

Internet VSMOKE: A User-Oriented System for Smoke Management

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Abstract—The Georgia Forestry Commission has developed an Internet-based, user friendly version of a USDA Forest Service smoke dispersion model called “VSMOKE.” The program provides an easy to use method to quickly evaluate what areas will likely be impacted by smoke from a wild or prescribed fire. This is particularly important in assessing air quality, public safety and health, and visibility along highways. This paper explains the program and use and interpretations, and looks in detail at the example of highway safety.

Introduction

Smoke from wild and prescribed fire has been an increasing concern in public health and safety over the last few decades. The Georgia Forestry Commission (GFC) encourages safe use of fire on forest lands in Georgia, and provides a number of smoke management tools that may be viewed at: <http://weather.gfc.state.ga.us/>

A smoke dispersion model was developed at the Southern Forest Fire Laboratory (U.S. Department of Agriculture, Forest Service) and published by Lavdas (1996). It was developed before the widespread use of the Internet and was for the “...smoke management professional” (Lavdas 1996).

In order to encourage the use of prescribed fire with due regard to air quality, the GFC has developed an Internet-based, user friendly version of VSMOKE.

To use the original VSMOKE model one must:

1. Set certain dispersion model parameter
2. Provide fuel loading data
3. Provide emissions data
4. Provide weather data

A number of additions and modifications were required to extend the use of VSMOKE to the general landowner in Georgia. The guiding philosophy in developing the system was ease of use for the general land owner, flexible for use in planning burns, and with sufficient sophistication to appeal to professionals in forestry and smoke management.

In: Butler, Bret W.; Cook, Wayne, comps. 2007. The fire environment—innovations, management, and policy; conference proceedings. 26-30 March 2007; Destin, FL. Proceedings RMRS-P-46CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 662 p. CD-ROM.

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System Components

There are four main components in the system:

1. The INPUT PROCESSOR – Interactive user input.
 - FALCON VIEW (<http://falconview.org>) extracts the latitude and longitude of the burn from a map mouse click.
 - Date and time of burn.
 - Acres burned.
 - Type of burn – headfire, backfire, flankfire.
 - User input options:
 - Fuels
 - Select fuel and emission information from the best match fuel photograph, or
 - Enter basal area, age of rough, height of the understory vegetation, and Society of American Foresters (SAF) cover type, or
 - Enter tons of fuel per acre and emission factor.
 - Weather
 - The program is preset to use weather from the GFC weather database. However, one can elect to manually enter the needed weather data.
2. VSMOKE – Hour by hour dispersion.
3. VSMOKE-GIS (Harmes and Lavdas 1997) – Hourly digital isolines output of concentrations (called each hour by VSMOKE).
4. FALCON VIEW (<http://falconview.org>) – Map output of concentrations from VSMOKE-GIS.

The Input Processor

When the GFC Smoke Management System is accessed from the GFC Web site, some choices are required. First, the date and time of the burn, the location of the burn, and firing technique are always required.

Location—A Georgia Tech Research Institute adaptation of FALCON VIEW (<http://falconview.org>) is used to aid the user in map location of the burn in order for the system to extract latitude and longitude. The user is presented with a map of Georgia with county outlines and names (fig. 1). The user clicks on the county where the burn will occur, then chooses successively more detailed maps to locate the fire (fig. 2). When properly located, a mouse click on the location will send a latitude and longitude to the system. This is used for generating weather for the location, and for the output plume graphics.

Date and time and other fixed data input—After selecting a map location the user clicks the “SUBMIT BURN LOCATION” bar at the bottom of the page. This will generate the screen to input date, time burn start, time burn end, acres burned, firing method, and fuel photo display option (fig. 3). Date and times are selected from drop down boxes. Acres burned are entered in the labeled box. Firing method and photo display option are selected from radio buttons.

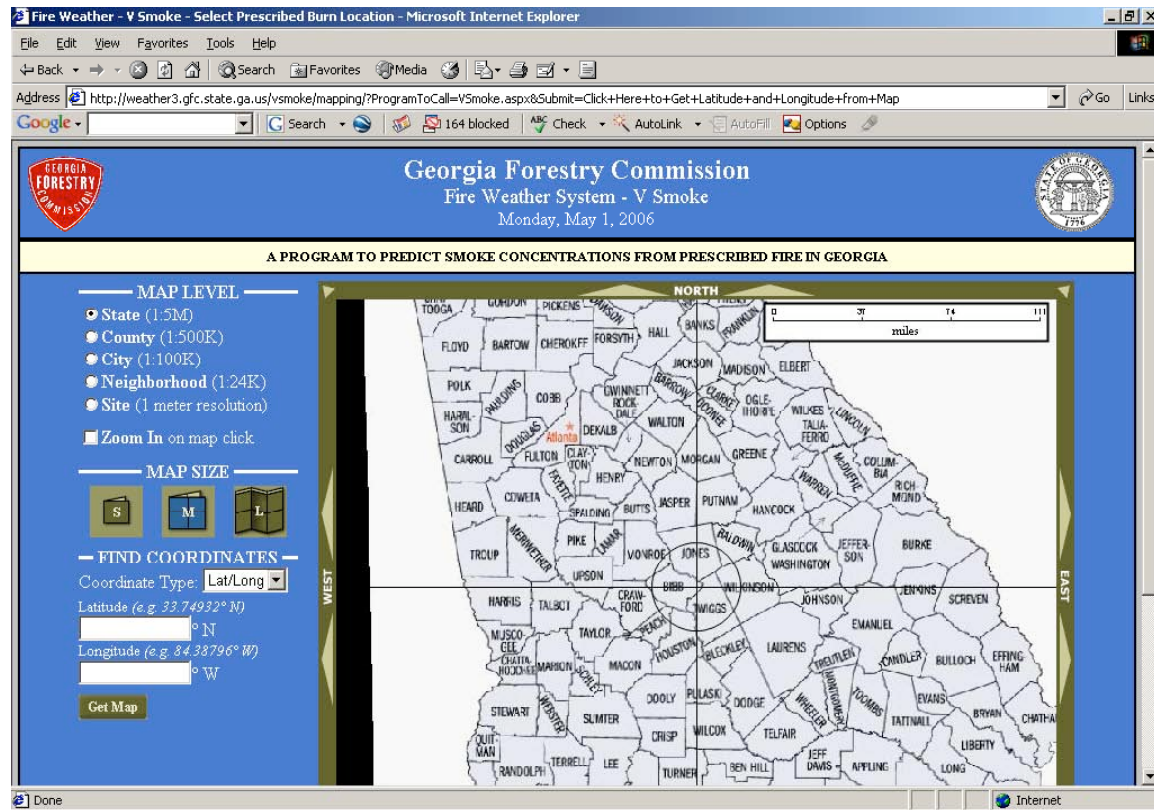


Figure 1—Map with county names for burn site selection in the Georgia Forestry Commission's Web-based VSMOKE.

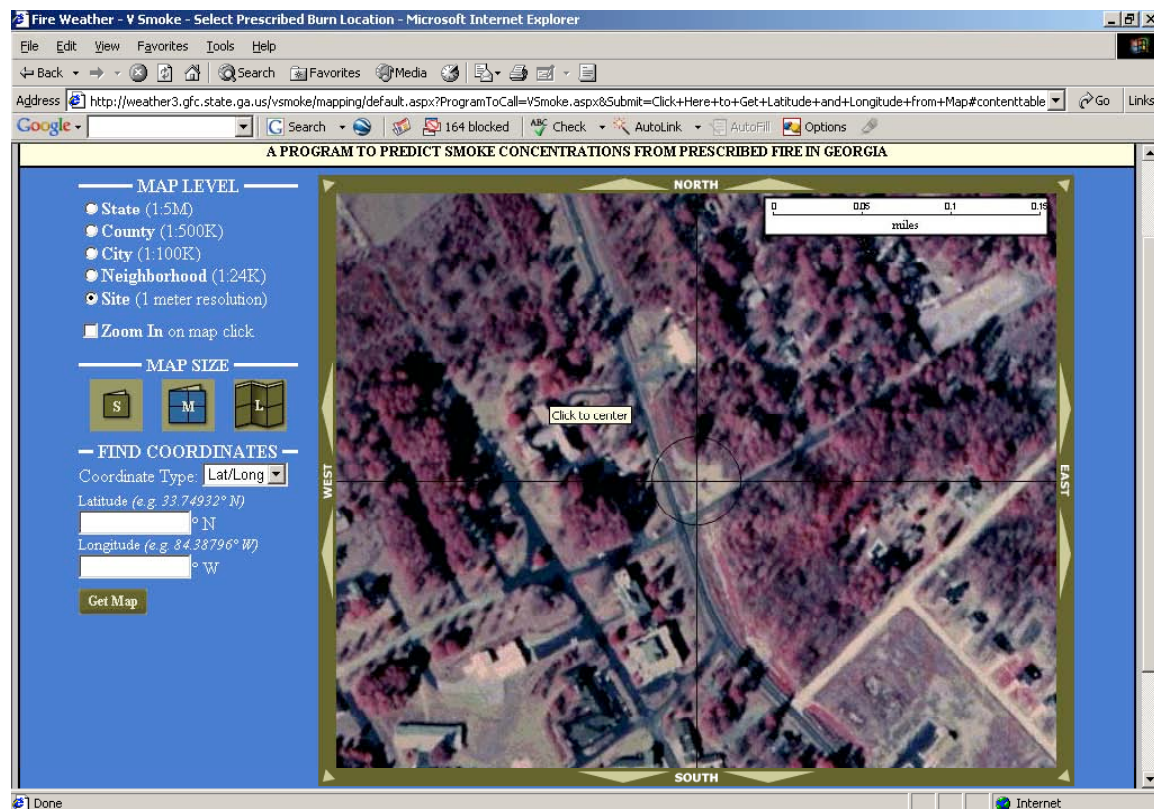


Figure 2—The most detailed site map selection in GFC Web-based VSMOKE. It is an aerial photo of 1 m resolution.

V SMOKE - A SMOKE MANAGEMENT MODEL FOR PRESCRIBED FIRE
Location and Fire Inputs

Latitude	32.807368
Longitude	-83.5385225
Date of Burn	Month: 5 Day: 01 Year: 2006
Ignition Time (24 Hour Clock)	1000 24 hour-time
Time Flames are to be out (24 hour clock)	1200 24 hour-time
Acres to be burned	100 Do NOT use Commas
Ignition Type	☒ Headfire ☐ Backfire ☐ Flank fire

Fuel Pictures or Manual Entry of Fuel Data

To generate fuel and smoke information from a photo series.

- ☒ Show All photos.
- ☐ Show photos for Coastal Loblolly.
- ☐ Show photos for Coastal Slash
- ☐ Show photos for Coastal Longleaf.
- ☐ Show photos for Piedmont Loblolly.

The classifications are based on Society of American Foresters Cover Type.

☐ To manually enter fuel and smoke information from stand characteristic. Suggested for professional foresters or those familiar with forestry terminology.

☐ To manually enter fuel and smoke information. Suggested for experienced users with extensive experience in fuel estimation and smoke management.

[Go to Fuel Data Entry Page](#)

Figure 3—Date of burn, time of burn, acreage burned, firing technique, and fuel data selection screen.

Weather—The user selects either manual weather input, or elects to automatically use weather from the GFC weather system localized to the burn latitude and longitude. The option to manually input weather data (fig. 4) can be used for preburn “what if” planning, or for those cases when the user has a high quality weather data set. The option to have weather automatically supplied by the system is recommended for the general user.

Fuel—There are three options to choose from in the fuels and emissions section. First, the user may choose to match his burn site with a forest scene photo stored on the system (fig. 5). When the best photo match is chosen, the model returns available fuel and emission factor. The second choice is for the user to input SAF cover type, basal area, age of rough, and height of the understory vegetation (fig. 6). When these variables are entered, the system will return available fuel and emission factor. The third option is for the user to directly input emission factor and available fuel (fig. 7). The first option is recommended for the general user. Its advantage is ease of use, and no specialized knowledge of forestry, meteorology, or smoke management is required. The disadvantage is that available fuel computations are not as site specific as other fuel options.

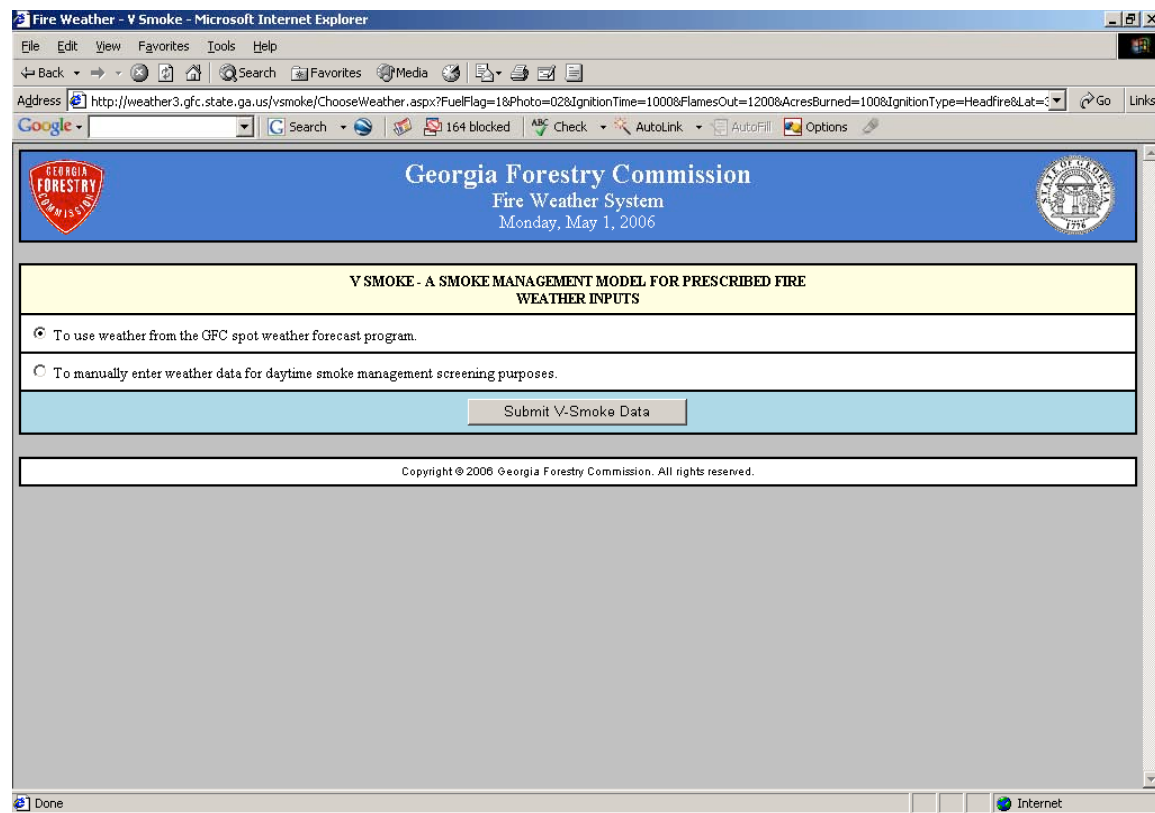


Figure 4—Weather data selection screen.

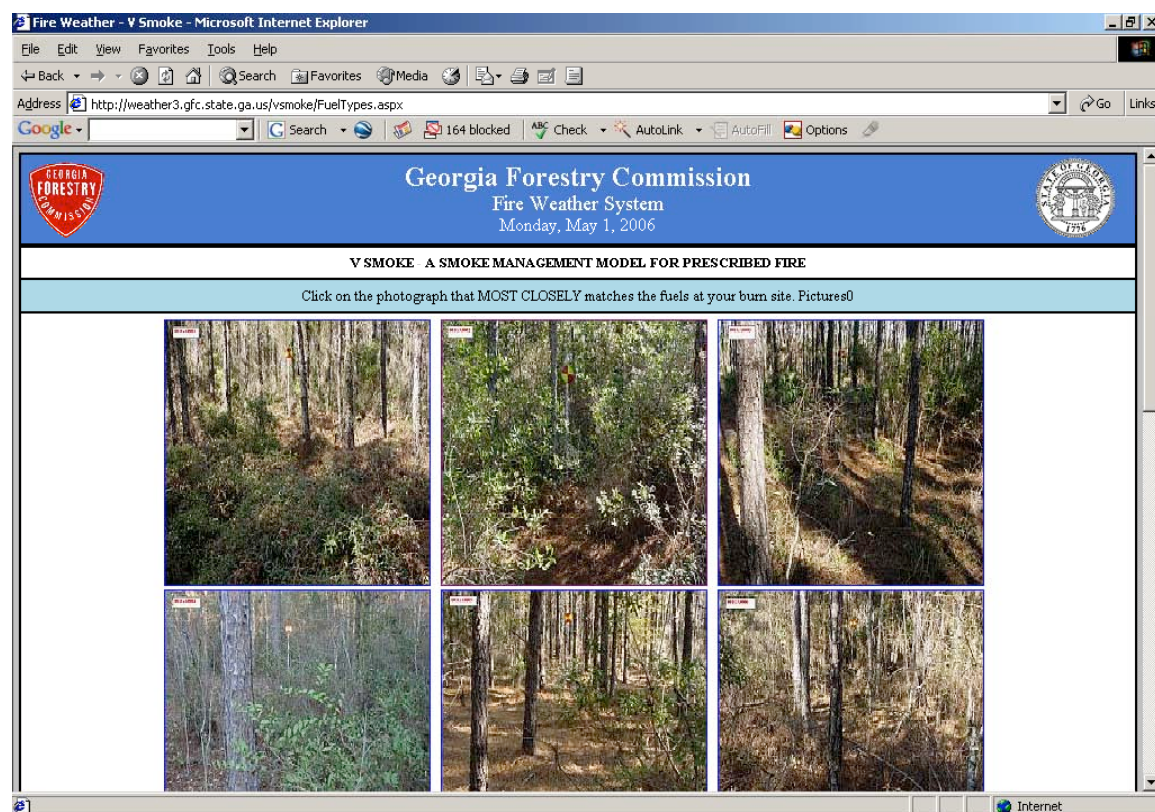


Figure 5—Fuel photo screen for fuel data input.

Georgia Forestry Commission
Fire Weather System
Monday, May 1, 2006

V SMOKE A SMOKE MANAGEMENT MODEL FOR PRESCRIBED FIRE

Basal Area (10 - 200)	50
Age of Rough (1 - 20) - Years	3
Height of Understory Vegetation (0-20) - Feet	5
Society of American Foresters Cover Type	☒ Coastal Longleaf Pine ☐ Coastal Loblolly ☐ Piedmont Loblolly

☒ To use weather from the GFC spot weather forecast program.
☐ To manually enter weather data for daytime smoke management screening purposes.

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Figure 6—Stand information input.

Georgia Forestry Commission
Fire Weather System
Monday, May 1, 2006

V SMOKE A SMOKE MANAGEMENT MODEL FOR PRESCRIBED FIRE

To directly enter Fuel Loading and Emission Information

Emission Factors	PM2.5 Flaming	PM2.5 Smoldering	Pounds per Ton
Available fuel	Tons per Acre		

☒ To use weather from the GFC spot weather forecast program.
☐ To manually enter weather data for daytime smoke management screening purposes. Although VSMOKE is specifically for daytime conditions, it will return an interpreted value for the Low Visibility Risk Occurrence Index.

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Figure 7—Manual fuel data input.

Output Processor

Running VSMOKE—When all inputs are complete, the user clicks on the “SUBMIT VSMOKE DATA” bar. The input processor then collects all user inputs, and computations based on these inputs, and runs the models.

Hour by hour outputs include:

1. Smoke plume concentrations displayed on a map background. The user may elect to view the output plotted on maps of different scale; figure 8. A plume that tends to be circular indicates most smoke is being lofted upward with associated good dispersion. A long pencil shaped plume indicates poor dispersion with most smoke remaining near the ground.
2. List of most smoke sensitive areas near the burn; figure 9.

Optional output selected from the screen following the plume output display; figure 10.

1. Inputs used by the model; figure 11.
2. Crosswind visibility downwind to 100KM (62.1 miles); figure 12.
3. Centerline smoke concentrations downwind from the fire to 100 km (62.1 miles); figure 13.
4. Low Visibility Risk Occurrence Index (LVORI) from time of fire until 1200 the next day; figure 14. The hours when the LVORI is greater than 7 indicate the atmosphere is conducive to low visibility, and the risk becomes greater as LVORI approaches its maximum value of 10. Values of LVORI less than 7 indicate smoke is unlikely to contribute to low visibility, with the likelihood becoming very small when LVORI reaches its minimum value of 1.

Cautions

Some cautions are in order. First, smoke dispersion models are an attempt to represent concentrations as sets of mathematical equations. Most models in use by the forestry community seem to do an acceptable job of representing this rather complex process. Two sources of error may make a large impact on the results. First, fuel data including emission factor, emission rate, and available fuel are potential sources of error. The authors regard the fuels inputs that were largely gleaned from the literature as being “Best operational available,” but recognize this as being an area in need of major improvement. Second, the model is obviously sensitive to errors in forecast wind direction. By inspection of the output plume, one can easily imagine a small change in wind direction might place the plume in an undesired location. Lavdas (1997) in an analysis of National Weather Service forecasts at the Macon, GA, airport, observed wind direction was within plus or minus 22.5 degrees of forecast wind about 38 percent of the time. When the difference was extended to plus or minus 67.5 degrees, the accuracy increased to about 79 percent. He also found that at higher wind speeds (15 mph and greater) accuracy increased by about 15 percent.

In a recent inhouse study, the GFC staff found similar differences in observed versus daily district forecast wind at Dawsonville, GA (table 1). In this case the wind was accurate to within plus or minus 45 degrees 79 percent of the time. These studies draw attention to the need for caution in interpreting the plume impact, especially at low wind speeds.

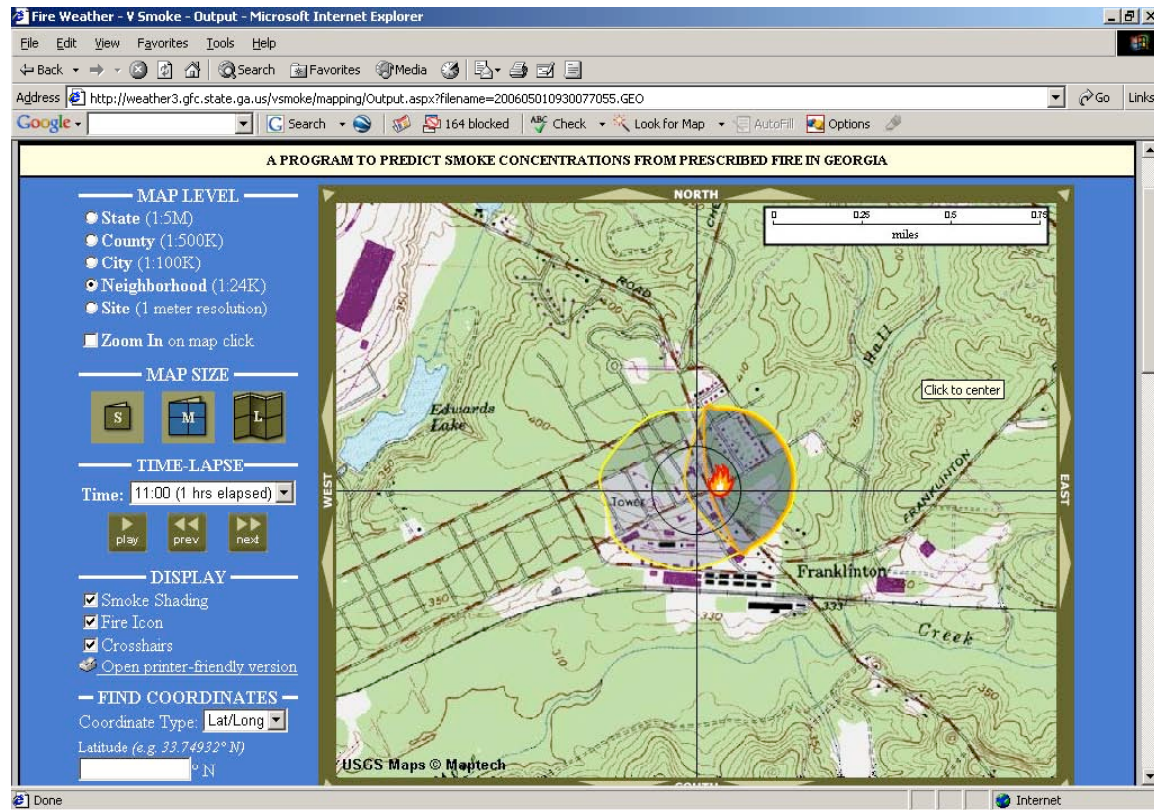


Figure 8—Plume output screen.

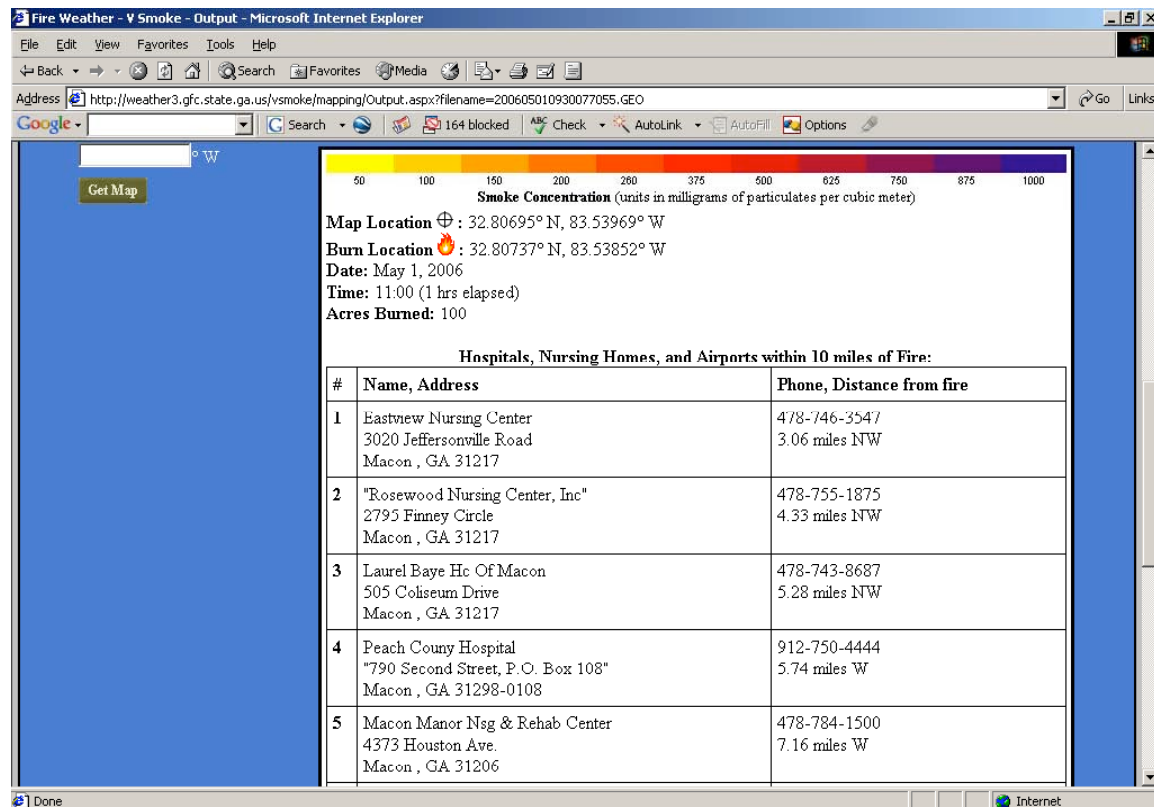


Figure 9—Listing of smoke sensitive areas.

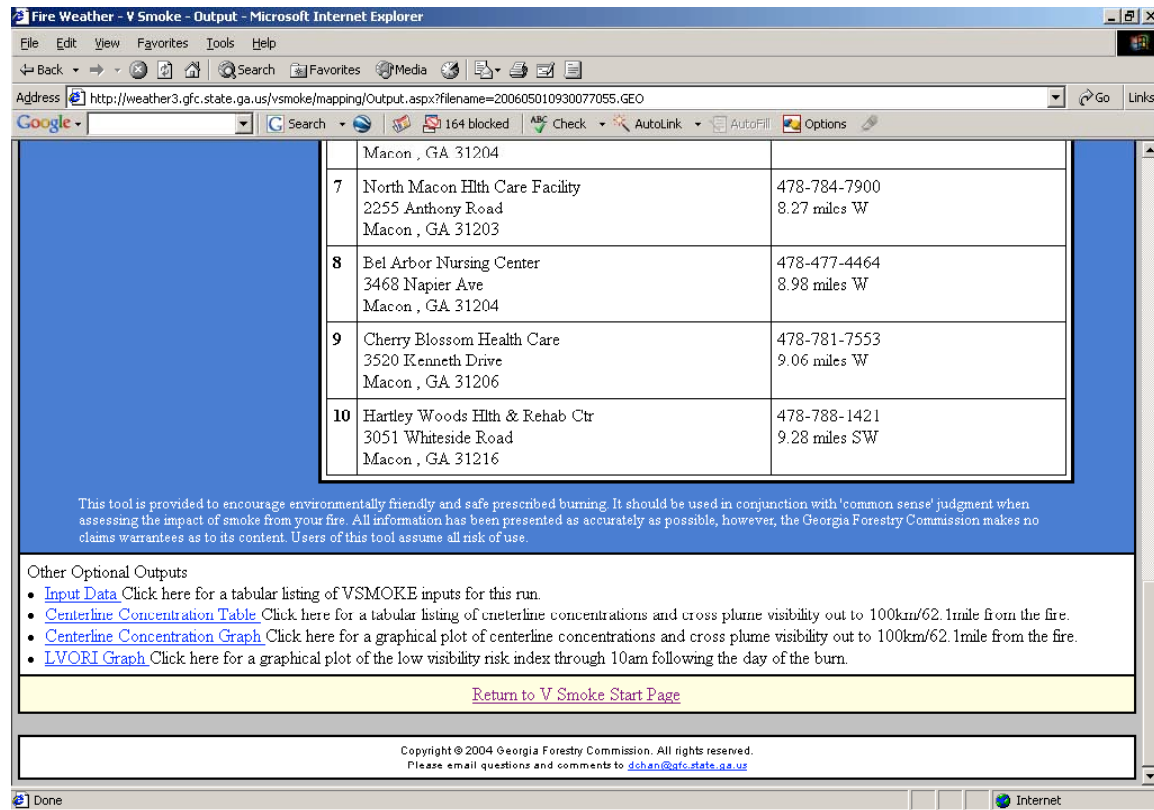


Figure 10—Optional outputs.

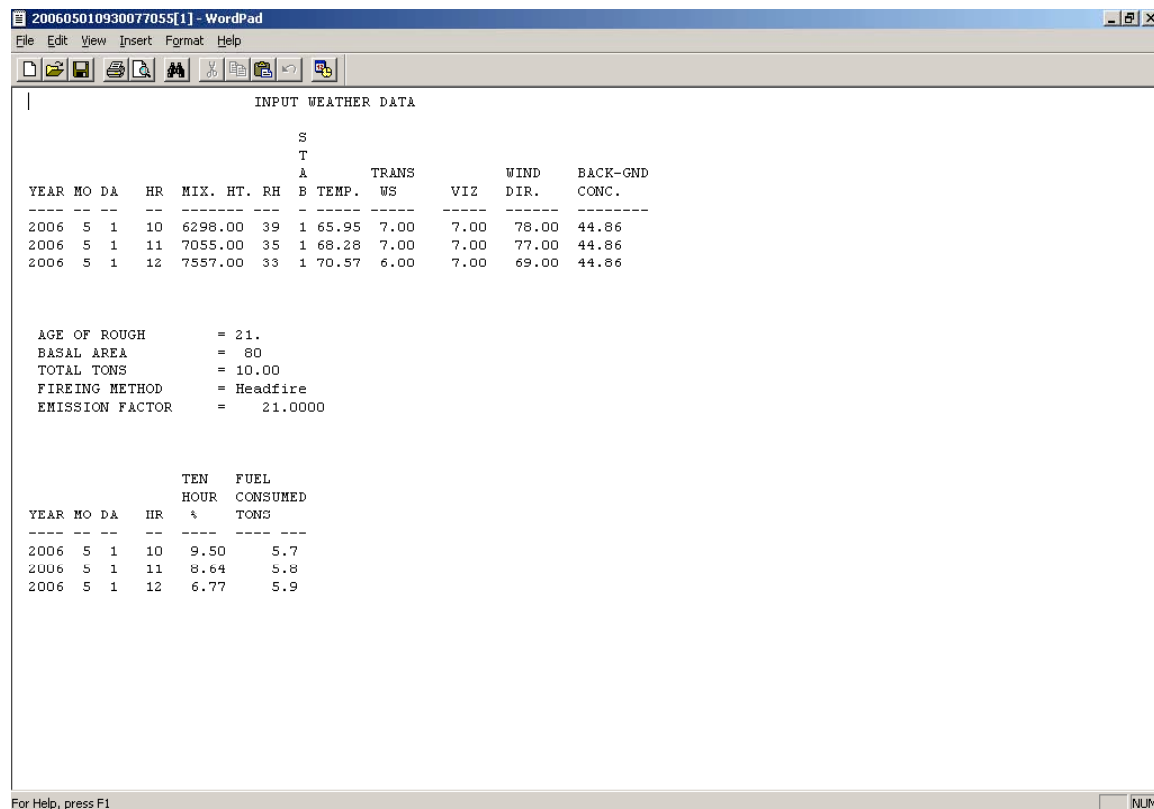


Figure 11—Weather data input used for the application.

http://weather3.gfc.state.ga.us/vsmoke/Data/200605010930077055.con - Microsoft Internet Explorer

Address http://weather3.gfc.state.ga.us/vsmoke/Data/200605010930077055.con

CENTERLINE CONCENTRATIONS FOR HOUR 10

HR	DOWNWIND KM	DISTANCE FROM FIRE MILES	TSP CENTERLINE CONCENTRATION (INCL. BKGPM) (UG/M**3)	CROSSPLUME VISIBILITY MILES
10	0.100	0.062	81.679	8.39453
10	0.126	0.070	74.046	0.44921
10	0.158	0.098	69.138	8.49488
10	0.200	0.124	64.348	8.53321
10	0.251	0.156	60.328	8.56538
10	0.316	0.196	56.710	8.59432
10	0.398	0.247	53.683	8.61850
10	0.501	0.311	50.931	8.64032
10	0.631	0.392	48.630	8.65830
10	0.794	0.493	47.130	8.66980
10	1.000	0.622	46.185	8.67704
10	1.259	0.782	45.614	8.68156
10	1.585	0.985	45.286	8.68435
10	1.995	1.240	45.104	8.68608
10	2.512	1.561	45.006	8.68713
10	3.162	1.965	44.961	8.68768
10	3.981	2.474	44.947	8.68775
10	5.012	3.115	44.939	8.68775
10	6.310	3.922	44.932	8.68775
10	7.943	4.937	44.927	8.68775
10	10.000	6.215	44.922	8.68775
10	12.589	7.824	44.918	8.68775
10	15.849	9.850	44.915	8.68775
10	19.953	12.401	44.912	8.68776
10	25.119	15.612	44.910	8.68779
10	31.623	19.654	44.908	8.68784
10	39.811	24.743	44.907	8.68792
10	50.119	31.149	44.906	8.68801

Done Internet

Figure 12—Centerline concentration for each hour in the burn period.

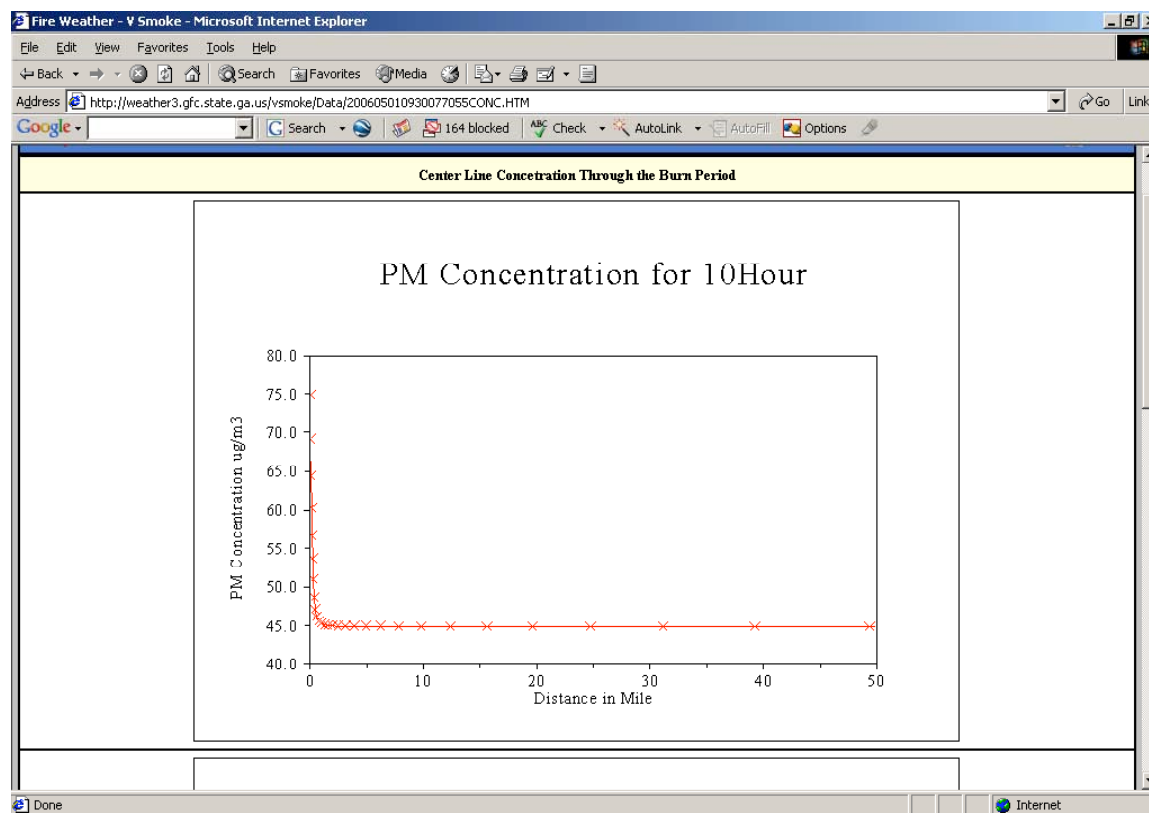


Figure 13—Centerline concentration graph for each hour in the burn period.

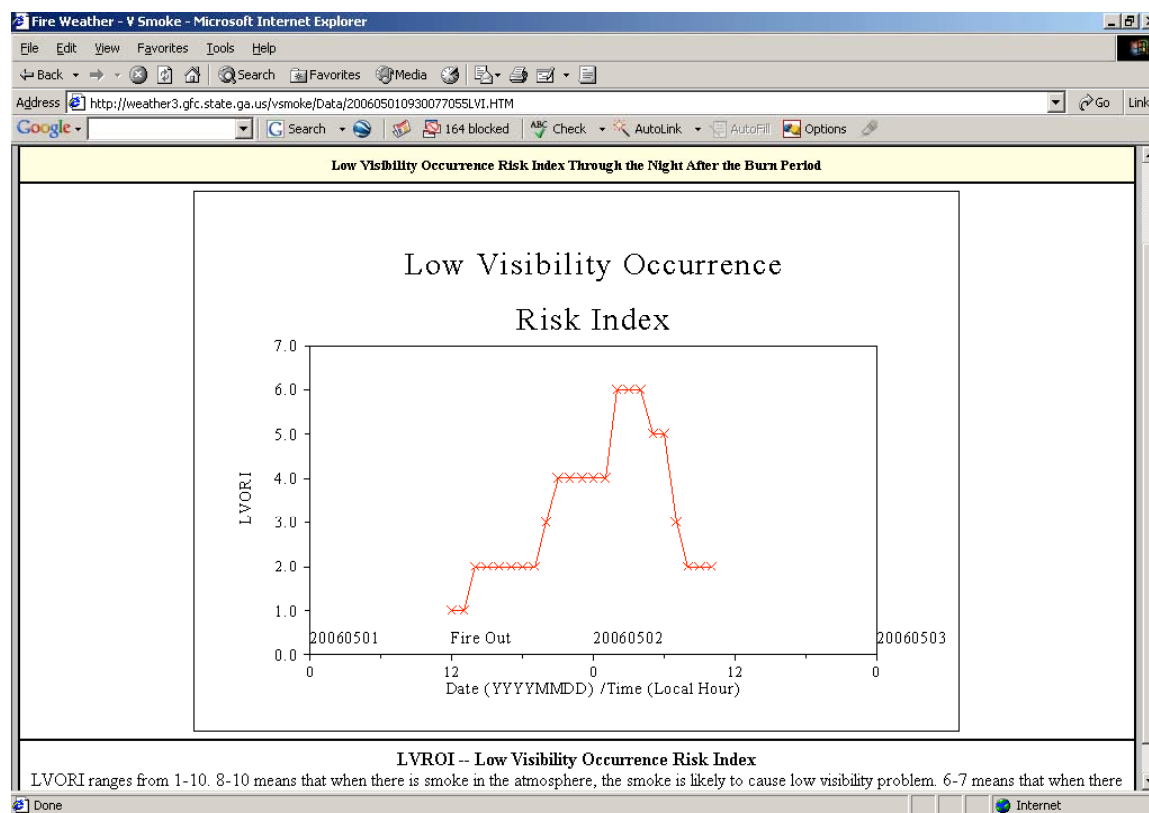


Figure 14—Low Visibility Occurrence Risk Index from the end of the burn to the following morning.

Table 1—Wind direction (observed - forecast) frequencies for the GFC weather station at Dawsonville, GA, from January 2002 to December 2002.

Wind direction (obs-fcst)	Months												TOT
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Degrees													
-91 <	1	0	2	1	3	2	1	1	1	2	1	1	16
-46 to -90	2	3	5	4	2	0	2	1	1	1	3	1	25
-1 to -45	4	7	9	8	6	2	3	3	3	9	3	6	63
HIT	11	11	6	14	9	14	5	3	7	5	13	14	112
1 to 45	4	7	8	1	2	3	5	5	2	5	3	6	51
46 to 90	0	0	0	1	2	0	2	0	0	2	0	1	8
> 91	4	0	1	0	1	0	0	0	0	3	1	2	12
Total	26	28	31	29	25	21	18	13	14	27	24	31	287

Use and Interpretation

The plume depiction provides a method to quickly evaluate what areas will likely be impacted by smoke from a prescribed fire. Unsafe highway visibility resulting from smoke typically extends outward to about 0.25 to 0.50 mile, but under poor dispersion can be much farther. The light to dark gray sections of the plume are the areas of most concern. If this section of the plume impacts a roadway, the burner should defer burning until more favorable conditions occur, or take special precautions such as placing warning signs along the highway, or perhaps paying an off-duty law enforcement officer to monitor the fire on site and reroute traffic or close the road as needed. Additional information concerning concentrations and visibility can be found in the screens following the plume screen. For example, the “Centerline Concentration Table” and “Centerline Concentration Graph” screens provide additional information on concentrations. “The Centerline Concentration Table” also provides estimates of cross plume visibility. These visibility values refer to daytime conditions. Additional information such as the LVORI should be evaluated for nighttime conditions.

The influence of smoke on highway is intuitive because smoke will obviously reduce roadway visibility if present. The question is what constitutes safe visibility? One way to answer this question is to consider automobile stopping distance as a function of speed. In the “Georgia Drivers Manual, 2005,” which can be viewed on line at <http://www.dds.ga.gov/docs/forms/FullDrivers-Manual.pdf>, data are presented that relate stopping distance to speed; these data were used to construct table 2. These numbers are not absolute, and the manual also lists six factors that influence stopping distance. These are:

1. Mental and physical reaction of the driver.
2. Type and condition of the pavement.
3. Kind of tires and tread composition.
4. Chassis (frame) design.
5. Type of brakes, condition, and balance of brakes.
6. Wind direction and velocity.

Suppose one is driving on a State road at the posted speed limit of 55 mph. Rounding this to 60 mph, and using values from table 2, the stopping distance would be between 252 and 372 feet. Next, examine the data from the “Centerline Concentration Table.” The first value is at 0.062 mile from the fire with an associated cross plume visibility of 8.39 miles. In this (as in most cases) roadway visibility is not a problem since the estimated visibility is much greater than the stopping distance. However, problems do occur, and using VSMOKE is a good way to evaluate the existence of a problem.

Table 2—Estimated emergency stopping distance by speed. Source: Georgia Drivers Manual, 2005

Driving speed (mph)	Driver reaction distance (ft)	Breaking distance (ft)	Total stopping distance (ft)
20	44	15-22	59-66
30	66	33-50	99-116
40	88	53-107	141-195
50	110	83-167	193-277
60	132	120-249	252-372
70	154	163-327	317-481

The boxed numbers on the map refer to smoke sensitive areas such as nursing homes. It is assumed the burner will make appropriate arrangements when nursing homes and hospitals are within the plumes area.

LVORI is not a perfect indicator of smoke induced low nighttime visibility problems on roadways. LVORI is essentially an estimate of the atmosphere potential to contribute to low visibility. Other factors that should also be considered include:

1. The fire is more than 3 miles from a road. Most nighttime visibility problems occur within 3 miles, but in exceptional cases may extend out to 30 miles from the fire.
2. The vegetation is continuous and heavy between the burn and a road. Heavy vegetation acts as a filter and slows the movement of smoke.
3. Logging roads, power lines, streams, or similar features can provide an unobstructed pathway between the burn and a road.
4. The road is at a higher elevation than the burn.

Future Development

The system is structured as a series of stand alone modules with a master calling routine integrated into the system. Consequently, the fuels, weather, emissions, or dispersion modules can be replaced as desired with a minimum of effort. Possible improvements include output from weather models such as MM5, better ways to estimate fuel loading, available fuel, and improved emission factors.

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