Smoke Model Evaluation Workshop

Golden, Colorado
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Contents:

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*Remote: Attended remotely via the internet

I. Next Steps and Path Forward

The primary goals for the Smoke Modeling Workshop were for participants to develop a current understanding of smoke models and modeling capabilities, and to develop agreement on how to evaluate applicability of smoke production and dispersal models for use in Colorado. While there are many models existent in the field today, focus was placed on the modeling frameworks Fire and Fuels Application (FFA) and BlueSky, along with the fuels inventory program Fuel Characteristic Classification System (FCCS). To a lesser extent the models Consume, First Order Fire Effects Model (FOFEM), Fire Emission Production Simulator (FEPS), and LANDFIRE were discussed. Going forward, four general questions will guide the investigation and initial testing of the models:

1. In what way can models be used to supplement the experience-based model that currently specifies permit conditions issued by the Air Pollution Control Division (APCD), Colorado Department of Public Health and Environment?
2. In what way can models supplement the burners' decision making processes, specifically impacting the go/no-go decision?
3. What needs to be done to evaluate these models?
4. What is the potential of models to estimate cumulative smoke impacts from multiple burns?

A key workshop result was the collective acknowledgement that accurate fuelbed data is critical to smoke modeling performance. Details of this will be discussed in Section II. Training in FCCS will be among the first action steps within the next 6-12 weeks. Additional short-term steps include seeking extant higher resolution (4km) meteorological data for Colorado and receiving training in the use of BlueSky and possibly other programs like HYSPLIT, which models dispersion. Over a longer-term (beyond 3 months), workshop participants discussed the need for empirical case studies, either a retrospective analysis of recent fires and smoke emissions and dispersion, and/or collecting data from actual burns to evaluate model performance.

A list of actions with their respective owners is below:

1. Organize 2 webinars on the topics of FCCS and BlueSky/dispersion models.
    - Southern Rockies Fire Science Network , Roger O., Paul L., Gordon P.
2. Look into getting 4 km WRF (Weather Research and Forecasting) data.
    - NCAR / Gabriele Pfister
3. Look for historical burn data for Colorado that could be used to evaluate model performance. Vallecito and Little Sand fires identified as likely candidates
    - Sarah Gallup / Andy Bundshuh
4. Collect data from a burn in Colorado
    - TBD / All interested parties
5. Run models with higher resolution weather inputs and new data collected on a burn.
    - APCD

Updates on items 2 and 3 can be found in section III of this report.

II. Summary Of The Meeting

The workshop was split into a morning session where presentations were made and initial discussions occurred, and an afternoon session primarily focused on discussion. The presentations were:

Gordon Pierce, APCD	Air Quality Perspective
Paul Langowski	Land Manager Perspective
Roger Ottmar	FERA tools / FFA overview
Sim Larkin	BlueSky Playground and SEMIP overview. Discussion of error sources in models

This report breaks the topics covered in the workshop into the following themes: scale issues, errors in the models and fuelbeds, model pathways, and monitoring. It does not attempt to cover all discussions verbatim.

Scale

The ability of computer models to accurately estimate smoke production and dispersion is highly dependent on the scale of relevant management questions, of analysis, and of available data. In particular, the grid size of the weather model is an important factor to take into consideration when evaluating how well that model is able to predict smoke behavior. The workshop discussions about scale included both the resolution of the models, and also what resolution was necessary in order for outputs to be useful to fire managers and to air quality regulators.

Scale is also an important factor in characterizing fuelbeds. For example, LANDFIRE data is more appropriate for landscape scale work, but to get better resolution for smaller scales, on the ground data needs to be taken. Tools like photo guides and actual fuel measurements are necessary to capture the many details that larger scale datasets like LANDFIRE miss.

Dispersion model performance is also affected by scale. Default meteorological data that is currently available from the National Weather Service has a grid size for Colorado of 12-30 km. A 4 km grid would improve resolution and can be readily incorporated into the BlueSky modeling framework. For the Pacific Northwest, modelers have access to 4 km weather grid data, and in California some data goes down to 2 km in size. Participants noted that once grid size becomes too small, the model is too 'computationally expensive' to run, in part because finer vertical grid resolution needs to accompany smaller horizontal grid cell sizes. As noted in the action items list, Gabriele Pfister will talk with her NCAR colleagues to see if 4 km grid weather data can be obtained.

Regarding model performance at smaller scales, it was noted by Sim Larkin that a very rough rule is that the model should have at least two grid cells comprising a desired resolution size. For a 4 km grid size, this would mean that the model would not be useful at 8 km or less. Sim commented that "within a couple grid cells of the fire itself, a dispersion model doesn't have a chance to come into its own" and that the better approach to questions about likely impacts closer to a fire is to use atmospheric structure and inversion potential locally. He said one can make a lot of good guesses by looking at the vertical structure of the atmosphere and the overall level and likely timing during the day of the emissions output. Further information sources that can help determine smoke transport is the ability of an area to create inversions and to have nocturnal drainage flows. The partial list of factors that affect transport at these smaller scales include:

- Vertical structure of the atmosphere / atmospheric stability
- Wind speed and direction, including variations over time and space
- Smoke output
- Plume structure and heat distribution of the fire

Regarding what resolution is needed from the models, smaller scales are desired for resolving localized smoke dispersion behavior. In the APCD presentation it was noted that problem smoke almost always involves one or more of the following: Impacts within a mile or two of fire, night and drainage flows, and fine scale topographic influences which are typically about ¼ mile in scale. Gordon Pierce noted that typically ¼ - 5 miles is the scale of interest.

At a larger scale, Patrick Reddy and Sim Larkin discussed that a prescribed burn of 1000 acres can sometimes affect areas 20 miles away in addition to areas closer to the burn. For smoke transport at these larger distances, the dispersion models may become useful. Patrick Reddy commented that, for a burn in the 1000 acre to 4000 acre range, it might be useful to see how the dispersion models performed when using 4 km WRF data.

Errors in Models and Fuelbeds

Errors in the models can come from numerous sources, however work has been done to evaluate the primary sources of error. Some of this work can be found on the Smoke and Emissions Model Intercomparison Project (SEMIP) website: http://www.airfire.org/projects/semip.

Sim Larkin gave a high level overview of which errors are important based on what you're trying to model. In terms of estimating smoke production, the biggest errors are associated with fuelbed characterization. Sim noted that "Fuel loading is the biggest choice we have to make," and both Sim and Roger Ottmar commented that fuel loads need to be ground-truthed. When estimating smoke dispersion, the biggest errors are associated with plume rise and fire timing. As an example, it can be important to know the number of acres of fuel consumed per hour, especially toward the end of the day.

Roger Ottmar noted that, especially for intermediate to fine scales, it is prudent to utilize an expert to characterize the fuels and build fuelbed datasets using FCCS. An alternative to FCCS is LANDFIRE, however Clint Wright noted that one needs to be careful with this data since fuel data is not based on detailed ground observations, but coarse-scale vegetation datasets.

A final issue on errors, which is somewhat related to the scale question above, is the performance of the models in Colorado's mountainous terrain. Some of the previous work done to verify the models, including burns in Florida, are done on flat terrain which simplifies the situation. Sim Larkin commented that BlueSky does have trouble with complex terrain features. This issue, along with diurnal changes and night time drainage will have to be evaluated as the model work moves forward. Currently none of the models discussed at the workshop address drainage flow. It was noted by Patrick Reddy that a cold pooling map has already been created during previous work at APCD which identified areas that are unusually prone to have night time drainage issues.

Model Pathways

A starting point for understanding the current suite of computer models that estimate smoke behavior is to break them down by the steps that they model in the smoke creation and dispersion process. These steps can be viewed as fuelbed characteristics (modeled by software including FCCS and LANDFIRE), volume and rate of fuel consumption (CONSUME, FOFEM, with embedded fire behavior algorithms), smoke emissions when fuels are consumed (FEPS), smoke plume rise, and dispersion (HYSPLIT, VSMOKE). While the example models listed are certainly not an exhaustive list of those available, they give a good idea of what types of models fall under what steps. Some models are capable of doing multiple steps in the process. More information on the models and resources for learning more about them are given in section IV of this summary report.

Given the multiplicity of models that can be used at each step in the process, a large number of 'pathways' can be constructed as the modeling process moves from fuelbed characterization to smoke dispersion. BlueSky Playground, which is the web-based version of BlueSky, specifically allows a user to select these various pathways. The question was then asked of Roger and Sim which pathway they would recommend for smoke modeling in Colorado. Roger suggests that, if users wanted a single pathway, then the combination of FCCS + Consume + FEPS + a dispersion model would be the best choice. For dispersion models, HYSPLIT is the most popular. Finally the issue of ensemble runs, which are groups of runs with slightly varying inputs in order to generate probabilistic outputs, was discussed. Sim Larkin notes that BlueSky Playground is not automatically doing these, but that it is relatively easy to implement this functionality. There is also some ability within the program to do runs by date in order to use a variety of historical weather scenarios.

Monitoring

Currently, there is a lack of systematic quantitative measurements of smoke from prescribed burns in Colorado. This makes it difficult to assess smoke from prescribed fires relative to air quality. There is a desire from both the air quality regulators and the land managers to instrument more burns in order to collect data on smoke emissions and dispersion. At this point in time, the details of how this will be done needs to be worked out. While many of the details for this work are beyond the scope of this modeling workshop conference, some questions that arose from this discussion were:

1. What methods and instrumentation are needed to document smoke distribution and concentrations and to collect the data?
2. Who can collect, process, and analyze this data?
3. How should one monitor a prescribed burn given variability of weather conditions and smoke trajectories?
4. How extensive a set of burns should be monitored in order to obtain data from which conclusions can be drawn?

These and other issues will need to be worked through in order to allow for successfully increased data collection on burns.

III. Post Workshop Actions and Notes

Since the conclusion of the workshop, feedback has been obtained for two of the action items, listed below.

Action Item #2: Look into getting 4 km WRF data (NCAR / Gabriele Pfister)

Gabi Pfister reports that, at NCAR, "…no group is running WRF at 4km or higher resolution on an operational basis." (Per e-mail to J. Howie, P. Reddy and others, April 10, 2013)

Action Item #3: Look for historical burn data for Colorado that could be used to evaluate model performance. Vallecito and Little Sand fires identified as likely candidates (Sarah Gallup / Andy Bundshuh)

After the workshop was completed, Sarah Gallup looked into this possibility but determined that the data was not sufficient for the Vallecito and Little Sand fires. Both have limited to adequate smoke data, but little or no relevant fuel load or fuel moisture data seems to be available.

IV. Smoke Model Resources

Smoke Models – Overview and Resources

A good starting point for getting an overview of some of the more important models is at the myfirecommunity.net site, run by Pete Lahm (USFS, Fire and Aviation Management) and the Smoke Committee of the National Wildfire Coordinating Group (SmoC). The following link takes you to the model summary portion of the web page:
http://myfirecommunity.net/Neighborhood.aspx?ID=279#technical

The models summarized are listed below. (Note: clicking on the link should download and open the summary document from myfirecommunity.net)

BlueSky
CalPuff
Consume
FCCS
FEPS
FOFEM
NOAA ARL Forecast
SASEM
SIS
SMARTFIRE
VSMOKE

[WFDSS Air Quality Tools]
For each model the summary covers items such as type of model, model description, key points, current level of use, and future commitment to that model.

Additionally, the National Interagency Fire Center (NIFC) has a short summary of a lot of the models, and links to them, at: http://www.nifc.gov/smoke/smoke_modeling.html

Modeling frameworks – BlueSky and FFA
The two primary modeling frameworks that allow for automated communication between many of these models are BlueSky / BlueSky Playground, and FFA.

1. BlueSky and BlueSky Playground
   BlueSky: http://www.airfire.org/bluesky/
   BlueSky Playground: http://www.airfire.org/data/playground/
   BlueSky is a modeling framework that is run on UNIX or LINUX based systems, and typically requires a considerable amount of computing resources. It can be configured many ways but is often used to create daily regional forecasts of smoke or air quality. The specific systems and institutions using these systems are listed on the site above.

   In order to provide the ability to perform custom model runs without the need to maintain a large server, BlueSky Playground has been developed, which is a web-based application that allows users to run BlueSky on the US Forest Service servers for specific burns of interest to the user. The user can customize their runs using this system. A few notes on BlueSky and BlueSky Playground from Sim Larkin are:
   - A new version of BlueSky Playground was released this past winter and is in Beta. The basic functionality of this tool is in place.
   - The main differences between FFA and the BlueSky programs is that BlueSky has dispersion modeling capabilities whereas FFA does not, and that FFA provides a more in depth interface for describing fuels. Otherwise, the two frameworks are similar, and there is current work to allow users of FFA to export their fire to BlueSky Playground in order to model smoke dispersion.

An overview of how the BlueSky framework incorporates different model components is shown in the figure below, taken from a paper by Goodrick, et al[1]. The paper is a very good overview of the different types of models, starting from the most basic and moving up in complexity. It also discusses how accurate some of the models have been at predicting smoke transport.

[1] Goodrick SL, Achtemeier GL, Larkin NK, Liu Y, Strand TM (2013) Modelling smoke transport from wildland fires: a review. *International Journal of Wildland Fire* **22**, 83-94. doi:10.1071/WF11116

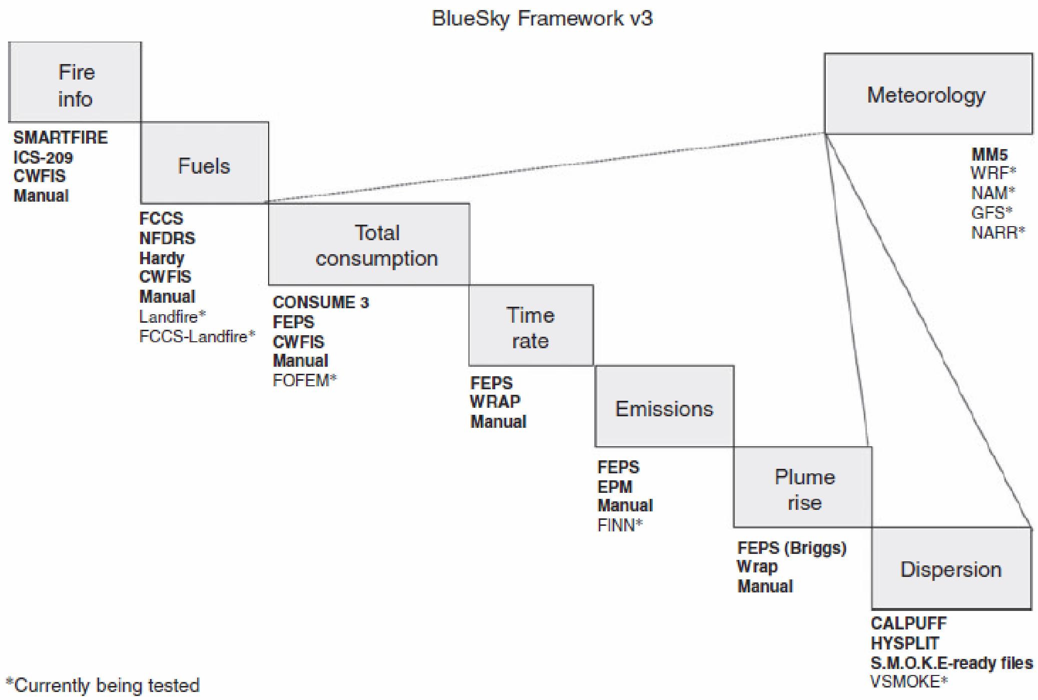

Fig. 5. The current BlueSky Smoke Modelling Framework including both standard distribution modules (bold) and those in testing (asterisks). Meteorological model output data are required for the dispersion step, but not for the consumption step. At the consumption step fuel moisture can be adjusted according to local conditions derived from satellite information (Tropical Rainfall Measuring Mission data) or a local weather station.

Figure 5 from Goodrick et al.[1]

The paper discusses many different models, not just BlueSky, and can be found at: http://www.publish.csiro.au/?paper=WF11116

2. FFA – Fire and Fuels Application.
   http://www.fs.fed.us/pnw/fera/
   FFA is a modeling framework from Fire and Environmental Research Applications (FERA) and it combines the Digital Photo Series, FCCS, Consume, Pile Calculator, and FEPS. A summary of FFA taken from "9--factsheet_FFA_1_17_13.doc" (Roger Ottmar) is given below:

   The FFA pathway in IFT-DSS will provide a single interface that combines the functionality of FERA's fire management tools and seamlessly imports and exports data between programs. The FCCS, Consume, FEPS, and the Pile Calculator will operate as individual calculators behind an interface geared toward developing reports requested by the user. For example, if users wish to calculate total consumption and emissions for a planned burn, they will create a fuelbed dataset, enter day-of-burn environmental variables, and view consumption and emissions output reports and comparison graphs. The fuelbed editor within IFT-DSS will include a link to the Digital Photo Series for reference during fuelbed editing.

Details of the subcomponents of FFA can be found at the link above. The chart below, taken from Roger Ottmar's presentation at the workshop, describes how each component of the framework fits together, and what their final output is.

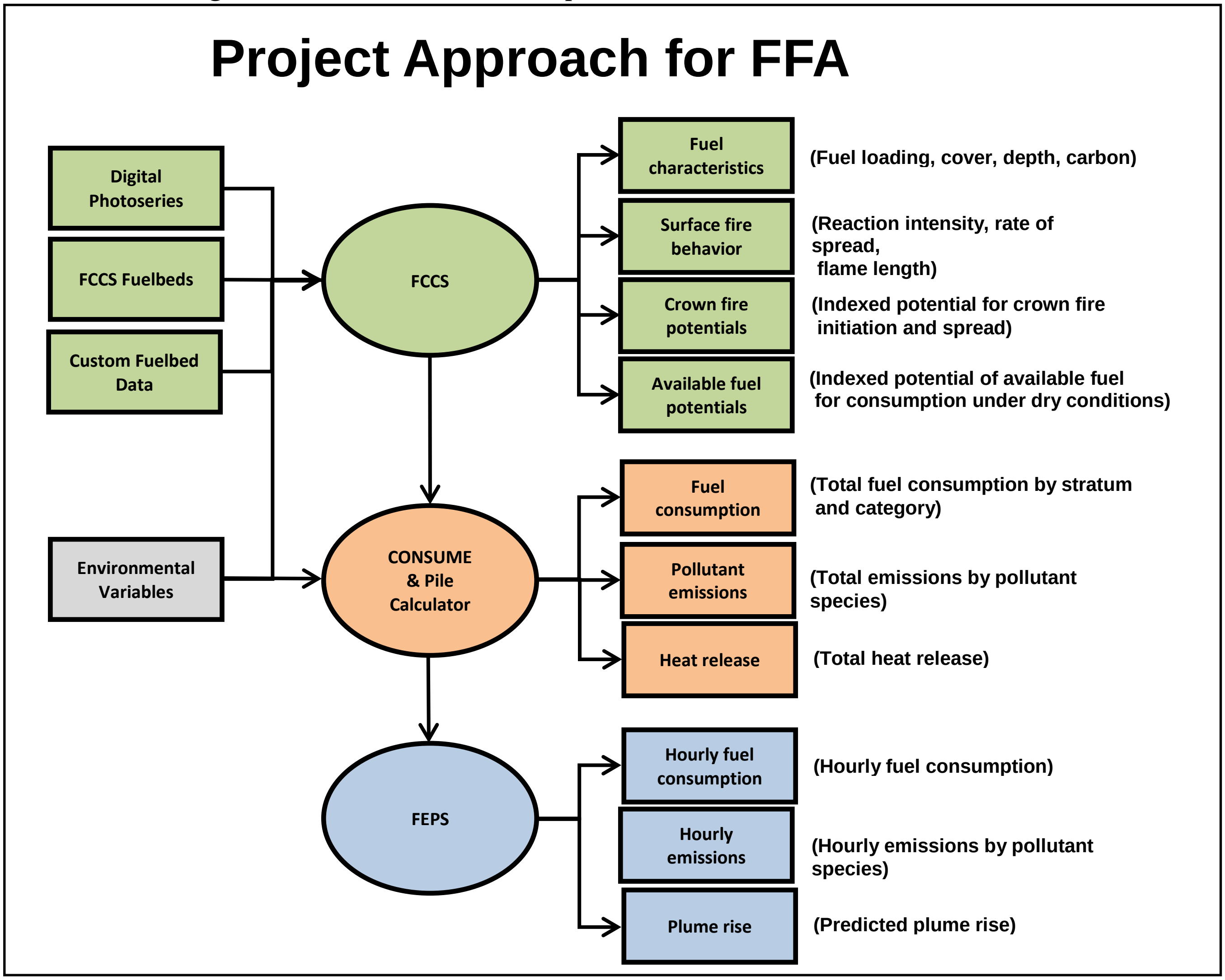

Fig 1: FFA overview from R. Ottmar, 2013.

Smoke and Emissions Model Intercomparison Project (SEMIP)
http://www.airfire.org/projects/semip/

This site addresses comparisons between models, as well as how models compare with observations, where available. Copied from this site, the description of purpose is:

> *Managers, regulators, and others often need information on the emissions from wildland fire and their expected smoke impacts. In order to create this information combinations of models are utilized. The modeling steps used follow a logical progression from fire activity through emissions and dispersion. In general, several models and/or datasets are*

available for each modeling step, and the resulting number of combinations that can be created to produce fire emissions or smoke impacts is large. Researchers, managers, and policy makers need information on how different model choices affect the resulting output, and guidance on what choices to make in selecting the models to use. Baseline comparisons are needed between available models that highlight how they intercompare, and, where possible, how there results compare with observations. As new models and methods are developed, standard protocols and comparison metrics are needed that allow these new systems to be understood in light of previous models and methods.

The Smoke and Emissions Model Intercomparison Project (SEMIP) was designed to facilitate such comparisons. In Phase 1, SEMIP:

- *examined the needs for fire emissions and smoke impact modeling;*
- *determined what data were available to help evaluate such models;*
- *identified a number of test cases that can serve as baseline comparisons between existing models and standard comparisons for new models;*
- *created a data warehouse and data sharing structure to help facilitate future comparisons; and*
- *performed a number of analyses to examine existing models.*