A listing of presentations is provided in Appendix C.
4. Dividing the attendees into smaller work groups. Three groups were charged to review the tools associated with the different model grouping shown in Figure 1 and to develop recommendations for improvements. The fourth group was charged to look at information requirements needed to perform smoke management tasks and recommend needed actions to improve the information resources.
5. Final plenary meeting of the group to synthesize the work group results and discuss recommendations for improving both smoke management tools and information resources.

WORKGROUP RESULTS

The original charge to the first three groups was as follows:

1. Identify any additional models not identified on the TASET website. For additional models, identify web and other reference material to be added to the site.
2. Discuss details of all of the models on the website and include suggestions about pros & cons for each model.
3. Discuss interfaces between model groups, namely:
    - What information is needed from other models (initial conditions, boundary conditions, etc.) to come into each model;
    - What form is best for the input data;
    - How are the input needs currently satisfied;
    - What does the group think needs to be done to improve interfaces between models.
4. Recommendations for future development of models; develop a priority listing of tasks.

The fourth group was charged to:

- Identify and prioritize key information requirements needed to perform smoke management tasks, including model inputs such as monitoring data and meteorological data, and other data.
- Identify the sources of this information and evaluate the effectiveness of these sources in satisfying the information requirements.

- Synthesize this information into a prioritized list of needed improvements in information resources and an elementary "cost/benefit" analysis of each recommendation, and,
- Discuss model validation and evaluation; summarize needs for experiments and field studies.

The following summarizes the results of each of the workgroups over the three-day workshop period.

Group 1 – Fire Behavior and Vegetation Growth Model Interactions

Group 1 was tasked to look at the interactions between vegetation models and fire behavior models. First some general comments and model evaluation criteria were generated, which include:

- Vegetation models should be applicable for multiple resources. This can have the effect of minimizing inconsistencies in outputs across resources.
  - Fundamental conflict:
    - Land manager must take a multiple resource-systems approach.
    - Regulations are based on a single resource independent of other resources.
- Fire/vegetation models are most appropriate in strategic planning for the evaluation of a broad range of "what ifs".
- Observed/actual vegetation maps are better than models at the tactical planning and operations level.
- Note: Recent editorial in *J. of Forestry* co-authored by a state forester and a member of U.S. House of Representatives calls for an annual cycle in forest and range inventory.

- Vegetation models should be biogeochemically based and need to include species composition and competition capabilities.
- User considerations:
  - Must involve stakeholders, i.e., landowners, public land managers, regulators, NGOs, etc. This means realistic involvement at the strategic level.
  - Ease of use is important, but time constraints, minimal expertise are not critical factors.
  - Smoke management strategies are a part of land planning, not an independent activity.
  - Smoke management needs to be incorporated into carbon budget analysis, e.g., for such international instruments as the Kyoto Accord.
  - Nearly all models were developed for research purposes—no consideration has been given to general use—this needs to be addressed.

- Useful web site: http://www.uni-freiburg.de/fireglobe
  - Global fire inventory

- Global fuels
- Global smoke
- Links to JRC

1) *Identify any additional models not identified on the TASET website. For additional models, identify web and other reference material to be added to the site.*

- Additions to list
  - The list of vegetation models should be reviewed by key scientists in this field, including Dr. Bob Keane, USFS RM Research Station, Dr. Steve Running, University of Montana, Dr. Ron Neilson, USFS PNW Research station.
  - The fire model list is complete.

2) *Discuss details of all of the models on the TASET website: include suggestions about pros and cons for each model.*

- Vegetation models on TASET website that do not meet the minimum criteria identified above.
  - FETM
  - VDDT/TELSA
  - SIMPPLE/MAGIS
  - FVS
  - SAFE FOREST

- Vegetation models that partially meet the criteria identified.
  - FIRESUM
  - MAPSS
  - FIRE-BGC

- No vegetation models incorporate fire adequately at present.

- Plant functional types in models may have to be modified in order to incorporate fire.

- Improved plant functional type—fuel description relationship is needed.

<u>Fire Models</u>

- All models are appropriate, but they need to be categorized as to spatial and temporal utility.

- Fire models must consider user needs in their design phase.

- Nothing significant missing in future updates.

- Best approach is to encourage current trajectory of model development.

- Data needs may be a problem in some models, e.g., FARSITE.

3) Discuss interfaces between model groups, namely:
   - *What information is needed from other models (initial conditions, boundary conditions, etc.) to come into each model?*
   - *What form is best for the input data?*
   - *How are the input needs currently satisfied?*
   - *What does the group think needs to be done to improve interfaces between models?*

- The model/data framework described in Figure 1 needs to modified to separate strategic planning from tactical planning and operations as shown in Figure 2. Dashed lines indicate the path skipping vegetation models in tactical planning and operations.

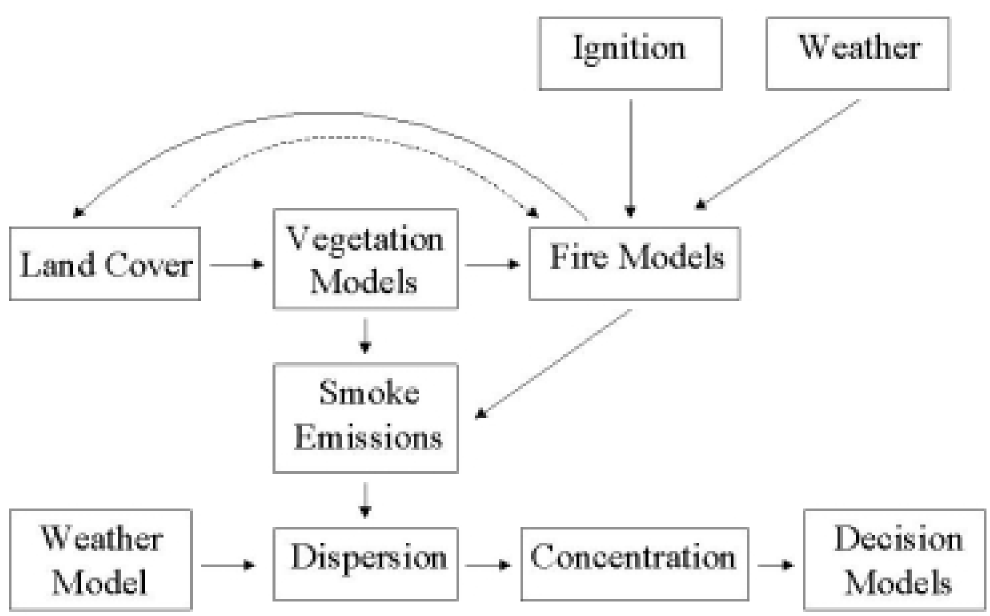


Figure 2. Revised Smoke Estimation Tool Set Framework

- Time frames
  - Strategic – 10 years to century, based on climatology
  - Tactical – annual, based on seasonal forecast, permitting
  - Operational – daily—weekly

- Process should focus on impacts.

- Rule based/expert system decision module is needed, should incorporate adaptive management (These models are beyond the scope of the TASET project.)

- Strategic planning is focused on "what if" and should be driven by probabilities.

- There is a need to include other disturbances in the system—precursors to fire, i.e., insect damage, windthrow.

- Need to establish a mechanism/forum for agreeing on a strategy for resource planning—need to include regulators, landowners, land managers, NGOs -- requirements/desires by regulators.

- Output from vegetation models is PFTs (a change in Plant Functional Types).

- Fire model inputs of fuels and PFTs need to be made compatible.

- Who will maintain the "shell" of SETS?

4) Recommendations for future development of models; develop a priority listing of tasks.

- Research
  - Fuel descriptors, plant functional type relationship is needed.
  - Improve fire representation in dynamic vegetation models.

- Overall system
  - Multiple resource approach smoke management is a part of land planning.
  - Focus on impacts—the land base.
  - Mechanism/forum to reach agreement in strategic plan (landowners, land managers, regulators, industry, NGO).
  - Decision module that feeds back to resource base.

<u>Groups 2 and 3 – Meteorological and Dispersion Models</u>

Groups 2 and 3 were combined because of the importance of the interface between meteorological models and dispersion models. Rather than explicitly address the models on the TASET website, the group decided to take an information-based approach to smoke management tools. In this approach, smoke management tasks were broken down into four categories:

- Strategic planning;
- Tactical planning and permitting;
- Operations, and,

- Evaluation and monitoring.

For each of these categories, the group formulated key decisions to be made and then identified information resources required to make these decisions and the sources of these information resources. A synthesis of this information for each level of smoke management tasks is provided in the following sections.

Strategic Planning

<u>Decision 1</u>

How much smoke can the air contain (from all sources) and still meet the requirements of ambient air quality standards, visibility, and public acceptance?

> Information requirement – With reasonable accuracy, how much smoke does the air contain now? Information source – Depends on location, but information can come from monitoring networks and from improved large-scale models such as Models-3.
>
> Information requirement – What are the limits on smoke with seasonal variations based on climatology? Information source – National Climatic Data Center (NCDC), state climatologists, backtracking through long-term integration of model runs.
>
> Information requirement – What are all sources of smoke and how much does each contribute to the overall amount of smoke? Information source – Emissions inventory.

<u>Decision 2</u>

How can smoke be optimally allocated from various sources and at different times of the year?

> Information requirement – Who is burning, how much, and when? Information source – Comes from communications among the burning community in the region. Fast track tracking programs such as PFIRS are being started on a state scale.
>
> Information requirement – What is the climatology of the region? Information source - National Climatic Data Center (NCDC), state climatologists, backtracking through long-term integration of model runs.
>
> Information requirement – What is the dispersion potential? Information source – Dispersion models, but need more depth of information.

Decision 3

How can burn goals be met given climate variations?

> Information requirement – What are climate variations and how do they impact burn goals? Information source – Long-term field exercises such as GEWEX, satellite observations and regional to global scale simulation model-based climatologies.

Tactical Planning and Permitting

Decision 1

Where and when is it safe to burn, how much can be burned, and how can resources best be allocated between prescribed burns and wildfires?

> Information requirement – What is the fuel moisture? Information source – On-site measurement and NFDRS.

> Information requirement – What are the weather parameters including wind direction, precipitation, and humidity? Information source – Climatology information as modified by large-scale weather events and regional forecast models.

> Information requirement – What are fuel conditions? Information source – Model output from models such as BEHAVE, FOFEM, and WFAS, as well as on-site measurements and observations.

Decision 2

How can public acceptance for the burn be gained?

> Information requirement – Where is the smoke going and what is in the way? Information source – Model information including emission, transport and diffusion data, and GIS information for sensitive receptors.

Operations

Decision 1

How much can be burned based on a risk assessment of standard exceedance, visibility impact, weather, safety considerations, and public acceptance?

> Information requirement – What is the weather? Information source – National Weather Service forecasts, observation networks, and other fire weather forecasts.
>
> Information requirement - What are the local fuel conditions? Information source – Local observations.
>
> Information requirement – What are the predicted smoke dispersion and transport? Information source – Models provide the pre-burn information; observations provide information during the burn – "man in the loop" is key.

Decision 2

What are the best techniques for smoke reduction and how long can the burn continue?

> Information requirement – What options are available/feasible within the purposes of the burn? Information source – Experience of burners is a critical element, although some information can be obtained from fire behavior models.
>
> Information requirement – What is the spot weather forecast including dispersion meteorology? Information source – National Weather Service and possible models such as 12km MM5.

Evaluation and monitoring

Decision 1

Was the burn duration appropriate and were the burn objectives achieved?

> Information requirement – In terms of the burn objectives, how much fuel was consumed and how intense was the fire? Information source – Measurement data from monitoring equipment.

Decision 2

Were there negative environmental impacts and were emissions targets met in terms of particulate matter produced?

> Information requirement – Were there any complaints from the public? Information source – Telephone calls.

Information requirement – Were emission standards violated? Information source – Monitoring equipment.

Group IV – Evaluation, Measurement and Management Programs

This group consisted primarily of smoke management tool users in both state air and federal land manager agencies. The group developed the following list of ideas for improving the smoke management tasks they are required to perform.

Regional Smoke Management Database which includes the following information:

1) Ambient AQ Data (accessible)
   - Existing NAAQS monitoring
   - IMPROVE monitoring
   - Satellite products

2) Acres Burned (source strength)
   - Acres scheduled
     - Date/time ignited
     - Historic data for future planning
   - Burn location (GIS)
   - Contact person

3) Definition of Regions & Airsheds
   - Cross-state boundaries issues
   - Utah has 3-5 airsheds
   - Idaho has 5 AQCRs with multi-airsheds/AQCR

4) Better Planning information
   - Spatial/temporal fire locations
   - 5- year-cycle for planning (10-year-cycle for Regional Haze)
   - Allocation of burn option among states

5) Visibility Issues information
   - Define natural background
   - How much burning compatible?
   - Feedback point for long-term, large-scale smoke impact analysis

6) Identify Alternatives to burning
   - Analysis and tracking
   - Projections of realistic alternatives

7) Wildfire vs. Prescribed Fire Information

Model Improvements

1) Further Develop Complex Terrain Models
    - Down-slope drainage

2) Models Need to Be Simple to Use
    - Commitment to provide adequate training of practitioners

3) Provide NAAQS and Visibility Projections

4) Allow gaming of alternatives to maximize airshed utilization
    - Allocate the resource
    - Multiple sources

5) Better Emission Factors (Beyond Present AP42) are Needed

6) Emission Inventories for Prescribed Fire
    - National
    - Regional

Certification of Models

1) Regional Impacts/Allocations require some standardization of models
    - Need guidance

2) SASEM needs to have formal EPA “Acceptance”
    - Recognition of limitations

3) NFSPUFF
    - Simpler data inputs
    - Ease of prep
    - Multiple sources
    - Limited to current meteorology

Complaints

1) Need Tracking System for complaints
   - Important feedback mechanism
   - Part of program impact analysis system

2) Must Be User Friendly
   - Complainant must be included as part of the big picture

SYNTHESIS OF WORKSHOP RESULTS

Significant findings of the workshop as generated during the work groups and in the plenary session are described below.

Key findings relevant to TASET include:

- A regional smoke management database is needed to provide information to planners and managers.
- Complex terrain models including down-slope drainage need to be developed.
- A system is needed to allow "gaming" of alternatives for allocation of resources and consideration of multiple sources, including the capability to model the probability of certain events given the selected alternatives. This could be a decision module incorporated within the framework of Figures 1 and 2.
- Better emission factors and national/regional emission inventories for prescribed fire are needed.
- Vegetation models should be applicable for multiple resources and should be biogeochemically based including species composition and competition capabilities.
- Nearly all vegetation models were developed for research purposes—no consideration has been given to general use—this needs to be addressed.
- No vegetation models incorporate fire adequately at present.
- Plant functional types in models may have to be modified in order to incorporate fire, and improved plant functional type—fuel description relationships are needed in vegetation models.
- Strategic planning is focused on "what if" and should be driven by probabilities.
- Climatology and emissions inventories are critical information requirements for strategic planning.
- Fuel moisture, fuel conditions, and climatology are critical information requirements for tactical planning and permitting.

- Weather and local fuel conditions are critical information requirements for burn operations.

- Fire intensity, fuel consumption, and emissions are critical information requirements for evaluation and monitoring and need to be available from monitoring equipment.

- Managers manage a multitude of resources, of which air is only one. Need to consider air along with the critical resources of vegetation and land cover.

- Specific emissions information is needed to perform air quality tradeoffs. Air quality modelers and emissions modelers need to work together to ensure that this is addressed.

- Feedback from the evaluation phase is critical to calibrate/validate models.

SMOKE ESTIMATION TOOL SETS FRAMEWORK

Figures 1 and 2 depicted a framework for smoke estimation tool sets. This section will expand this framework based on the results and findings of the workshop to tailor the framework to the different task areas of strategic planning, tactical planning, operations, and evaluation.

In order to estimate smoke from wildland burning, spatially explicit land cover, condition, and topographic data must be merged with meteorological information to formulate initial and boundary conditions for prediction models. Prediction models are of many types but basically involve a probabilistically framed statistical estimate of future condition. Some of these are based strictly on statistical experience; others are based on a "process simulation" which attempts to model natural system behaviors. This is made difficult because of the seemingly random, chaotic nature of the linked atmosphere/biosphere complex within which wildland fire operates.

The system involves a set of interacting components. Vegetation changes over time in response to a number of influences, including weather and disturbances (fire, disease, insects). The interaction between fire processes and vegetation is dependent on the condition of the vegetation, weather, and climate influences among others. The burning process consumes vegetation (fuel), generates heat and airborne emissions of combustion products or smoke, a mix of gases and small particles (aerosols), leaving a residual of ash and unburned vegetation. Emissions, in turn, interact with ambient meteorology, being transported, diffused, chemically reacted upon, and removed. The result is a dynamic distribution of gas and aerosol concentration in space and time. In order to predict concentrations of smoke at specific locations, this full complex of component databases must be linked with the statistical and simulation models.

Figure 1 provides a representation of one way that these components might be connected to assist in smoke management.

In developing this formulation of databases and model components, we consider that a separate set of interacting and linked components may be needed for each of the task domains that are appropriate for smoke management, namely, strategic, tactical, operational and evaluation activities. Thus, a different, yet linked, set of components might be most appropriate for each level of task activity. Conceptually, this is illustrated in Figure 3.

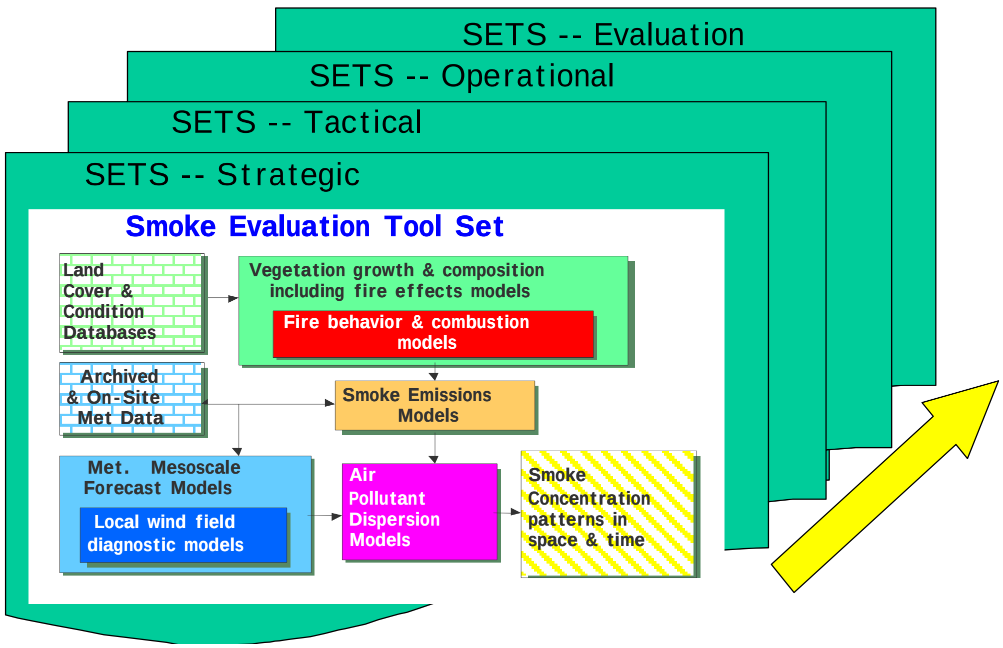


Figure 3. Differing Tools for Different Tasks, with Feedback

Figure 3 allows the set of tools appropriate at the strategic planning level to be different from the set of tools needed for tactical planning, and so forth. However, it is critical for these tools to have the capacity to be linked between different levels of activity. Indeed, it is the absence of such linkage in contemporary practice that has been identified as a problem by individuals, especially those with regulatory responsibilities for smoke management.

In fact, there are two problems of linkage that have been identified. First, at each level of enterprise, for example at the strategic level, the tools used by all parties to the process should be compatible and interactive. Projections by one set of stakeholders using a set of tools should be related to projections by other stakeholders using a different set of tools. In fact, the 1977 Clean Air Act acknowledged the need for uniformity and consistency in the application of air quality models for regulatory purposes and mandated the EPA to establish formal modeling guidelines and an associated review and acceptance policy.

For smoke management, it is important that any models used in the land management planning process to make projections are equally acceptable for the air quality State Implementation Plan (SIP). Agreement between models used by different parties in the other three areas of activity is equally important.

Perhaps of even greater significance, model projections between strategic, tactical, and operational applications need to be consistent. While we recognize that different tools will be used at each of these levels, it is clear that there needs to be an understandable relationship between smoke projections made for each of these applications. There needs to be a linkage between the land management plan, the permitting of burns, the actual conduct of the burning and finally with an evaluation of the effectiveness of the burning activity. To discuss the nature of these relationships is beyond the scope of our activity here.

In addition, at each level of activity, there are many differing contextual considerations, for example, including:

- Scales of operation;
- Large or small burns;
- Single or multiple burns;
- Mixtures of planned prescribed wildland fire and wildfire;
- Current airshed loading, i.e. the amount of clean air available;
- Distance to sensitive areas, non-attainment areas, and,
- Other agricultural burning.

Because of these differences, we do not, in general, recommend a single model for each component application. Rather we recommend at least two models. One of these is a screening tool while the second is a more complex tool capable of providing a more refined analysis.

VII. Recommendations

Nine specific recommendations developed as a result of the TASET project are targeted to each of the smoke management task areas; strategic planning, tactical planning and permitting, operations, and evaluation. Project recommendations are summarized below and in the recommendation tables contained in Appendix A. In addition to listing the recommendations here, included below are short summaries of each recommendation in a format that the JFSP Board can use for discussion about future research they may choose to undertake.

The Forest Service National Strategic Plan (Sandberg et al.,1999) recommended nine specific strategies for furthering modeling and data analysis for fire and air quality. They identified:

1. Fuels & Fire Characterization;
2. **Emission modeling systems;**
3. **Transport, dispersion, and secondary pollutant formation;**
4. **Air quality impact assessment;**
5. **Emissions tradeoffs and determinations of natural visibility;**
6. **Impact and risk assessment of emissions from fires;**
7. Monitoring guidelines and protocols;
8. **National fire and air quality information database;**
9. Public information and protection.

TASET, in recommending nine specific projects for Joint Fire Science Program consideration, addresses all of these strategies, specifically enabling the six listed in boldface. However, the TASET recommendations are more specific, recommending for example, detailed specific approaches to accomplish them.

Strategic planning
The TASET project has confirmed that there is a pressing need for development of better and more coordinated planning tools to be used by both the fire community and air quality regulators. The task area where this is most pressing is strategic planning. Strategic planning, especially for the development of State Implementation Plans (SIPs) under the Clean Air Act, will be receiving relatively greater attention in the coming decade because of new regional haze regulations and a proposed PM2.5 national ambient air quality standard. Supporting this effort is the number one priority recommendation from TASET.

Models required for SIP analysis share a number of characteristics that need not be reviewed here except to comment that they must meet stringent capability and acceptability requirements by the entire stakeholder community. This includes, not only land managers and fire practitioners, but air quality managers, regulators, and scientists, industrial participants to clean air decision-making and the interested public. Among major concerns is the realization that we all share one atmosphere. This atmosphere is linked physically & chemically, pollutants from industrial sources merge with those from natural sources, from the managed use of fire and all other human activity. One consequence of the introduction of all these pollutants means that it is necessary to consider both the natural hydrocarbon emissions from vegetation, other ozone precursors, and smoke emissions in the same simulation models. Smoke can no longer be considered as a stand-alone pollutant, it must be considered in the context of all the other pollutants and their associated control strategies. In order to do this smoke management modeling need not be separated from but integrated with all other air quality modeling done for a SIP. The EPA developed Models3/Community Multiscale Air Quality Model (CMAQ) has been designed to accomplish this integration and comparative one atmosphere simulation. Unfortunately, running the Models3/CMAQ is an intensive and complex process requiring large, dynamic data inputs, a wide variety of staff with diverse and different backgrounds and capabilities, and significant computational and communications infrastructures.

The first TASET recommendation (#1) does not call for development or application of this complex modeling approach to smoke and fire. Rather, we feel it is necessary for the fire research community to establish a continuing commitment and capability as a part of **regional efforts to develop and apply Models3/CMAQ** and similar complex, one-atmosphere, simulation systems. Thus, TASET recommends financial participation in support of participants in the regional meteorological and air quality modeling consortia. These consortia are developing in support of air quality modeling requirements for ozone, regional haze, and PM2.5 regulatory requirements. Our recommendation is to fund additional work in these locations to add fire and smoke considerations into the mix of source categories being studied.

Additional strategic planning needs involve supporting this complex model application.

Secondly, (#2), there is a need for a greater scientific understanding of the nature of the relationships between fire, visibility and fine particulate. Much of this understanding is developing as a result of an active research community but it is accumulating in a disparate variety of journals that are not always read by the diverse workers in the community. Since the development and application of complex air quality simulation models calls for the merging of this disparate science along with various more operationally oriented issues, we propose the convening of a **Visibility & Fire Conference**. This Conference would bring together internationally recognized authorities in visibility and smoke to make invited presentations, submit contributed papers, and develop a book.

Third, (#3), complex models require **detailed emissions inventories**. A detailed emission inventory linked to vegetation models, GIS, fire models, fire occurrence, and fire planning. Because the model requires detailed emissions information, this inventory needs to include VOC and PM2.5 speciation to the extent possible. Since the land management community has expended considerable effort in developing tools to predict vegetation dynamics, this systems needs to be fully integrated with such emerging systems.

Fourth, (#4), there is a need to advance the capabilities of **remote sensing tools** and technologies to provide improved input data from model applications and to evaluate the validity of model estimates. Remote sensing tools are needed to identify vegetation dynamics, fuel condition, fire activity, and smoke plumes from routine satellite observations. Advancing spectral and spatial resolution in emerging generation of new instruments holds promising potential to provide meaningful operational information.

Tactical Planning and Permitting

Much of the technology needed at the tactical planning and permitting level has actually been developed and is being employed in different locations at the present time. Thus, much of the need in this area is for standardization and national acceptance of preferred approaches.

The fifth TASET recommendation, (#5), actually supports both strategic and tactical planning efforts; however, its most pressing need is associated with tactical planning. One of the important functions for the Models3/CMAQ system is the ability to run and to keep track of multiple scenarios, changes, and alterations in complex input fields, such as emissions inventories, changes in model versions and presence and absence of alternative scientific formalisms, and a host of other details. Models3/CMAQ manages this complex record keeping via science and scenario "managers." This sort of functionality, tracking complex alternative maps of planned fire use, of historical and contemporary wildfire occurrence, of smoke management planed and accomplished, is needed by smoke managers. Thus, we recommend that **a simplified, engineering (or gaming) version of the Models3/CMAQ applied to forest and agricultural smoke and fire** is needed.

The sixth recommendation (#6) has applications in the operational as well as the tactical planning area. It supports efforts initiated by the EPA and the federal land manager’s activity known as IWAQM (Interagency Working Group on Air Quality Modeling). IWAQM has worked for nearly ten years to standardize the application of air quality simulation models for applications in the complex mountainous terrain of the western United States. The primary focus of this activity has been the use of models for permitting new stationary sources of air pollution under the Prevention of Significant Deterioration component of the Clean Air Act. Through this process, a combined meteorological and dispersion models system, known as CalMet/CalPuff, has been recommended for these applications. Because this model system has received regulatory acceptance, it seems logical to recommend its use for smoke permitting and tactical applications. Application of CalMet/CalPuff to simulate smoke produced from various types of fire activity is a high priority. However, currently, the system is considered too complex for routine application. Land managers have been advocating the application of a much simpler model know as NFSPuff. NFSPuff has decided advantages in terms of its user interface; however, it is not likely to achieve regulatory acceptance. Therefore, our recommendation is to **develop a user interface for CalMet/CalPuff having the look and feel that is acceptable to smoke managers**.

The seventh (#7) recommendation also has applications in the operational area as well as in tactical planning and permitting. We recommend that **the existing tool SASEM be upgraded and approved as a national smoke management screening tool.** SASEM has received wide acceptance as a screening tool for permitting prescribed burning. The term screening tool recognizes that the model has limitations in terms of dealing with complex terrain and associated plume behavior. EPA approves models for specialized application as screening tools. By this, they mean that the model can be used to project impact of an emission source with the assurance that the projection is conservative, namely that it over-predicts impact. Thus, regulators can be assured that the fire is not likely to lead to violations of any air quality standards. SASEM is easy to use, is based on acknowledged technologies, and should meet EPA's requirements for approval as a screening technique. This recommendation is to upgrade SASEM to operate efficiently in an MS Windows environment, to reflect the latest emissions projection tools, and to work through EPA's procedure for formal acknowledgement of SASEM as a regulatory screening tool.

Monitoring and Evaluation

The eighth (#8) recommendation is to **accurately measure emissions from a wide array of wildfire and prescribed fires**. Current understanding of the emissions from forest fires is not sufficient to be introduced into the complex atmospheric chemistry models needed for SIP purposes. An improved characterization of the flux of gaseous and particulate emissions from different levels and types of fire in diverse ecosystems will be necessary in the future. Both chemical and physical characterization of these emissions will be needed. A series of detailed experimental programs will be required in order to characterize these emissions.

The ninth (#9) recommendation calls for the **development and use of back trajectory tools for the evaluation of smoke from forest fires**. These techniques have proven useful in assessing the contribution of different sources to the final impact measured at receptors. They should prove useful for characterizing the downwind impacts on visibility and PM2.5 caused by significant fire events.

VIII. Conclusions

Tasks associated with smoke management activities were identified. A structured analysis was used based on a simple decision model. The model considered specific actions or "tasks" undertaken by air quality managers and land managers separately while conducting strategic planning, tactical planning, operations, and evaluation and monitoring for smoke management. For each action, information needed to conduct the task and the appropriate sources of that information, especially models and datasets, were identified. The resulting smoke management tasks map is too complex and cumbersome to reproduce here, but can be retrieved from our website at:
http://www.cira.colostate.edu/smoke/taskflow/default.htm

This smoke management task map we used to develop a survey that was made available from our website and distributed to a large number (over 150) of smoke managers in an effort to obtain their opinions about the need for better tools (models and datasets). Following the survey, a Workshop was held at Colorado State University to review the status of current smoke management tools as well as to discuss the needs for additional tools.

Finally, the authors have reduced the volume of information generated into a set of nine specific recommendations for what might be termed "next steps" for consideration by the community. While, we initially envisioned our final product would be a more comprehensive system of tools (models) and linkages of those tools to datasets (for example as outlined in Figure 1, we decided that there were so many different parallel paths being pursued, that it would be less than responsible to recommend still another). Rather we chose to suggest nine specific opportunities that should be pursued to reach the next level of technically advanced smoke estimation tools.

The nine recommendations are included in the executive summary of this report.

IV. References

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X. Appendices
Appendix A: Recommendation Tables

Table A-1. TASET Project Recommendations: Strategic Level

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Fuels Information	Remote sensing	Gather information on fuels loading and condition at landscape scale	Information for fuel loading, fuel types, and conditions at 1 KM pixel resolution	HIGH	$200,000 per year (costs potentially lowered by cooperation with NASA, NOAA, DOI, and DOD)	Five years
Fuel Consumption Model	FBPS/BEHAVE	Simulations/ estimates of fuel amounts actually to be consumed	Improved projections of fuel consumption for emissions calculations	___	As funded by JFSP	On-going
Emissions Model	EPM/FOFEM	Simulations/ estimates of actual emissions	Improved projections of emissions for regional, state, forest, and district level planning; include emissions species/precursors critical to visibility and ozone	____	As funded by JFSP	On-going
Meteorology Data Source	Regional climatologies; NOAA AWIPS and USDA AWIPS	Provide information to run models in a prognostic mode	Improve access, work with AWIPS and NOAA Port technologies for data delivery at all organizational levels	MEDIUM	$100,000 a year	Two years to develop basic infrastructure for support strategy and demonstration project; suggest partnership with USDA World Outlook Board and NOAA Labs

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Meteorology Models	MM5/RAMS and CALMET	To predict fire behavior/conformance with burn prescription; input files for dispersion models.	Needs wider access to regional scale simulations with information available to fire managers for long-term planning.	HIGH	$400,000 per year (combination with Dispersion Models)	Eight years (suggest “Smoke Estimation Tools (SETS) Grants Program,” fund two $200,000 per year, 2 year programs.)
Dispersion Model	CMAQ (e.g. EPA MODELS 3) and CALPUFF	Provides basic information on how fire emissions will support state programs for PM2.5, regional haze, and ozone.	Needs wider access to regional scale simulations with information available to fire managers for long-term planning.	HIGH	$400,000 per year (combination with Meteorology Models)	See: Meteorology Models section
Evaluation Tools	Remote sensing And Fire Emissions Data Structure	Provide basic information on area burned within 10% accuracy; Provide for national emissions database useful in SIP/TIP development and large-scale planning.	Implementation of newer generation satellite information and data algorithms; New-generation web-based data structure for fire emissions inventory with linkage/data feed mechanisms to dispersion models	MEDIUM	$150,000 (remote sensing); $150,000 year (data structure – potential cost partnership with EPA, states)	Two years; Three years

Table A-2. TASET Project Recommendations: Tactical/Permitting Level

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Fuels Information	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)	HIGH	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)
Fuel Consumption Model	CONSUME	Simulations/ estimates of fuel amounts actually to be consumed	Improved projections of fuel consumption for emissions calculations		As funded by JFSP	On-going
Emissions Model	EPM/FOFEM	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)		As funded by JFSP	On-going
Meteorology Data Source	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)	MEDIUM	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)
Meteorology Models	MM5/RAMS, CALMET,	Provides information to predict fire behavior/conformance with burn prescription; input files for dispersion models.	Improved information/ spot forecasts to local fire managers through web-based delivery system; new model interface for CALMET so that it can be operated at local offices in a "NFSPUFF" emulation mode.	HIGH / MEDIUM	$400,000 per year in regional centers from strategic level/ $150,000 per year.	Eight years for centers program from strategic level; Three years for CALMET/ CALPUFF project
Dispersion Model	CALPUFF and SASEM	Provides basic information on how fire emissions will support state programs for PM2.5, regional haze, and ozone; information to receive permits to burn.	New model interface for CALPUFF so that it can be operated at local offices in a "NFSPUFF" emulation mode; New generation SASEM with single and multi-fire modes.	MEDIUM CALMET / HIGH SASEM	$150,000 per year for CALMET/ CALPUFF (included in Meteorology Models); $65,000 per year for SASEM	See: Meteorology Models section; Two years for new generation SASEM

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Evaluation Tools	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)	Same as Strategic (covered by that section)		Same as Strategic (covered by that section)	Same as Strategic (covered by that section)

Table A-3. TASET Project Recommendations: Operations Level

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Fuels Information	Improved field techniques and technologies	Fuels information at grid resolutions down to ten meters for emissions calculations using newer generation GIS based models	As funded by JFSP		As funded by JFSP	On-going
Fuel Consumption Model	CONSUME/ BEHAVE	As funded by JFSP	As funded by JFSP		As funded by JFSP	On-going
Emissions Model	EPM	As funded by JFSP	As funded by JFSP		As funded by JFSP	On-going
Meteorology Data Source	Same as Strategic (covered by that section); Next Generation WIMS; new technology for on-site meteorology (SODARS/ LIDARS and portable weather stations)	Same as Strategic (covered by that section); WIMS modification by NFS to use AWIPS data stream; Need for upper-air soundings and local scale transport meteorology for smoke transport/ trajectories	Same as Strategic (covered by that section); New WIMS must be modified to use data from AWIPS; Use of SODARS/ LIDARS for upper-air soundings will need development of low-cost (>$8000) units; New automatic weather station data stream interface to proposed CALMET/ CALPUFF system, new generation SASEM, and fire behavior models	Same as Strategic (covered by that section); HIGH/ URGENT (WIMS); MEDIUM (SODARS/LIDARS/weather stations)	Same as Strategic (covered by that section); WIMS funding covered by NFS but JFSP should coordinate; $150,000 – SODARS/ LIDARS; $25,000 –weather stations	Same as Strategic (covered by that section); New WIMS must be completed within one year period or less; Two years – SODARS/ LIDARS; Three years – weather stations
Meteorology Models	CALMET	To predict fire behavior/ conformance with burn prescription; input files for dispersion models.	New model interface for CALMET so to operate at offices in a NFSPUFF emulation mode.		Same as Tactical/ Permitting (covered by that section)	Same as Tactical/ Permitting (covered by that section)

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Dispersion Model	CALPUFF and SASEM	Provides basic information on if emissions will violate permit to burn.	Same as Tactical/ Permitting (covered by that section).	MEDIUM CALMET-CALPUFF / HIGH SASEM	Same as Tactical/ Permitting (covered by that section)	Same as Tactical/ Permitting (covered by that section)
Evaluation Tools	New fire site/ sensitive receptor emissions and ambient concentration techniques (e.g. Eye-safe LIDARS)	Measurement of non-point emissions and concentrations to ascertain emissions targets in plans and permits, also ensuring standards were not exceeded.	Development of Eye-safe LIDARS for field use to measure emissions species (including ozone pre-cursors), particle size distributions, ambient concentrations in ambient standards range, and visibility.	HIGH	$250,000 per year	Three years

Table A-4. TASET Project Recommendations: Evaluations Level

Models or Tools Recommended	Recommended Information Source, Tool, or Model	Purpose and Need	Modifications Needed	Priority of Modification	Cost Estimation	Estimated Development Time
Fuels Information	Same as Operational (covered by that section)	Same as Operational (covered by that section)	As funded by JFSP		As funded by JFSP	On-going
Fuel Consumption Model	CONSUME/ BEHAVE	As funded by JFSP	As funded by JFSP		As funded by JFSP	On-going
Emissions Model	EPM	As funded by JFSP	As funded by JFSP		As funded by JFSP	On-going
Meteorology Data Source	Historical records and data/ information collected at site	Trajectory/ receptor modeling to complete post-fire assessments	Data archive structure needed to store and disseminate on-site data, climate records, and seasonal weather simulations (as completed by Ferguson under JFSP)	LOW	$50,000 a year	Two years (starting after operational recommen-dations completed)
Meteorology Models	CALMET	Provide adjusted local-scale, high-resolution wind fields for trajectory/ Receptor modeling.	Same as Operational (covered by that section)		Same as Operational (covered by that section)	Same as Operational (covered by that section)
Dispersion Model	Trajectory/ Receptor models (National Park Service model guidelines and models)	Provides source information if emissions violated permit to burn, standards, planning goals, or SIP.	Formalization of NPS procedures and guidelines; development of model user interfaces and data input structures.	LOW	$100,000 a year	Three years
Evaluation Tools	Carbon source evaluation procedures and techniques for PM2.5 filters	Assessment of fire contributions to ambient standards violations and visibility impairment.	Development of new filter analysis techniques.	HIGH	$250,000 per year	Three years

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C -- Workshop Agenda

Wednesday, February 2

Time	Subject
9:00-9:30	Welcome & Introductions (Fox)
9:30-10:00	Review of TASET, SETS, and Workshop format (Fox/Wallace)
10:00-10:30	Importance of Smoke Management (Hirami & Riebau/USFS)
10:30-10:50	BREAK
10:50-11:10	TASET Survey results (Asmus/Colorado State University)
11:10-11:30	Overview of Vegetation dynamics modeling (Fox/CIRA)
11:30-11:50	Fire behavior, combustion, & effects model (Reinhardt/Finney)
12:00-1:00	LUNCH
1:00-1:20	Overview of Smoke Emissions Models (Sandberg/PNW)
1:20-1:40	Overview of Models for Smoke Management (Ferguson/PNW)
1:40-2:00	GIS experiences with Fire (Menakis/RMS)
2:00-2:20	The Florida Smoke Management Program (Brenner/Fla)
2:20-2:40	Discussion/Charge to smaller groups ➢ Fire/Vegetation Interaction Modeling/Fosberg ➢ Meteorological Modeling/Wallace ➢ Dispersion Modeling/Riebau ➢ Evaluation/Measurement/Management programs/Fox
2:40-3:00	BREAK
3:00-5:00	Small group discussions

Thursday, February 3

Time	Subject
9:00-9:30	Diagnostic & local scale models (Ciolek/AlphaTrac)
9:30-10:00	Overview of Air Quality and Dispersion modeling (Vimont/NPS)
10:00-10:30	BREAK
10:30-11:00	Models 3 (Ching/EPA)
11:00-11:20	USDA's AWIPS Link to NOAAPORT (Rippey/USDA)
11:20-11:40	Long Range Forecasting and Fire Modeling (Fujioka/PSW)
11:40-12:00	Source attribution modeling (Gebhart/NPS)
12:00-12:30	LUNCH
12:30-1:30	Satellite Observation Capabilities (Bleiweis/USA)
1:30-3:00	Smaller group discussions ➢ Fire/Vegetation Interaction Modeling/Fosberg ➢ Meteorological Modeling/Wallace ➢ Dispersion Modeling/Reibau ➢ Evaluation/Measurement/Management programs/Fox
3:00-3:30	BREAK
3:30-3:45	Review of discussions (plenary)
3:45-5:00	Continued smaller group discussions

Friday, February 4

Time	Subject
8:30-9:00	Workshop Conclusions (Fox/Riebau)
9:00-9:20	Smoke Management in Canada (Lee/CFS)
9:20-9:40	Smoke Management Programs & WRAP (Lahm/USFS, AZ)
9:40-10:00	Smoke Management Research Needs (Malm/NPS)
10:00-10:20	Accuracy of meteorology and dispersion modeling (Pielke/CSU)
10:20-10:40	BREAK
10:40-12:00	Continued smaller group discussions ➢ Fire/Vegetation Interaction Modeling/Fosberg ➢ Meteorological Modeling/Wallace ➢ Dispersion Modeling/Riebau ➢ Evaluation/Measurement/Management programs/Fox
12:00-1:00	LUNCH
1:00-3:00	Final discussions/Wrap-up/Critique

Appendix D -- Survey Forms

Smoke Management User Needs Assessment

This smoke management user needs assessment is part of a project funded by the Joint Fire Sciences Program to evaluate the current status of, and the need for, additional smoke management tools. ***This assessment is your opportunity to provide planners with your input regarding the development and implementation of smoke management models and data systems that will ultimately be used by you to do your job.***

As the starting point for this survey, two reports were used to assist in defining both a list of tasks and a list of information sources or tools. One report used was EPA's Interim Air Quality Policy on wildland and prescribed fire that proposes a set of tasks for States, Tribes and local air quality managers to follow. Execution of these tasks requires information, which comes from a variety of information sources or tools. Information sources include data, databases, models, standards, and guidelines. Therefore, the second report used was the initial set of information sources/tools derived from last year's national strategic plan for wildland fire and air quality, which identified smoke management models and data systems that need to be developed and implemented. The purpose of this survey is to have you identify the tasks you perform, the information sources/tools you use to do your job, and to identify user-based priorities for improving the focus and coordination of research and development of future tools and information sources. The entire survey will provide a user-based assessment of the tools and information sources currently in use. The whole survey should take approximately 20 minutes.

Name: ____

Address: ____

____

Phone: ______________________________

FAX: ______________________________

E-mail: ______________________________

Agency: ____

Job title:
____

How many years in position? ________________

For each of the following, please indicate:
ONLY for tools you currently "use" to do your job, please evaluate:

- "Importance" of this tool or information source to execute task(s),
  3 = Very Important 2 = Somewhat Important 1 = Not Important
- "Ability" of this tool or information source to do what you need it to do,
  3 = Very Good 3 = Somewhat Good 1 = Poor
- "Need" to change to or develop different tool or information source to better perform task(s),
  3 = High 2 = Moderate 1 = Low

Models & Systems of Models:

Fire models:	Use	Importance	Ability	Need
Example: BEHAVE: Fire behavior and fuel modeling	X	3	1	1
BEHAVE: Fire behavior and fuel modeling				
FARSITE: Fire growth simulation program for PC's				
FOFEM: Fire effects simulation model				
FBPS: (Fire Behavior Prediction System) Fuel Models				
FireLib: Predicts spread rate/intensity of free-burning fire				
FIRES: (PC) Eval. the perf. of fire danger rating indexes				
FVS: Links stand dev., fuel dyn., fire beh., fire effects				
NEXUS: (EXCEL) links surface to crown fire predicting				
NFDRS (National Fire Data Rating System) Fuel Model				
RERAP: Calculates information needed to manage fires				

Smoke emission production models:	Use	Importance	Ability	Need
CONSUME: Fuel cons. and smoke emissions prediction				
EPM: Smoke emission production model				

Meteorology & dispersion models:	Use	Importance	Ability	Need
MODELS3: EPA's Comprehensive simulation system				
NFSPUFF: complex terrain dispersion simulation model				
MM5 Mesoscale meteorolical prediction model				
CalMET: Mesoscale meteorological diagnostic model				
CalPUFF: Disp. simulation model interactive with CalMET				
SASEM: Source emission & dispersion model				

TSARS: field officers to test fire presc. for SM problems				
TSARS-Plus: Wind & dispersion model for complex terrain				
VALBOX: Dispersion simulation model				
Ventilated Box Model: Dispersion simulation model				
VSMOKE: Dispersion simulation model				
VSMOKE-GIS: Dispersion simulation model, linked to GIS				
PLUMP: plume rise sim. Mot./air mod. & fire bound. input				
AFWIN: Mesoscale met. and regional dispersion model				

<u>For each of the following, please indicate:</u>
ONLY for tools you currently "use" to do your job, please evaluate:

- "Importance" of this tool or information source to execute task(s),
  3 = Very Important 2 = Somewhat Important 1 = Not Important
- "Ability" of this tool or information source to do what you need it to do,
  3 = Very Good 3 = Somewhat Good 1 = Poor
- "Need" to change to or develop different tool or information source to better perform task(s),
  3 = High 2 = Moderate 1 = Low

<u>Other information sources:</u>	Use	Importance	Ability	Need
Forest Plan				
Fire Management Handbooks				
Fire Management Preparedness and Planning Handbook				
FEIS: Complete encycl. of fire ecology of plants and animals				
NFMAS (National Fire Management Analysis System)				
NIFMID (Nat. Interagency Fire Mgt. Integrated Data)				
NIIMS (National Interagency Incident Management System)				
NWCG Smoke Management Guidelines				
Southern Forestry Smoke Management Guidebook				
Prescribed Fire Smoke Management Guide				
SIP (State Implementation Plan)				
Guidelines for preparing a NEPA Air Quality Analysis				
EPA's Interim Air Policy on Wildland and Prescribed Fires				
Prescribed Burning Background Document And Technical Information Document For Prescribed Burning Best Available Control Measures (EPA)				

<u>Data Sources:</u>	Use	Importance	Ability	Need
Spot weather forecasts				
MfFSF: monthly fire weather forecasts				
IMPROVE data (Interagency Monit. of Prot.Visual Env.)				
Relative Greenness Maps				
WIMS: Weather Information Management System				
Internet weather sites				
Internal fire emissions databases				
EPA AP-42				
NWS Forecast (National Weather Service)				

Temp. and wind profiles from daily pilot balloon releases				
Visual smoke operations				

<u>For each of the following, please indicate:</u>
ONLY for tools you currently "use" to do your job, please evaluate:

- "Importance" of this tool or information source to execute task(s),
  3 = Very Important   2 = Somewhat Important   1 = Not Important
- "Ability" of this tool or information source to do what you need it to do,
  3 = Very Good   2 = Somewhat Good   1 = Poor
- "Need" to change to or develop different tool or information source to better perform task(s),
  3 = High   2 = Moderate   1 = Low

<u>Instruments:</u>	Use	Importance	Ability	Need
Filter packs				
PM10 & PM2.5 samplers				
MIE Inc. Model DR-2000 DataRAM PM samplers				
Airmetrics MiniVOL samplers				
RadianceResearch nephelometer				
RAWS: remote weather data collection platform				
FRM (Federal Reference Monitors)				

Please add any other information or data sources, tools, instruments, or models we do not have included in the above list that you use to do your job and rate each.

<u>Other</u>	Use	Importance	Ability	Need

Please indicate which *tasks* you currently do in your job:

Strategic Planning:

_____ Update Forest Plan (Federal)/Forest Stewardship Plan (State and private).

_____ Evaluate costs, benefits and environmental impacts of using fire as a land management tool, including the use of prescriptive criteria that are measurable and will guide selection of appropriate management actions in response to wildland fires and prescribed burning.

_____ Provide input to and participate in development of Smoke Management Program.

_____ Collaborate with State/Tribal air quality managers (air regulators) to achieve goals of: (a) allowing fire to function in its natural role in the wildlands, and (b) protecting public health, visibility and regional haze, and welfare by minimizing smoke impacts.

_____ Develop mechanisms to notify air quality managers of (1) plans to significantly increase their future use of fire for resource management,(2) air quality impacts of fire, and (3) appropriate steps to mitigate those impacts, including appropriate alternative treatments.

_____ State Air Quality and Smoke Management Policy and Regulations

_____ Address conformity of fire plans.

_____ Provide internal policy direction concerning feasible alternatives to fire use when such use is not justified by resource management benefit considerations.

_____ Provide input to and participate in regional fire activities.

_____ Assessment of firefighter's exposure to smoke and develop management strategies to monitor and reduce exposure levels.

_____ Develop/Update Smoke Management Program.

_____ Update SIP/TIP.

_____ Develop control strategies.

_____ Develop regional strategies for smoke management.

_____ State Air Quality and Smoke Management Policy and Regulations

_____ Collect information on projected fire activity.

Tactical Planning:

_____ Identify goals for the use of fire.

_____ Calculate and evaluate trade-offs between mechanical, chemical and fire land treatment (Element of the NEPA process).

_____ Specific Burn Plans

_____ Predict amount of fuel consumed with fire treatment.

_____ Conduct air quality and visibility impact evaluations of fire activities.

_____ Develop ambient air monitoring plans.

_____ Identify the potential for smoke intrusions into sensitive areas.

_____ Model air quality and visibility impacts.

_____ Identify sensitive receptors.

_____ Project impacts of fire for a specific project.

_____ Submit permit request with appropriate projections, etc. to appropriate regulatory authority.
_____ Track approvals and any required restrictions, additional information, etc.

<u>Please indicate which *tasks* you currently do in your job:</u>

<u>Operations</u>
______ Inform smoke sensitive receptors about fire progress.
______ Identify location for smoke sensitive people to go to during burn or other mitigation procedures.
______ Enforce burn parameters are in accordance with permit restrictions.
______ Obtain and evaluate weather dispersion and visibility forecast.
______ Issuing spot smoke forecasts.
______ Receiving and accommodating public complaints.
______ Compare dispersion to standards/guidelines and permit requirements.
______ Participate in final decision to burn.
______ Determine likelihood that fire prescription will be met.
______ Monitor weather and dispersion.
______ Monitor fire impacts.

<u>Evaluation and Monitoring:</u>
______ Determine if short-term implementation and effectiveness goals achieved identify fuel consumed and ecological benefits accrued.
______ Assess ecological impacts.
______ Assessment of specifically impacted resources.
______ Determine if long-term goals are achieved.
______ Assess post-burn fuel loading and ecosystem condition.
______ Evaluate regional and inter-jurisdictional impacts.
______ Compare standards and guidelines against incremental loading.
______ Evaluate any negative public reactions.
______ Determine total incremental loading from burning in the region.
______ Document impacts to state ambient air quality PM10 and PM2.5 monitoring data

<u>Permitting:</u>
______ Prepare permit application for single or multiple prescribed burns.
______ Predict smoke impacts for permit application
______ Review, approve or disapprove permit.
______ Evaluate permit applications according to criteria from Smoke Management Program.
______ Monitor approved permits to determine validity of projections.

Please list any additional tasks:
____
____
____
____

National Strategic Plan for Wildland Fire and Air Quality:
EXPRESS Team Funding Priorities

Many of you filling in this survey, may be aware that a significant group of people interested in smoke management met in November, 1997 at a national workshop in Nebraska City, NE. One result from that workshop is a recently published **National Strategic Plan for Wildland Fire and Air Quality: Modeling & Data Systems** (Sandberg, et al., 1999. USDA--Forest Service, Portland, OR.) This National Strategic Plan identifies a number of specific activities, called Program Strategies, that should be done in order to improve smoke management. In order to provide additional support for developing funding for the specific program strategies identified in the National Strategic Plan, we are asking for your rankings of these projects. It is felt that this ranking can have a positive influence on decision-makers, hence on the actual implementation of this National Strategic Plan.

In developing this survey, we have used information contained in the National Strategic Plan as guidance. In the following questions, we have listed key program strategies from the National Plan. We are asking for your evaluation of these key program strategies in terms of their importance to you and to your job. Specifically, we are asking you to rank the strategies in order of importance to you and your job related needs. The National Strategic Plan specifically seeks to "foster efficient development and implementation of modes and data systems." The Express Team considered, as do we in this survey, Planning, Operations and Monitoring/Evaluation to be relevant categories to specific models and data systems. However, the Express Team further separated the categories into source strength, ambient air quality, and effects. In asking this next group of questions, we maintain their hierarchy rather than trying to fit their breakdown into to ours or vise versa.

National Plan for Wildland Smoke and Air Quality Program Strategies:
For each of these three elements (**Planning, Operations & Monitoring**) and associated subgroups (**Source Strength, Ambient Air Quality, Effects**) please rank the relative importance to you and importance in accomplishing your job, the following listed program strategies. Please rank the top five by (1) choosing the five most important to you, and (2) placing **either** a "1" = most important, "2" = second most important, "3" = third most important, "4" = 4th most important, and "5" = 5th most important next to each of the five chosen in **each category**.

1. Planning

1.1. Source Strength

Please rank from 1= most important, to 5=5th most important the following:

A. _____ Develop and document all available emission factors applicable to forest fires; incorporate these factors into AP-42 for event through national-scale estimation; update AP-42 to be more user-friendly.

B. _____ Complete a set of geographically resolved National emission source strength models (i.e., production by chemical speciation and particle characteristics) that are coupled to fire behavior models for inputs to emission inventories, transport models, ozone production and receptor impacts.
C. _____ Develop a nationally applicable wildland fuel classification system, inventory and database to monitor fuel conditions, fuel treatments, and changes in fuel characteristics over time which would include spatial attributes and a method for reporting between land and air managers.
D._____ GIS-based fire regime map (both current and historic); undertake extensive studies of all major ecosystems with purpose of determining historic fire return intervals to include time of year, intensity of burn, frequency, area of extent.
E._____ Develop methods to collect fire and emissions model data for local agencies (city, county, district) to use that are compatible at state to national levels.
F._____Identify information gaps for assessing burn characteristics and emissions generation.
G._____ Develop wildfire fuel consumption estimation techniques; improve fuel consumption models for natural fuels under-burning in short rotation ecosystems.
H._____ Provide training programs for using available methods for determining fuel conditions and estimating emissions.
I._____ Agreed upon models, guidance for states/tribes for SIP/TIP development.
J._____ Develop policy/guidance on “natural” or “background” needed for emissions comparisons, and regulatory purposes and public information/education.
K._____ Develop a guide with more specific statements of fuel loads based on area (region), fuel types, time of year, past burn frequency, and actual availability of fuels for consumption base on recent weather parameters.
L._____ Compile a national spatially resolved emissions inventory of current and planned future prescribed burning in the United States.
M._____ A nationally applicable fire emissions trade-off model (e.g., FETM)
N._____A system for evaluating fuels management treatments (efficacy/effectiveness of fuel treatments as well as emissions).
O._____ A system for prioritizing fuels management treatments for optimizing emissions.
P._____ A system for (spatial and temporal) scheduling fuels management treatments over long periods of time (i.e., planning, not operational, smoke management).

1. Planning

1.2. Ambient Air Quality

Please rank from 1= most important, to 5=5th most important the following:

A. _____ Determine the “natural” visibility conditions for regional haze evaluations for all areas of the country; develop a modeling system that would evaluate trade-offs between prescribed fires, wildfires and other treatments;

conduct long-term research on emissions trade-offs from treatment vs. wildfires.

B. _____ Develop integrated analyses and assessment system to deal with regional haze, NAAQS, nuisance smoke, depositions, etc. including dynamic databases, emission, meteorology and air quality modeling covering all scales.

C. _____ Develop five regional (NE, SE, MW, NW, SW) model testing data sets (meteorology, fuels, emissions, plume tracks, concentrations, etc.) to evaluate objectively the technical excellence, performance and implementation (use by field personnel) of proposed smoke dispersion models.

D. _____ Develop a strategic planning tool that utilizes GIS for regional to national assessment of potential visibility, regional haze and air quality that addresses the conflict between stable burning and unstable burning conditions. The GIS module would include monthly climate, current and potential fuel loading, known emission sources, and simple dispersion algorithms.

E. _____ Develop remote sensing methods for measuring smoke movement and concentration. Includes: airborne remote/sensing image analysis for tracking single-fire smoke plumes night and day; van-mounted lidar/radar for measuring particle concentration throughout the whole plume.

F. _____ Produce a report that brings together fire planning process requirements across agencies to facilitate the linkage between the planning and the permitting processes.

G. _____ Identify existing effective smoke management plans, and make them available as examples.

H. _____ Develop linked EUR and LANG air quality models.

I. _____Develop air quality modeling forecast system.

J. _____ Develop emission factors for all vegetation types.

K. _____ Develop user-friendly protocols for implementation of planning tools.

L. _____ Research carbon-sequestration issues (to support joint implementation)

M. _____ Develop a framework for planning within the current regulatory environment.

N. _____ Develop a strategy for monitoring as a element of planning.

O._____ Further develop complex terrain models.

1. Planning

1.3. Effects on Receptors

Please rank from 1= most important, to 5=5th most important the following:

A. _____Establish a wildland fire information clearinghouse to maintain fire and air quality, spatial and non-spatial data and information in a Federal Geographic Data Committee (FGDC) format and metadata standards searchable on the Internet.

B. _____ Hold a series of workshops with stakeholders to agree on interagency model coordination for consistent model development, use guidance and evaluation; decide which models to use and how: an assessment of existing models; display modeling results, graphically or visually, at a level appropriate for the general public.

C. _____ Establish a national fire database (wildland and prescribed fire) that contains the minimum data needed by air resource managers.

D. _____ Synthesize existing research and information on risk assessment to public and firefighters from fire emissions. Develop and improve risk assessment models for air pollution effects from fires.

E. _____ Develop a communication plan in cooperation with state forestry and air quality agencies for the general public regarding positives and negatives of wildfire effects. The plan should allow for displaying modeling results graphically and visually.

F. _____ Assess public attitudes (at all levels) toward prescribed fire and emissions, using surveys, media reviews, literature searches, etc. (whatever vehicle is appropriate).

G. _____ Develop and implement a public (national, regional, all levels) survey regarding attitudes on prescribed fire and smoke.

H. _____ Develop a questionnaire(s) or other vehicle(s) of validating perception of general population regarding air quality and use of prescribed fire.

I. _____ Maintain a technical infrastructure supported by modelers on staff in land management agencies; linked with software company to provide software support manuals.

J. _____ Have full-time smoke modelers on staff in land management agencies.

K. _____ Maintain a technical infrastructure to operate models.

L. _____ Set up a long-term epidemiological study of fire emission effects at firefighter and community level.

M. _____ Identify receptors in a given area to determine scale of the problem.

N. _____ Partner with health organizations to set up an epidemiological study for fire long-term effects at the community level.

O. _____ Revise AP-42

P. _____ Quantify economic and environmental trade-offs of wildfire versus prescribed fire. Priority is local level but it needs to be done at all levels.

Q. _____ Quantify economic benefits of prescribed fire on ecosystems.

2. Operations

2.1. Source Strength

Please rank from 1= most important, to 5=5th most important the following:

A. _____ Develop a comprehensive fire and smoke management system that links behavior, fuel consumption, emissions, and dispersion models. This system must be user-friendly and must accurately represent the full array of fuel types and conditions.

B. _____ Develop a standard set of default or inferred pre-burn fuel condition classes 9average loading and variance) for all cover types in the U.S. for emission inventories or smoke management decisions.

C. _____ Develop a standardized dynamic database/model to document data, such as date, location , acres, fuel types, weather, cost, and emission for all fire events, and to analyze expected results based on past experience to learn from mistakes and replicate successes.

D. _____ Make realtime burn, local weather information available to all users to enable a better emissions production estimate to be made for the operations phase.

E. _____ Update (and re-format to make user-friendly) EPA's AP-42, or similar information for emission factor compilation.

F. _____ Increase quantity an quality and improve delivery of training opportunities among agencies and universities to encourage wise fire and smoke management practices for federal, state, and tribal governments, and private sector.

G. _____ Enable the ability to document the benefits of activities that reduce emissions at the event scale, tracked and aggregated to the other scales.

H. _____ Develop larger-scale models that can take vent inputs and forecast state or regional effects.

2. Operations

2.2. Ambient Air Quality

Please rank from 1= most important, to 5=5th most important the following:

A. _____ Update and develop wildland emission factors and fuel moisture nomograms; develop nomograms that are applicable to all parts of the country (currently only address the West); update emission factors for all fuel types.

B. _____ Develop an interagency task force to coordinate, develop/approve of an operations level smoke management modeling system to address air quality, emission production, and dispersion for varying types of fires and complexity.

C. _____ Develop a uniform, linked, air quality, fire and meteorological database that supplies sufficient data for operational decision-makers to use models developed by inter-agency task force.

D. _____ Develop a mechanism for fire emissions impact information to be disseminated to the public during planning and operational phases in response to wildland fire activities.

E. _____ Develop a mechanism to incorporate wildland fire impacts on air quality into on-site suppression decisions. A mechanism to transfer and disseminate this information for offsite decision-makers and the public.

F. _____ Incorporate wildfire impacts of air quality into decision-making both on and off-site. Develop realtime data systems that include monitoring thresholds and guidelines for health advisories when needed.

2. Operations

2.3. Effects on Receptors

Please rank from 1= most important, to 5=5th most important the following:

A. ______ Develop a real-time analytical tool (computerized data display system) linked to GIS and easily communicable that integrates current meteorology (fine scale meteorological data fields) and air quality data to provide a complete picture of the near and far field impacts of emission from an ongoing burn.

(Prerequisite: Development of a real-time ambient air monitor that is readily available for easy deployment near chosen receptors around burns.

B. _____ Develop a spatially interactive database of information and characteristics of all types of receptors that can be linked to emissions information to evaluate hazards. (Prerequisite: Expansion and improvement of the emissions database for fuel types and conditions, and fire behavior.)

C. _____ Develop an annotated list of educational tools and techniques including notification, a model law for burner certification, and model bylaws for fire council establishment.

D. _____ Develop an expert knowledge base that aids in rapidly selecting receptor accommodation and source manipulation techniques (including costs, effectiveness and practicality) to mitigate impacts on receptors.

E. _____ Develop criteria to determine when a receptor impact becomes unacceptable and determine the practicality of receptor mitigation strategies (e.g., a matrix of impacts and mitigation techniques).

F. _____ An easy-to-use dispersion model that uses current data to predict air pollutant impacts 3, 6, and 12 hours into the future.

G. _____ Regional fire weather and smoke forecast offices provide tailored support to all burners.

H. _____ Develop standardized emissions inventory system linked to GIS and reported in daily situation report.

3. Monitoring

3.1. Source Strength

Please rank from 1= most important, to 5=5th most important the following:

A. _____ Facilitate a forum where land managers and air resource managers will form partnerships to establish common standards and guides for monitoring and modeling source strength of fires and publish in a nationally accepted guidebook. Synthesize existing knowledge of fuel loading, fuel consumption, and emissions models for all ecosystems. Publish a national fuels inventory sampling guidebook that covers all sampling methods.

B. _____ Use fuels photo series and expert field knowledge to develop and expand fuel characteristic classes to represent other fuel types not currently available.
C. _____ Validate and modify fuel loading, fuel consumption, and emission models for all major fuel types. Update and validate fuel consumption models with field measurements.
D. _____ Establish an integrated and consistent approach for collecting input variable to estimate daily emissions from fires (e.g., wildland fire recording form).
E. _____ Develop a virtual web page that will provide an integrated and consistent approach to the collection, calculation, storage, maintenance, dissemination, and evaluation of fuel loading, area burned, fuel consumption, and emissions production for fires. Data sets would be aggregated by latitude/longitude, fuel model, date, owner class, fire type, and emissions across all scales.
F. _____ Extend natural/activity fuels photo series to include additional major fuel types for fuel loading monitoring.
G. _____ Link weather models to dispersion models.
H. _____ Establish demonstration science/management/public partnerships to work on monitoring source strength pilot projects.
I. _____ Create and support an information system (i.e., Internet discussion group) focusing on monitoring source strength related issues.

3. Monitoring

3.2. Ambient Air Quality

Please rank from 1= most important, to 5=5th most important the following:

A.. _____ Develop air quality, visibility, and meteorological monitoring protocols to support, assess, and evaluate wildland fire impacts. Protocols should include siting, operation and maintenance, quality assurance and quality control, system design, etc; cover both temporal and spatial scales; public notification; as well as the differences between wildfires and prescribed fires.
B._____ Conduct air quality, visibility, meteorological monitoring to provide data to assess wildfire and prescribed fire impacts.
C._____ Develop and maintain a national information system for air quality, visibility, and fire data and receptor impacts.
D. _____ Develop training programs, or identify existing programs to address needed skills for air quality, visibility and meteorological monitoring operations, data use, interpretation, and analyses.
E. _____ Perform intensive field monitoring studies to assist in network design, protocol development, model development and evaluation, and pollutant (e.g., O3, Nox, VOC, PM) impact assessments.
F. _____ Develop a standard portable monitoring system for ambient air quality, visibility, and meteorology.
G. _____ Provide support and assistance to parties affected by wildland fires (e.g., tribes, private individuals, local and remote communities) for air quality, meteorological, and visibility monitoring.

3. Monitoring
3.3. Effects on Receptors
Please rank from 1= most important, to 5=5th most important the following:

A. _____ Develop information needs for short-and long-term impacts (e.g., economic, medical, ecological, social, political, and public safety).
B. _____ Develop central/federal body drawing on existing organizational models (e.g., FEMA, National Interagency Fire Center (NIFC). ICS) to plan and coordinate responses to smoke impacts on receptors.
C. _____ Define and establish protocols and organization of response teams appropriate to scale of smoke event.
D. _____ Establish dose response relationships between smoke and receptors for short term and long term exposures (public and tribal communities, subgroups, and ecosystems).
E. _____ Implement a retrospective and perspective epidemiological analysis in communities with high smoke impact incidents.
F. _____ Do a screening risk assessment (and refine if warranted) of adverse impacts among key populations.
G. _____ Develop a centralized information management system for smoke levels and receptor impacts.

Please mail the completed survey to:
Cheryl Asmus, Ph.D.
Colorado State University
105 Sage Hall
Fort Collins, CO 80523-1879
Thank you.

Appendix E--Tool Lists

Tools: Fire Models
BEHAVE
FARSITE
FOFEM
FBPS
FireLib
FIRES
NEXUS
NFDRS
RERAP

Tools: Smoke Models
CONSUME
EPM

Tools: Meteorology and Dispersion Models
MODELS3/CMAQ
NFSPUFF
MM5
CalMET
CalPUFF
SASEM
TSARS
TSAR-PLUS
VALBOX
Ventilated Box Model
VSMOKE-VSMOKE-GIS
PLUMP
AFWIN

Tools: “Other” Information Sources
Forest Plan
Fire Management Handbooks
Fire Mgt. Preparedness and Planning Handbook
FEIS
NFMAS
NIFMID
SIP
Southern Forestry Smoke Mgt. Guidebook
Prescribed Fire Smoke Mgt. Guide
Guidelines for preparing a NEPA Air Quality Analysis.
EPA’s Interim Air Policy
RX Burning Background and Technical Inf. (EPA)

Tools: Data Sources
Spot Weather Forecasts
MfFSF
IMPROVE
Relative Greenness Maps
WIMS
Internet Weather Sites
EPA AP-42
Internal Fire Emissions Databases
NWS Forecast
Temperature and Wind profiles from daily balloon releases
Visual Smoke Operations

Tools: Instruments
Filter Packs
PM10 & PM 2.5 Samplers
MIE Inc. Model DR-2000 DataRAM PM Samplers
Radiance Research Nephelometer
RAWS
FRM’s

Appendix G--Papers and Presentations

a) Innes, J.L. Beniston, M., Verstraete, Editors. **Biomass Burning and its Inter-Relationships with the Climate System.** Kluwer Academic Publishers, Dordrecht, The Netherlands.

Managing smoke in United States Wildlands and Forests: A Challenge for Science and Regulations. D.G.Fox, A.R.Riebau, R.W.Fisher 299-320.

b) First Joint Fire Sciences Program Conference and workshop. Crossing the Millennium: Integrating Spatial Technology and Ecological Principles for a New Age in Fire Management. Boise, June 1999

Invited Paper: The New Smoke Management. A.R. Riebau, D.G. Fox; C. Hardy (see below).

c) California Association for Fire Ecology (CAFÉ), 1999. Symposium: Fire Management Emerging Policies and New Paradigms. November 1999.

Presentation: Technically Advanced Smoke Estimation Tools.

d) Where There's Fire, There's Smoke: Fine Particulate and Regional Haze. D.G. Fox, W.C. Malm, B.Mitchell, R.W.Fisher. EM: Air & Waste Management Association's Magazine for Environmental Managers. November 1999. p. 15-24.

The New Smoke Management

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National Program Leader for Atmospheric Research
USDA Forest Service, WFWAR Washington, D.C.

Douglas Fox
Senior Scientist
Cooperative Institute for Research on the Atmosphere
Colorado State University, Fort Collins, Colorado

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Abstract: In the next few years, the United States Environmental Protection Agency (EPA) will implement new regulations for the management of atmospheric particulate matter 2.5 microns and less in diameter ($PM_{2.5}$), tropospheric ozone, and regional haze. These three air quality issues relate directly to forest and agriculture burning. Fire generates $PM_{2.5}$ and other ozone precursor gases that reduce visibility. Hence, wild and agricultural land managers will be subject to these new regulations much as industrial and mobile sources have been for the past 25 years. In addition, these new regulations come at a time when private as well as public land managers throughout the United States are developing plans to increase their application of fire as a management tool. Prescribed fire will remain viable as a tool for land managers with these new regulations, but only under a new paradigm of smoke management. This paradigm will include formal "state-approved" Smoke Management Programs, and will of necessity require use of new and 'approved' technologies that have been subjected to public and stakeholder scrutiny as existing regulatory tools. These programs will acknowledge that wildland fire is different from conventional human-caused air pollution sources. They will recognize that the managed use of fire is a superior option to wildfire from public safety and health perspectives. But, in circumstances where fire is used for primarily economic rather than ecological reasons, procedures to steadily reduce emissions will likely be required.

I. **Introduction:** Why the new regulations are good news for wildland fire practitioners

A. What the standards will say.

The process for setting ambient air quality standards involves the development of a scientific analysis of the impact of the particular pollutant on the health and 'welfare' of the people of the United States. In the case of ozone and of $PM_{2.5}$, particulate matter less than 2.5 micrometers in diameter, recent analyses have been conducted that have led to the promulgation of new values or levels for ambient air quality. In the case of ozone, this did not result in a totally new standard but rather the standard was reformulated to a lower magnitude but averaged over a longer time. In the case of $PM_{2.5}$, it was determined that PM2.5, no matter what it consists of, is harmful to human health when found in concentrations greater than an average of 65 micrograms per cubic meter over a 24 hour period, or greater than 15 micrograms per cubic meter for over a year. This entirely new standard was issued, while also maintaining the existing standard for PM10 (ten micrometers in diameter) because scientific toxicological studies suggest that the smaller size is an important characteristic in health impacts, especially for children and individuals with limited respiratory function.

In May of 1999, the US Circuit Court of Appeals for the Washington, DC Circuit, stayed the EPA from implementing revisions of the Ozone and $PM_{2.5}$ standards. Relevant to our discussion, the Court did not find EPA's scientific analysis flawed, nor did it find that either ozone or $PM_{2.5}$ were not health risks to the public, quite the contrary. The Court, essentially, agreed that scientific evidence suggests both pollutants are likely to be "non-threshold" pollutants. As such, the Court found that EPA failed to identify compelling reasons for selecting the specific levels that they did. It seems this is more an issue of legal argument and presentation than substance. Thus, we believe it would be incorrect to assume that there will not be National Ambient Air Quality Standards (NAAQS) for $PM_{2.5}$ promulgation. The magnitude may shift some as a result, but the fact of the standards is likely to remain. An appeal of the DC Circuit decision is currently being considered by the U.S. Supreme Court.

It is important to realize that these standards are based on scientific study, peer and political review. The public has determined, through the Congress and a history of over 40 years since adoption of the Clean Air Act, that it wants to breathe healthy air and it wants to be able to see natural visibility in its National Parks and Wildernesses. Over this period of time, in order to achieve an improving level of air quality, many segments of our society have been impacted. Manufacturing industries, utilities, indeed all of us who drive a car, have had to accommodate to the demand for clean air. Because smoke from forest and agricultural burning makes a significant contribution to $PM_{2.5}$ loading and to impaired visibility, smoke will no longer be exempted from regulatory consideration. It is incumbent on the land management community to help in identifying and quantifying its contribution to degraded air quality as well as the tradeoffs between wildfire and managed use of fire. Alternatives to burning, wherever possible, must be utilized. Burning must be conducted in a cooperative and appropriate manner in order to minimize the contribution from smoke on ambient air quality.

B. Who the standards will apply to.

The standards we are discussing are federal standards, mandated by the Clean Air Act and promulgated by the Environmental Protection Agency as directed by the Act. The Clean Air Act establishes a federal baseline and directs individual states, and tribes, to enforce these standards and to develop programs to ensure that the standards will be met. These programs, called State Implementation Plans (SIPs), are developed by the states (and tribes, Tribal Implementation Plans, TIPs) and are enforced by the states/tribes. A specific provision of the Clean Air Act requires that federal activities must "conform" with all of the requirements of individual S/TIPs.

C. How and when will they be applied.

SIPS and TIPS are developed individually by each State. EPA sets a general direction and provides suggestions to develop SIPs, for what their minimum requirements are, and for the timeframes for their submission and revision. In the case of visibility, or regional haze, as the proposed regulatory program is called, EPA has promulgated regulations that call for a program that shows continuous progress toward the goal of no visibility impairment in Class I areas. They have established a 60-year timeframe for reaching this goal, and suggest that progress toward the goal be evaluated every five years. SIPs will have to be revised to accommodate this activity by mid decade. In a similar fashion, States will need to promulgate $PM_{2.5}$ programs. Proposed revisions for $PM_{2.5}$ were slated to begin in 2004, however, these are pending the final Supreme Court decision.

D. How will all of these standards affect smoke emissions?

EPA in cooperation with federal land managers and States in April 1998 issued an Interim Policy on Wildfire and Forest Burning. This policy identifies a clear path for considering the effects of smoke on visibility and $PM_{2.5}$. The regional haze regulations codify this policy by referring to the need for states, as part of the SIP process, to develop Smoke Management Programs. The elements of what constitute a good smoke management program are described in detail in the next section of this paper.

E. What will a violation of the standards mean?

The Interim policy makes it clear that smoke from forest burning will be treated just like any other source of pollution, unless a Smoke Management Plan is established and formally put in place. In the circumstance where a Smoke Management Plan is established, smoke that results from a forest burn conducted for improving ecological functioning may be exempted from determination of non-attainment. However, burners who violate the conditions of their applicable Smoke Management Program will be subject to specific penalties as specified in the program and in each state's SIP.

II. The process of smoke management

Recently, we were awarded a grant from the Joint Fire Sciences Program (JFSP) to develop a conceptual picture of the next generation of technically advanced smoke estimation tools. In order to design this tool kit, we have looked comprehensively at all of the activities that are associated with smoke management. We developed an outline of Smoke Management Task flows (http://www.cira.colostate.edu/smoke/taskflow/). Land/fire manager tasks were considered separately from air quality manager tasks and separated into the following four categories:

- Long-range or strategic planing:
- Shorter time or Tactical Planning, including Permitting:
- Operations
- Monitoring and Evaluation.

Based on this task categorization, we crafted a survey that has been sent to over 200 people involved in smoke management and is now available on the Internet. The objective of the survey is to obtain user input concerning the tools currently being used for smoke management and their priorities for improving the existing tools and the needs for new tools.

In the four sections below, we outline the tasks that we have identified for managing smoke.

A. Strategic Planning

- Update Forest Plan (Federal)/Forest Stewardship Plan (state/private).
- *Evaluate costs, benefits and environmental impacts of using fire as a*
- land management tool.
- Provide input to and participate in Smoke Management Program development.
- Collaborate with State/Tribal air quality managers (air regulators) to
- both allow fire in its natural role and protect public health and visibility.
- Notify air quality managers of fire plans, potential impacts and possible alternative treatments.

- Address conformity of fire plans.
- Provide internal policy direction concerning feasible alternatives to fire.
- Provide input to and participate in regional fire activities.
- Assess firefighter’s exposure to smoke and develop management strategies to monitor and reduce exposure levels.
- Update SIP/TIP.
- Develop regional strategies for smoke management.
- State Air Quality and Smoke Management Policy and Regulations
- Collect information on projected fire activity.

B. Tactical Planning including Permitting

- Identify goals for the use of fire.
- Calculate and evaluate trade offs between mechanical, chemical and fire
- land treatment (element of the National Environmental Policy Act/NEPA process).
- Specific Burn Plans
- Predict amount of fuel consumed with fire treatment
- Conduct air quality and visibility impact evaluations of fire activities.
- Develop ambient air monitoring plans.
- Identify the potential for smoke intrusions into sensitive areas.
- Model air quality and visibility impacts
- Identify sensitive receptors
- Project impacts of fire for a specific project
- Submit permit request with appropriate projections, etc. to the appropriate regulatory authority
- Track approvals and any required restrictions, additional information,
- Approve or disapprove burn permits

C. Operations

- Inform smoke sensitive receptors about fire progress
- Identify location for smoke sensitive people to go to during burn or other
- mitigation procedures
- Enforce burn parameters in accordance with permit restrictions.
- Obtain and evaluate weather dispersion and visibility forecast.
- Issuing spot smoke forecasts
- Receiving and accommodating public complaints
- Compare dispersion to standards/guidelines and permit requirements
- Participate in final decision to burn
- Determine likelihood that fire prescription will be met
- Monitor weather and dispersion
- Monitor fire impacts
- Inform smoke sensitive receptors about fire progress.
- Enforce burn parameters in accordance with permit restrictions.
- Obtain and evaluate weather dispersion and visibility forecast.

- Compare dispersion to standards/guidelines and permit requirements.
- Receiving and accommodating public complaints
- Participate in final decision to burn.
- Determine likelihood that fire prescription will be met.
- Monitor weather and dispersion.

D. Monitoring and Evaluation

- Determine if short-term implementation and effectiveness goals are achieved.
- Identify fuel consumed and ecological benefits accrued.
- Assess ecological impacts.
- Assessment of specifically impacted resources.
- Determine if long-term goals are achieved.
- Assess post-burn fuel loading and ecosystem condition.
- Assess ecological impacts.
- Evaluate regional and inter-jurisdictional impacts.
- Compare standards and guidelines against incremental loading.
- Evaluate any negative public reactions.
- Determine total incremental loading from burning in the region.
- Document impacts to state ambient air quality PM_{10} and $PM_{2.5}$ monitoring data

A diagrammatic presentation along with identification of some of the tools needed to inform smoke management tasks can be found on the CIRA smoke and fire research page at http://www.cira.colostate.edu/smoke/taskflow/default.htm.

III. Smoke Management Programs and State Implementation Plans

A. What is a State Implementation Plan?

The State (or tribal) Implementation Plan is a mechanism established by the Clean Air Act to link federal clean air activities with Sate (or tribal) activities. In particular, the S/TIP codifies federal statues at the state level allowing the state to implement its own air quality management program, while ensuring that federal standards are maintained as a minimum baseline.

Specifically, Sections 107 and 110 of the Clean Air Act give each state the responsibility to ensure that ambient air quality is maintained at or below the National Ambient Air Quality Standards (Sullivan 1997). The SIP establishes source specific procedural and substantive standards to accomplish this. These vary depending on the status of areas, either currently attaining the NAAQS (attainment areas) on not (non-attainment areas.)

Section 110(a)(2) requires that the SIP be established after reasonable notice and public hearing, and that it shall include:

- Enforceable emissions limitations (These are usually determined by modeling each source's specific air quality impact and determining an emission level that will ensure attainment of the NAAQS.)
- Air quality data
- Enforcement
- Interstate air pollution
- Adequate personnel, funding, and authority
- Monitoring and emission data
- Contingency plans to restrict emissions that present a imminent and substantial danger to the public
- Revision of the SIP to deal with any changes in NAAQS, new methods of attainment and any findings by EPA of inadequacy
- Non-attainment area requirements
- PSD pre-construction review and permitting requirements (including federal Class I areas, Wilderness and National Parks, where visibility and other air quality related values are afforded special protections)
- Air quality modeling as prescribed by the EPA
- Permit fees
- Local consultation

In addition, the Act stipulates a number of procedural requirements that must be followed.

An additional requirement from the Clean Air Act (Section 176©) is "conformity." Federal conformity requires that no federal department may engage in, support in any way, or provide financial assistance for, or license, or approve any activity that does not conform to a SIP. The 1990 Amendments strengthened conformity, requiring that all state actions (1) conform with the purpose of the SIP, and (2) do not cause or contribute to new violations of NAAQS, increase the severity or frequency of existing violations, or otherwise delay attainment.

The SIP also includes provisions for how States should implement the PSD program. For non-attainment area's SIPs require a list of things, including implementation on existing sources of air pollution of "Reasonably Available Control Technology," annual incremental reduction of pollution emissions, inventory, permits, and emissions budgets.

B. What is a Smoke Management Program?

Smoke Management Programs are formally identified in the Interim Air Quality Policy on Wildland and Prescribed Fire (U.S. EPA, 1998.) Smoke Management Programs "…establish a basic framework of procedures and requirements for managing smoke from fires managed for resource benefits and are typically developed by States/Tribes with cooperation and participation by wildland owners/managers."

The basic components of a Smoke Management Plan include programs, policy and procedures that provide for:

Authorization to Burn;

Minimizing Air Pollutant Emissions, including:

2.1 Evaluating costs, benefits and environmental impacts of using fire as a land management tool, including the use of prescriptive criteria that are measurable and will guide selection of appropriate management actions in response to wildland fires and prescribed burning;
2.2 Collaborating with State/Tribal air quality managers (air regulators) to achieve goals of: (a) allowing fire to function in its natural role in the wildlands, and (b) protecting public health, visibility and regional haze by minimizing smoke impacts;
2.3 Developing mechanisms to notify air quality managers of (1) plans to significantly increase their future use of fire for resource management, (2) air quality impacts of fire, and (3) appropriate steps to mitigate those impacts, including appropriate alternative treatments.

Smoke Management Components of Burn Plans:

3.1 Actions to minimize fire emissions;
3.2 Evaluate Smoke Dispersion
3.3 Public Notification and Exposure Reduction Procedures
3.4 Air Quality Monitoring

Public Education and Awareness

Surveillance and Enforcement

Program Evaluation

Optional Air Quality Protection (for example creating special protection zones or buffers around wildland/urban interface areas, non-attainment areas, or Class I areas.

In the Interim Policy, the following are suggested as “strong indications” that an SMP is needed:

- Citizens increasingly complain about smoke intrusions;
- The trend of monitored air quality data is increasing (approaching daily or annual NAAQS for PM_{10} or $PM_{2.5}$) because of significant contributions from fires managed for resource benefits;

- Fires cause or significantly contribute to monitored air quality already greater than 85% of the daily or annual $PM_{2.5}$ or PM_{10} NAAQS, or;
- Fires in the area significantly contribute to visibility impairment in federal Class I areas.

IV. Tools of the trade

We have identified the various tasks associated with smoke management, as stated above, from the perspectives of long- and short- range planning, operations and monitoring/evaluation.

A key smoke management task is to predict contributions to particulate concentration and visibility that result from burning. Aspects of this prediction including spatial scales, accuracy, chemical distributions, and associated details distinguish one simulation from another. Different combinations of models are appropriate for different problems and specific tasks. However, here we identify some of the assortment of tools that are available to accomplish the tasks. Below, we list and comment on some of the models that are available to manage smoke.

Smoke Management Models can be discussed from a variety of different perspectives. We limit consideration to those models which simulate the physical, chemical and biological systems or components of the system. Therefore, we have divided our consideration into the following categories:

- Forest ecosystem growth and composition dynamics
- Fire behavior and combustion processes
- Smoke and PM emission physics and chemistry
- Mesoscale meteorological diagnosis and forecast
- Local scale wind field model
- Dispersion (transport, diffusion and removal)

A. Forest ecosystem growth and composition dynamics

Forest ecosystem growth and composition models are used to predict forest changes over time. Forest growth rates and composition change in response to a number of stimuli, including:

- natural successional dynamics;
- natural disturbance processes (insect, disease, and fire), and;
- human-caused disturbance processes (activities like harvest, thinning and prescribed fire, roads, etc.)

A wide variety of models have been developed by foresters over the years to predict forest development and the effectiveness of various interventions. These models are important to smoke management, to help evaluate the need for and effectiveness of fire and alternatives to fire use in the different forest ecosystems.

A recent research project, A Risk-based Comparison of Potential Fuel Treatment Tradeoff Models (http://www.rfl.psw.fs.fed.us/jfs/) provides a brief review of three of these models SIMPPLLE/MAGIS; VDDT/TELSA; and TOM/FETM. Our description is adapted from information on the project web page. Vegetation Disturbance Dynamics Tool (VDDT/TELSA) and Simulating Vegetative Patterns and Processes at Landscape Scales/Multi-resource Analysis and Geographic Information System (SIMPPLLE/MAGIS) are similar models that simulate change by classifying individual spatial grid cells with successional class, age and probability of disturbance. Management activity alters these probabilities.

Forest Vegetation Simulator (FVS) (http://www.fs.fed.us/fmsc/fvs/index.htm) (Wykoff et al., 1982) was developed as a system of models designed to simulate effects of management actions (harvest, thinning, planting) on long term forest structure. Reinhardt and co-workers have constructed a simulator to assess the risk, behaviors and impacts of fires within this structure (Beukema et.al. 2000). The Fire and Fuels Extension to FVS incorporates models of fuel dynamics, fire behavior and fire effects into the base model of forest stand development. Effects of timber harvest, fuel treatment, and fire on subsequent fuel dynamics, stand development, and potential fire intensity can be simulated for a period of decades. The goal is to provide forest managers with a method for assessing the effects of treatment alternatives on fuel dynamics and fire potential into the future. Currently, these are calibrated for the northern Rocky Mountains. Geographic variants for FVS exist for most of the forested land in the United States. and the fire and fuels extension can be linked to these variants with some additional work.

Inputs include stand exam type data including a tree list to describe the stand. Initial fuel loadings can be set, but default values are available. Treatments including harvest, planting, prescribed fire, fuel treatment, and wildfire must be scheduled and described.

Outputs include tables depicting surface fuels and standing dead and live biomass over time; fire behavior, fuel consumption, smoke production, and tree mortality in the event of a fire; stand characteristics over time; and potential fire intensity (flame length, crown fire potential) over time.

This program offers for the first time a method for projecting site specific effects of treatments on fuels and fire potential over the mid- to long-term. It uses standard, widely available data.

Programmatic Fuels Management Trade-off Model (TOM/FETM) (Schaaf et al.,

1996) simulates change in forest composition over time using user defined "transition matrices." These matrices contain knowledge-based algorithms to transfer the contents of selected fuel condition classes (FCCs) over time to different FCCs in response to thinning, harvest, mechanical treatment, wildfire, and prescribed fire, allowing up to six treatment levels.

FIRESUM (Keane et.al. 1989) is a gap replacement model that follows a Monte Carlo simulation of birth, growth and death of trees on small (400 m2) 'plots.' FIRE-BGC (Keane et al., 1996) is an ecosystem process simulation of the dynamics of the ecosystem and its effects on biogeochemical cycles in response to fire and other disturbances,

B. Fire behavior and combustion processes

Fire behavior models

BEHAVE: Fire behavior and fuel modeling

Detailed Information from www.fs.fed.us/amf/fire/fire1.html/.
The BEHAVE Fire Behavior Prediction and Fuel Modeling System includes five programs that has been in use since 1984 (Andrews 1986; Andrews & Bradshaw 1990; Andrews & Bradshaw 1997; Andrews & Chase 1989, Burgan 1987; Burgan & Rothermel 1984.) BEHAVE has been used for projecting ongoing fire, prescribed fire planning, fuel hazard assessment, initial attack dispatch, fire prevention planning, and training. BEHAVE models are primarily physically based and can be applied anywhere. BEHAVE is run by user-supplied input. For example, fuel model, fuel moisture, wind speed and direction, and terrain slope are used to calculate rate of spread, flame length, and intensity.

The next generation of BEHAVE will include improved models for (Andrews & Bevens 1998):

--Fine fuel moisture from hourly weather data
--Containment, with additional suppression options
--Transition to crown fire
--Crown fire spread
--Large fuel burnout behind the fire front
--Consumption of organic ground fuel
--Emission production
--Soil heating

FOFEM: Fire effects simulation model

First Order Fire Effects Model (FOFEM) is an easy-to-use computer program for predicting effects of prescribed fire and wildfire. FOFEM (Reinhardt 1993) predicts fuel consumption, smoke production and tree mortality. Area of applicability is nationwide on forest and non-forest vegetation types. FOFEM also contains a planning mode for prescription development. Potential uses include wildfire impact assessment, development of salvage specifications, design of fire prescriptions, environmental assessment and fire management planning. FOFEM can also be used in real-time, quickly estimating tree mortality, smoke generation and fuel consumption of ongoing fires. FOFEM contains data and prediction equations that apply throughout the United States, for most forest and rangeland vegetation types that experience fire. The program uses four geographic regions, and SAF/FRES vegetation types to stratify data and methods.

FOFEM was designed so that data requirements are minimal and flexible. Default values are provided for almost all inputs, but users can modify any or all defaults to provide custom inputs. FOFEM computes the direct effects of prescribed fire or wildfire: fuel consumption by fuel component for duff, litter, small and large woody fuels, herbs, shrubs and tree regeneration, and crown foliage and branchwood; mineral soil exposure, smoke production (lbs./acre) of CO, PM_{10}, and $PM_{2.5}$; and percent tree mortality by species and size class. Alternatively, if the user enters desired levels of these fire effects, FOFEM computes fuel moistures and fire intensities that should result in desired effects.

FARSITE: Fire growth simulation program for PC's

FARSITE: Fire Area Simulator, Version 3.0, Released December 1997
FARSITE is a fire growth simulation model. It uses spatial information on topography and fuels along with weather and wind files. FARSITE incorporates the existing models for surface fire, crown fire, spotting, and fire acceleration into a 2-dimensional fire growth model. FARSITE runs under Microsoft Windows operating systems (Windows 3.1x, 95, NT) and features a graphical interface. Users must have the support of a geographic information system (GIS) to use FARSITE because it requires spatial landscape information. FARSITE is used for long-range projections of active wildland fires and for fire planning purposes.

FARSITE also requires time series of weather and wind profiles

FARSITE produces many types of outputs:

* 2D and 3D visible maps of fire growth and behavior, saved as color bitmaps
* Graphs of fire area and perimeter over time, saved as bitmaps or printed
* Tables of fire area and perimeter over time, saved as bitmaps or printed
* GIS vector and raster files of fire growth and behavior (spread rate, intensity etc.) that can be imported to GRASS or ARC/INFO for display and analysis
* Zoom windows into 2D and 3D landscapes
* Runtime modification of ignitions, control lines, fuel changes

FARSITE automatically computes fire growth and behavior for long time periods under heterogeneous conditions of terrain, fuels, and weather using the existing fire behavior models. FARSITE is a deterministic model, meaning that you can relate simulation results directly to your inputs.

FARSITE can be used for fire gaming, asking multiple "what-if" questions and comparing the results
A discussion forum is available on the FARSITE homepage.

WFAS: Wildland Fire Analysis System
WFAS is a framework for the next generation fire danger/behavior system. It will present; Fire Danger Maps, Fire Weather Observations, Next Day Forecasts, Dead Fuel Moisture Maps, Live Fuel Moisture - Greenness Maps, Drought Maps, Lower Atmospheric Stability Index Maps, Fire Weather Network, and links to Other Fire Weather Sites.

WFAS will assess fire potential, develop strategic plans, provide broad area fire potential information for fire managers and the Public, and survey fire weather observations.

C. Smoke and PM emission physics and chemistry

CONSUME (Ottmar & Sandberg 1985) predicts fuels consumption for broadcast burns or understory burns in logged units and in natural fuels. The model was developed for the Pacific Northwest area but can be applied in other timber types and mixed conifers too. Model inputs include fuel moisture, daily weather data, fuel inventory, and unit data. Outputs include fuel consumption for each size class by date or by adjusted 1000-hr fuel moisture, target fuel moisture predictions, weather summary, and unit summary. It can be used to develop burn prescriptions to meet resource management objectives and as input data for smoke emission predictions.

EPM: Smoke emission production model
Emissions Production Model (EPM) was developed for calculating smoke emissions from prescribed burning of logging slash in the Pacific Northwest. EPM is the smoke emissions production engine for SASEM, VSMOKE, CALPUFF and NFSPUFF dispersion models. EPM produces emission production rates, at three-minute time steps for three size classes of particulate matter and for several gases. EPM also produces the rate of heat release for application to plume rise models. It has recently been improved with new smoldering decay rates and a new ignition module.

D. Meteorological forecast and diagnostic models.

There are many models that have been developed over the years to predict (advance meteorological fields in time) and diagnose (fill in details of meteorological fields from limited observations) wind and related dispersion information to support smoke management..

Forecast models:

In the prediction category there are essentially two models that are being applied on a regular basis, MM5 and RAMS. MM5 and RAMS are similar mesoscale meteorological forecast models. They have undergone many years of development as to improve both the understanding of meteorological dynamics and the ability to forecast changes in meteorology on this and smaller regional scales. MM5 was originally developed at Penn State University and is a is a continuing development of the mesoscale research group at NCAR (http://www.ncar.edu) RAMS has been developed in the Atmospheric Sciences Department at Colorado State University (http://www.atmos.colostate.edu) These models are not for the casual user. They are very complex and require streaming inputs of observations as well as larger scale meteorological simulations. Thus, they are primarily operated by NOAA weather service or academic organizations. The data they generate are widely available for many locations around the globe on an assortment of web sites.

Diagnostic models:

In the diagnostic category there are a number of different tools that have been applied for smoke management. However, the most relevant and applicable is CalMet. CalMet is undergoing approval by the EPA for application in regulatory applications. A bit less complex than MM5 and RAMS, it nevertheless requires a meteorologist or similarly trained individual to apply. Meteorological data are needed as inputs for whatever time periods are being diagnosed

E. Dispersion (transport, diffusion and removal) models

Coupled wind and dispersion models

MODELS3: EPA's Comprehensive air quality modeling system, includes capability of mesoscale meteorological prediction from MM5 or RAMS as well as other models

The Models-3 current release contains three types of environmental modeling systems: meteorological, emission, and chemistry transport. It also includes a visualization and analysis system. The purpose of each of these systems and a brief introduction are as follows:

Meteorological Modeling System - provides descriptions of atmospheric motions; fields of pressure, moisture, and temperature; fluxes of momentum, moisture, and heat; turbulence characteristics; clouds and precipitation; and atmospheric radiative characteristics. The MM5 meteorological modeling system in incorporated in Models-3 current release. A system linking to the RAMS is anticipated shortly.

Emission Modeling System - simulates trace gas and particulate emission into the atmosphere depending on surrounding meteorological conditions and socioeconomic activities. Typically, emissions are broken down into point sources, line sources (on-road mobile), and area sources. A point source tracks emissions from a single source (e.g., a boiler stack or a dry cleaner). A line source tracks emissions that follow a road (e.g., cars or trucks). Area sources include off-road mobile sources, biogenic emissions, and other sources that are often related to the earth's surface where humans, animals, and plants reside. At this time there is no linkage to fire emissions, although the authors are working on doing this. Models-3 Emission Projection and Processing System (MEPPS) in the current Models-3 release contains 5 individual processors. These processors include the Inventory Data Analyzer (IDA), the Input Emission Processor (INPRO), the Emission Processor (EMPRO), the Output Processor (OUTPRO), and the Models-3 Emission Projections processor (MEPPRO).

Chemistry Transport Modeling System - simulates various chemical and physical processes that are thought to be important for understanding atmospheric trace gas transformations and distributions. Generally, the chemistry-transport model relies on a meteorological model for the description of atmospheric states and motions and depends on emission models for the anthropogenic and biogenic emissions that are injected into the atmosphere. The chemical transport modeling system in the current Models-3 release contains 8 individual processors. These processors include land-use processor (LUPROC), the meteorology-chemistry interface processor (MCIP), the emissions-chemistry interface processor (ECIP), the photolysis rate processor (JPROC); the initial conditions processor (ICON); the boundary conditions processor (BCON); the main chemical-transport model processor (CCTM); the process analysis processor (PROCAN)

Visualization and Analysis System - plots and graphs data that have been created by one of the Models-3 modeling systems or that have been imported into Models-3. Visualization techniques are an important part of air quality data analysis. The Models-3 visualization and analysis system provides several packages that can plot or graph data. Three-dimensional animation capabilities are also provided in the system.

TSARS-Plus: Combined wind and dispersion model for complex terrain, using CalMet like wind diagnostic model, NUATMOS.

NFSPUFF: complex terrain dispersion simulation model for complex terrain (Hardy, et.al. 1993)

NFSPUFF is a screening/planning level, three-dimensional, gridded wind field smoke emissions and trajectories puff model. It is designed to predict ground level concentrations of particulate matter and gaseous pollutants from multiple sources in complex terrain in the Western United States. The model incorporates an emission production module (EPM) with National Weather Service predictions for upper-air winds, extrapolated to the surface, to predict potential pollutant transport. Tabular, 2-D and 3-D graphics are displayed.

Terrain effects are computed with a user's option of 1, 2, 4, and 8 km resolution in the western US between 30 and 50 degrees north latitude and 100 to 125 degrees west longitude. This domain includes Washington, Oregon, Idaho, Montana, California, Arizona, Utah, New Mexico, Colorado, Wyoming, and portions of North and South Dakota, Nebraska, Kansas, Oklahoma, Texas, British Columbia, Alberta, Saskatchewan, Baja California, and Sonora.

The user-input scheme is menu driven with each module treated separately. Once a module is selected, a list of input questions is presented. If out-of-range values are entered a help screen appears defining the variable limits along with a prompt for entering a legal value. This provides a "no questions asked" format and good error trapping.

NFSPUFF (Breyfogle & Ferguson 1995) is fast, easy and visually pleasing to run. Little or no prior computer or burning experience is necessary to use it. It is an ideal screening tool. Also, because it can model up to 100 burns simultaneously over a broad geographic area, it may provide a reasonable planning tool.

Dispersion models

CalPUFF: Dispersion simulation model interacts with CalMet to diagnose concentration impacts in complex terrain. The combined tool is currently receiving EPA's approval to be used as a regulatory model. (http://www.epa/gov/oaqps)

SASEM: Source emission and dispersion model , is a first level screening tool for use in planning, Gaussian dispersion model designed to predict ground level particulate matter and visibility impacts from single sources in relative flat terrain in the western United States.
SASEM utilizes internally calculated plume rise and emission rates based on specified fuel types and configurations. The model is limited to particulate matter and visibility impact assessments; simplicity requires several physical assumptions.

PLUMP: 1-dim./vert. plume rise simulation Mot./air mod. and fire bound. Input Plump is a one-dimensional vertical motion air model with a fire boundary input. It contains full cloud physics. A vertical sounding of the atmosphere can be examined for cumulus cloud formation and the possibility of pyrocumulus. This instance of PLUMP contains MS-DOS programs. Several representative soundings are included, and a manual for installation and use.
PLUMP can be used to predict the possibility and severity of pyrocumulus clouds, and the possibility of penetration of inversions by the smoke from prescribed or natural fires.

F.. Monitoring techniques and data systems

Data systems

FEIS: Complete encyclopedia of fire ecology of plants and animals
The Fire Effects Information System (FEIS) is a computerized encyclopedia of information describing the fire ecology of more than 1,000 plant and animal species and plant communities. FEIS summarizes current information. The FEIS Knowledge Base describes plant and wildlife species, and plant communities, from all over North America.

NFMAS (National Fire Management Analysis System)
NIFMID (National Interagency Fire Management Integrated Data)
NIIMS (National Interagency Incident Management System)
WIMS: Weather Information Management System

Internet weather sites
Internal fire emissions databases
EPA AP-42 (list of emissions factors from all sources)
NWS Forecast (National Weather Service)

Instruments

Temperature and wind profiles from daily pilot balloon releases
Visual smoke operations
Filter packs
PM_{10} and $PM_{2.5}$ samplers
MIE Inc. Model DR-2000 DataRAM PM samplers
Airmetrics MiniVOL samplers
Radiance Research nephelometer
RAWS: remote weather data collection platform

Satellites

Specifically, satellites provide observation capability for monitoring different fire characteristics: fire susceptibility, active fires, burned area, smoke and trace gases. Several satellite systems are currently available for fire monitoring with different capabilities in terms of spatial resolution, sensitivity/saturation level, spectral frequency, overpass time and repeat frequency. Fires are very variable in size, duration, temperature, and in the humid tropics have a strong diurnal cycle. No one system provides optimal characteristics for fire monitoring--multi-sensor data fusion is needed to optimize the use of current systems. Global retrospective satellite active fire mapping using single satellite system has been coordinated by the International Geosphere Biosphere Program (IGBP) using AVHRR (Advanced Very High Resolution Radiometer) data for 1992/3 from international ground stations. NOAA-NGDC has developed a global fire data base for 1994/5 using DMSP-OLS data.

A near real-time multi-source fire monitoring system (including classified data) is currently being developed for the United States to support the Interagency Fire Center in Idaho--satellite fire susceptibility maps are also being generated for the United States and Alaska.

A near-real time multi-source active fire monitoring system is currently being developed at NOAA-NGDC for the current burning season in Brazil (DMSP, GOES, AVHRR) as part of their Significant Event Imagery activity.

A small number of countries have developed their own regional AVHRR satellite fire monitoring systems using direct read-out; e.g., Brazil, Russia, and Senegal.

Research groups have provided regional examples of trace gas and particulate emissions from fires for Brazil, Southern Africa, and Alaska.

Research groups are providing field and aircraft measurements of fires and emissions for satellite product data validation and new sensing systems and algorithms design.

V. The New Smoke Management

Guidance documents on methods and techniques for managing smoke from forest and rangeland burning have been developed and distributed by numerous agencies for a variety of users. The various guidance documents relating directly to forest and rangeland burning can be grouped into several classes, as summarized by the following:

- State or regional guidance prepared by individual States or geographically organized groups for local or regional application;
- Guidance produced by individual federal agencies for national application within the respective agency;
- Federal regulatory agency (EPA) documents produced for use by the States' air quality agencies;
- Multi-agency (e.g. National Wildfire Coordinating Group—NWCG) guidance documents which are generalized products intended for national application by land managers;

<u>State or regional guidance documents</u> –
Arizona, Oregon, Washington, California, Florida, **Southern Forestry Smoke Mgt. Guidebook: A Guide for Prescribed Burning in Southern Forests.**
<u>Guidance produced by individual federal agencies</u> –

BLM Fire Effects Guide
Fish and Wildlife Service website called "**Smoke Signals**."

Federal regulatory agency (EPA) documents –

While most of the available guidance documents have generally been developed and distributed by land management agencies rather than by air regulatory agencies, one noted exception is EPA's "*Prescribed burning background document and technical information document for best available control measures [BACM]*" (U.S. EPA 1992). The stated purpose of the BACM document is to provide technical information (primarily to State regulators) on prescribed burning. It provides background information useful in determining appropriate smoke mitigation and control measures, and also provides guidance on implementation of control strategies for areas in non-attainment status for PM-10. These control strategies are provided for the States to use in both their State Implementation Plans and in their Smoke Management Programs.

A discussion of state-of-knowledge emission reduction techniques is provided in Chapter 9 of EPA's BACM document (U.S. EPA 1992). However, this chapter is not limited to control strategies for wildland burning; that is, it also includes many burning situations other that fires in forests and rangelands. Also, the techniques are synthesized from information available nearly 10 years ago (1990-1992). Additionally, the relative effectiveness and applicability of the various emission reduction techniques are not addressed.

NWCG's Prescribed Fire Smoke Management Guide – The Prescribed Fire and Fire Effects Working Team of NWCG developed, edited, and published the Prescribed Fire Smoke Management Guide in 1985 (NWCG 1985). The Guide focuses on national smoke management principals and provides generalized information on smoke management objectives, regulatory requirements, smoke production, smoke management techniques, and smoke monitoring and evaluation. The scope of the information in the Guide is intentionally simple and terse, and its' application is kept necessarily broad. A reader of the Guide will notice that much of the discussion in the Guide relative to control strategies is similar, if not identical, to respective discussion in EPA's BACM document (U.S. EPA 1992). This is a partially a reflection of the relatively small cadre of experts contributing to each of the documents. More importantly, it is evidence that there was reasonable consensus regarding the limited control strategies that were available and also about how to present them to users.

New Revisions to the Smoke Management Guide – Recent developments in new knowledge and increases in fire use have motivated a complete revision of the Guide, which is currently underway. While there have been surprisingly few new contributions to the suite of smoke management and control techniques, significant new and better knowledge is now available for estimating activity levels and smoke production. Consequently, both the applicability and the relative effectiveness of control techniques can now be quantified to levels of accuracy acceptable by, and meaningful to State and local air quality agencies. This improved ability to determine the effectiveness of various control techniques is becoming a critical component for managing recent and proposed future substantial increases in prescribed fire activity levels. An example of anticipated increases in fire use can be seen from the revised federal policy on wildland fire (cf http://www.fs.fed.us/fire/policy.shtml)

The revised NWCG Prescribed Fire Smoke Management Guide will provide a much more comprehensive treatment of fire use, smoke production, and smoke management techniques. It differs from the original Guide in three significant ways. First, it is written not just for fire use practitioners, but for local and regional air quality regulators as well. In that regard, the revised Guide has an extensive background volume, including such sections *as*:
Fire in Wildlands—A Primer;
Fire and Emissions Processes; and
Wildland Fire Smoke Impacts (including public health visibility, safety and nuisance smoke, and fireline worker exposure).

Volume II of the revised Guide addresses smoke management, including three primary sections:

1) *The Need for A Smoke Management Program*, which discussions recent policy and regional developments such as the Western States Air Resource Council FIRES (Fire Initiative for Restoration of Ecosystems) Initiative, and recommendations and current activities relating to the Grand Canyon Visibility Transport Commission;
2) *Fundamentals Of A Smoke Management Program*, containing material most similar to that in the 1985 Guide; and
3) *Smoke Management Techniques*.

The section on smoke management techniques is the second significant departure from the 1985 Guide. This section not only presents state-of-knowledge smoke management and control techniques, but it also quantifies the relative effectiveness of each technique with respect to geographic areas. To accomplish the assessment of techniques, each will be evaluated by regional panels and will be quantified per the following:

- What are the operationally feasible smoke management and control techniques for a respective geographic area?
- How applicable is a technique in each respective area in terms of operational opportunities to use the technique?
- What is the range of operational effectiveness of a technique in each respective area, quantified by applying appropriate activity levels and emission factors both to typical and to extreme vignettes (examples of average, most-, and least-effective outcomes)?

Through a recent Interagency Agreement with U.S. EPA, EPA has agreed to use the section on smoke management and control techniques as EPA's reference document for BACM. EPA is funding the regional panels mentioned above and also a final synthesis of the panel results which will constitute a major portion of the new Guide section. Consequently, the section will supercede the existing BACM documentation discussed in the previous section of this paper.

VI. Conclusions

EPA proposes new regulations for improving air quality across the nation. These regulations are good news for us all; they will protect and enhance public health, aid in maintenance of ecosystems (e.g., avoid adverse effects of ozone), and provide for clear air in parks and wilderness areas.   Smoke from prescribed fires will be regulated by state and tribal air agencies under the provisions of State Implementation Plans (SIPs) for particulate matter and visibility. Prescribed fire emissions which result in elevated ozone concentrations may also be managed under S/TIPs.   Smoke emissions from all burning activities will be factored into regional haze assessments, but, cooperation between land managers, agriculturists, and air regulators can assure a regulatory environment that is fair and well-reasoned. Most (if not all) states will develop formal Smoke Management Programs (SMPs), especially in areas of non-attainment for NAAQS where smoke enters. Smoke Mangers will continue to use a variety of "high technology" tools but, as these tools enter the regulatory arena in a more formal sense, they will be evaluated under the same criteria that air quality management techniques use to manage industrial sources are now evaluated. Smoke management will mature into an activity that encompasses: Long range or strategic planing; Shorter-term or Tactical Planning, including Permitting; Operations; Monitoring and Evaluation. This will ultimately engender an increased professionalism in smoke management with increased needs for training, experience, data, planning, legal understanding, analysis, and cooperation.

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