Using Smoke Modeling Tools for Prescribed Fire Planning and Implementation

A Quick Set of Instructions (*Revised December 2017*)

Fire Management Officers (FMOs) in Region 8 are using smoke modeling more often in both the prescribed fire planning process as well as in the implementation of those plans. The Air Resources Team is available to provide training to FMOs on smoke modeling tools, including the Fire Emissions Production Simulator (FEPS), VSMOKE and VSMOKE-GIS, and PC HYSPLIT.

- FEPS is used to estimate emission and heat release rates from the prescribed fire event. FEPS yields inputs to both the VSMOKE and the HYSPLIT models.
 - As part of its calculations, FEPS requires user inputs for fuel loading and/or consumption for the unit that is being burned. Site specific fuel plot data will be the best source for these inputs, but if such data are not available FEPS also provides canned fuel loading and consumption data for various types of forest stands.
- VSMOKE is a simple screening model for prescribed fire planning. Using FEPS outputs, various meteorological conditions are entered into the VSMOKE model to simulate certain scenarios and assess the worst-case predicted downwind concentration from the proposed fire.
- PC HYSPLIT
 - The Ready version of HYSPLIT is a web-based model that uses many assumptions to estimate predicted downwind pollution concentrations. <u>At this time, the R8 Air Resource Team does not recommend the Ready version because of concerns about over-prediction of downwind concentrations.</u>
 - The PC version of HYSPLIT provides a more refined prediction of downwind concentrations. The Air Resources Team can model HYSPLIT for field personnel, if requested.

This document outlines the steps necessary to run FEPS, VSMOKE and HYSPLIT. Since both VSMOKE and HYSPLIT use emission and heat release rates from FEPS, instructions to run that program are presented first. Then, instructions for running VSMOKE for planning purposes start on page 5. Finally, on page 13, the instructions to run HYSPLIT PC begin.

If anyone needs assistance to better understand these instructions, members of the R8 Air Resource Team are available to provide train and/or assist with a particular problem. Contact information is:

- Bill Jackson (828-257-4815): North Carolina, Cherokee, Francis Marion Sumter, Savannah River, and Chattahoochee-Oconee
- Judy Logan (501-321-5341) : Ouachita, Ozark-St. Francis, Kisatchie, Texas, Mississippi
- Melanie Pitrolo (828-257-4213): Any Forest
- Daniel Stratton (828-257-4226): Any Forest

Use FEPS to Create Emissions and Heat Input Files for VSMOKE and HYSPLIT

To estimate downwind concentrations from a prescribed fire event, first calculate the hourly emission rates and heat release rates from the fire. Use the Fire Emissions Production Simulator (FEPS) to calculate hourly emission rates and heat release rates. The paper, "Using FEPS Results as Inputs to Smoke Dispersion Models: Identifying the Relative Importance of Parameters within the Tool," gives detailed information about how to run FEPS. As a refresher, the basic steps used to obtain the emissions, heat release, and plume profile for the fire from FEPS are listed below:

1. Open FEPS, either from the VSMOKE form or from the Windows start menu; and create or load a prescribed burn event. Once an event is created/loaded, the main FEPS screen with its five user input tabs appears. Enter the fire event information (start and end date) in the left side of the form, then click save.

FEPS - Bro	adcast p	Fore	User	Inpu	ts				
Event Information	ion (requir	Fuel Loading	Fuel	Moisture		Consumption		Hourly Input	Data
Event Name Start Date End Date	Broadca 3/12/20 3/15/20	ast Forest 1 D4	¢	25 char)	Fire Shape Event Type Fire Type	Linear pr Emission Broadca	ogression Inventory st Natural Fu	el 💽	
Descriptive Info Permit or Fire # Description Comment	ormation (optional)	¢	25 char)	Lc	cation Deg ngitude . titude .	ree Minutes 90 0 40 0	Seconds	
Broadcast Forest 1		User Event	Broadcast	Natural Fr	uel III	Save	Event: Valid	Cancel	√alid

- 2. To obtain consumption information, there are three options: Use FEPS to calculate the consumption, import consumption information from the CONSUME software program, or directly enter consumption based on your best professional judgment.
 - a. If you use FEPS to calculate consumption, go to the Fuel Loading tab and enter the fuel profile name and select the fuel bed type. Then, in the Fuel Moisture tab, pick the fuel moisture. In the Consumption tab, select "calculate and save".
 - b. If you are not using FEPS to calculate the consumption, go to the Fuel Loading tab, clear the fuel bed information, and then create a name for the fuel profile. Next, go to the Fuel Moisture tab and set the fuel moisture at "Very Dry". Then go to the Consumption tab to either import or type in the consumption.
 - i. To import a CONSUME file, click on Actions→Import Consumption→Import from Consume 3.0. Use the drop down menu, as shown below, to select and import the CONSUME project. Note that the Unit and Fuelbed may be selected as well.

FEPS - Cons	ume Imports		
File Actions Help	To import a Co project from	nsume Project i the drop-down i	nto FEPS, select the appropriate menu, then click Import Data.
Event Information	Fuel Loading	Fuel Moisture	Consumption Hourly Input Data
Fuel Profile	Project, Unit and/or Fuelbe Consume Project	a. _{Un} Impo	orting Consume
Med Forest	Southern Examp	le 👻	Results
Unused	Northeast Examp	ole	· · ·
Unused	Western Example		
Unused	Boreal Example		
Linused	Test		
	FEPS_Import		
	You may loug and resource	CaseSi Consume 3.0 Fuelbe	ed, or
	you may load the cumulat	ive results from a Project o	r Unit.
		_	Import Data
Consume Imports	User Event E	Broadcast Natural Fuel	Feb 19 2009 Event: Valid Tab: In Edit

ii. If you know what the consumption will be, either from field measurements or by best professional judgment, manually enter that information into FEPS as shown below.

🆀 FEPS -	Broa	dcas	st Fo	rest	1										
File Actions	s Help														
Event Infor	mation	Υ	Fuel L	oading	Ϋ́	Fu	uel <u>M</u> ois	ture		<u>C</u> on	sumpti	on	יו	Hourly Inp	out Data
Fuel Consu	Fuel Consumption (tons per acre) Total Cons. (T/A)							Entering Your Own							
Fuel Profile	Can Sł	hrub Gra	ass Wdy	Litter	Bdest	Pile	A/G	Duff	Total	6	7	0			4.0
test1	0.0		0.0 0	.0 0.1	0.0	0.0 (8.5	1.5) 10.0	C	_ons	um	puo	n Da	ua 📋
Unused	0.0	0.0	0.0 0.0	.0 0.1	0.0	0.0	0.0	0.0	0.0	Torrer	of a rad	coll to :	the usl		tod bu
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Ĩ.	Flami	ing				Short T	erm S	molde	ring <	2 hrs	Long T	erm S	molde	ring	
Fuel	Inv	Cons	s. Dep F	lesT	Next	Inv	Cons.	Dep	ResT	Next	Inv	Cons.	ResT	Next	
Profile	%	T/A	inch	hrs	day	%	T/A	inch	hrs	day	%	T/A	hrs	day	
test1	57	4.6	0.5	0.12	0.00	57	4.6	0.4	0.22	0.01	83	0.9	15.66	0.94	
Unused	0	0.0	0.0	0.00	0.00	0	0.0	0.0	0.00	0.00	83	0.0	15.66	0.94	
Unused		0.0	0.0	0.00	0.00	0	0.0	0.0	0.00	0.00	83	0.0	15.66	0.94	
Unused	0	0.0	0.0	0.00	0.00	0	0.0	0.0	0.00	0.00	83	0.0	15.66	0.94	
Unused	0	0.0	0.0	0.00	0.00	0	0.0	0.0	0.00	0.00	83	0.0	15.66	0.94	
Hover over an explanat	the colun tion of abl	nn head breviatio	ings for ons.				<u>R</u> ese			Calculate	and Sav	e	C	ancel]
Broadcast Fore	st 1		User	Event		Broadca	ast Nati	ural Fue	el .	Dec	18 2008	Even	it: Valid	Та	b: Valid

- 3. After entering the consumption information for the prescribed fire event, go to the Hourly Input Data tab. Enter the hourly meteorological data, along with the fire spread information, for each hour of the active burn phase. There are two views within this tab: the "Hourly Data" and the "Daily Temperature and Humidity Extremes".
 - a. The "Hourly Data" view is below. You must enter the hourly information for the active burn phase, including the rate of spread of the fire, the transport and mid-flame (<u>not</u> surface) wind speeds, and the stability class. Note that in the absence of site-specific met data, mid-flame wind speeds are assumed to be 40% of the surface wind speed values (e.g., a surface wind speed of 5 miles per hour is assumed to have a mid-flame wind speed of 2 miles per hour).

Event Inforr	nation	1 1	-uel Loading	3	Fuel Mo	isture		nsumption		Hour	ly Input Data
Date and Ti Date	ime Time	Area (acres)	% of area b Med Forest	Unused	r each fuel Unused	I profile Unused	Unused	Trans	Wind @	Pasquil)
3/12/2004	00	0	100	0	0	0	0	15	0	E	
3/12/2004	01	0	100	0	0	0	0	15	0	F	
3/12/2004	02	0	100	0	0	0	0	15	0	F	
3/12/2004	03	0	100	0	0	0	0	15	0	F	
3/12/2004	04	0	100	0	0	0	0	15	0	F	
3/12/2004	05	0	100	0	0	0	0	15	0	E	
3/12/2004	06	0	100	0	0	0	0	15	0	E	
3/12/2004	07	0	100	0	0	0	0	15	0	E	
3/12/2004	08	0	100	0	0	0	0	15	0	D	•
er-specifie we the area ess F6 to co ess F7 to co Hourly D	d burn a for that opy % ar opy all % ata	reas are di time-step t rea or met. area or m	splayed in r to be interpo info from th et. info from	ed. To dele plated by FE is selected in the select	te a user-sp EPS, select t cell to the b ed day to al Export to E <u>x</u>	pecified burn the cell and oottom of the I following c cel for editir	n area and press F5. column. lays.	Hov colu exp abb	er over (imn head lanation reviation	or click o lings for of s and us Canc	n an age.

b. The "Daily Temperature and Humidity Extremes" view is on the next page. You must enter in the humidity information (daily minimum/maximum and the hours that they occur).

Fuel Loadir	1g)	Euel Moisture	Consumption	
Fuel Loadir	ng /	Euel Moisture	Consumption	
Fuel Loadir	ng	Fuel Moisture	Consumption	· · · · · · · · · · · · · · · · · · ·
			Consumption	Hourly Input Data
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s Hour	Temp F	RH%	Doily Minim	
x RH 05	50	65		,111
<i>n RH</i> 14	85	25	and Maximu	m 🛛
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x RH 05	50	65		
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4. Run FEPS by clicking on the button below and to the right of the Help menu. After clicking on this button, you can exit the program. Results are ready to be used in either VSMOKE or HYSPLIT.

Event Inform	nation		Fuel Loadin	g	Fuel <u>M</u> o	isture	<u>C</u> o	nsumptio	<u> </u>	Hour	ly Input Data
ate and T	ime		% of area l	burning fo	r each fuel	profile		Meteor	ology		
Date	Time	Area (acres)	test	Unused	Unused	Unused	Unused	Trans Wind	Wind @ Flame	Pasquill Stability	
2/8/2010	11	388	100	0	0	0	0	10	5	С	
2/8/2010	12	675	100	0	0	0	0	10	5	С	
2/8/2010	13	963	100	0	0	0	0	10	5	С	
2/8/2010	14	1250	100	0	0	0	0	10	5	D	
2/8/2010	15	1250	100	0	0	0	0	15	5	D	
2/8/2010	16	1250	100	0	0	0	0	15	5	D	1
2/8/2010	17	1250	100	0	0	0	0	15	5	D	
2/8/2010	18	1250	100	0	0	0	0	15	2	D	
2/8/2010	19	1250	100	0	0	0	0	15	2	D	-
er-specifie ve the area ess F6 to co ess F7 to co Hourly D	d burn a for that opy % a opy all % ata	areas are t time-step irea or me 6 area or	aisplayed in to be interp t. info from ti met. info from	red. To dele olated by FE he selected n the select	te a user-sp EPS, select t cell to the b ed day to al Export to Ex	becified burn the cell and ottom of the I following c	n area and press F5. e column. lays.	Ho co ex ab	ver over o lumn head planation (breviation)	or click or lings for of s and us Canc	n an age.

Running VSMOKE or VSMOKE-GIS

There are two ways to run the VSMOKE model. Either use the Arc GIS interface, or simply use the VSMOKE form. If you use ArcMap to display the VSMOKE results graphically, follow all of the instructions below. Otherwise, skip down to 2.

Navigate to the c:\vsmkgs folder. Click on the c:\vsmkgs\vsmoke.mxd file which opens the ArcMap
project. (Some desktops contain an icon named vsmoke.mxd. If so, simply double click on it to open the
ArcMap project.) Once the ArcMap project is open, add any layers needed in the VSMOKE project, *i.e.*forest boundary, burn units, etc. At that point click on the match button as shown on the following screen
capture, and then click the map location where the burn will take place.



2. After either clicking on the map, or opening "VSMOKE and HYSPLIT Interface" from the Windows Start Menu, the VSMOKE dialogue box will open. The screen that is shown below will appear. Click on "VSMOKE and VSMOKE-GIS."

VSMOKE, VSMOKE-GIS, and HYSPLIT User In	terface
	User Interface for VSMOKE-GIS and VSMOKE, and Produce Emissions Input Files for HYSPLIT
	Version 2.5.0
	VSMOKE and VSMOKE-GIS are simple smoke dispersion model for prescribed and wildland fires in flat to gently rolling terrain
Copyright: Public domain	William Jackson, USDA Forest Service Lee Lavdas, retired USDA Forest Service Dale Loberger, Environmental Systems Research Institute David N. Kelly, Forest Resource Consulting Inc.
Disclaimer: VSMOKE and VSMO recipient may not assert any pro other than Goverment-produced provided 'as is' without warranty warranties of merchantability and all responsibility for the accurac	OKE-GIS software is in the public domain and the prietary rights thereto or represent them to anyone as programs. VSMOKE and VSMOKE-GIS software is of any kind, including but not limited to the implied d fitness for a particular purpose. The user assumes y and suitablity of these programs for a specific
VSMOKE and VSMO	KE-GIS HYSPLIT

3. The X and Y Coordinates screen will appear. If you clicked on an ArcMap project to open VSMOKE, the coordinates are already populated with the values you chose. Otherwise, enter the latitude and longitude in decimal degrees. Click Close.

VSMOKE and VSMOR File View Emissions PM Set	E-GIS Input Values	Exit Help
Title [Do not use any commas in the Emission and Heat Release Rai	e title or more than 72 characters)	Number of isopleths for VSMOKE-GIS 5
insure of whether your coord ried over from ArcMap, clic Coordinates".	tinates k "Get Get Coordinates	ate [698.5
Carbon Monoxide Surface Temperature (F) Atmospheric Pressure (millibars)	Required for VSMOKE-GIS Y Coordinate (meters) 365818.277 X Coordinate (meters) 1230547.521	If and an inc. And Manuard and the
Meteorology Transport windspeed 7 (miles per hour)	Required for VSMOKE Longitude (decimal degrees) -84.372 Latitude (decimal degrees) 35.101	latitude and longitude (in decimal degrees).
Calculate Stability Class with V Time Zone <u>5</u> Year (e Surface Wind Speed (miles per hour) 5	Close	imulation .5 for 2:30 pm) 10 siling 3000
Inputs used only in VSMOKE-GI	S e sunset (daylight) Stability Class for 3 VSMOKE-GIS	3 (Slightly unstable)
Status		2/9/2010 10:55 AM

4. The main VSMOKE input screen appears. Retrieve the FEPS results first by clicking **Emissions**, then click **Retrieve FEPS...Emission Rates**, as shown below.

VSMOKE and VSMOKE-GIS Input Values	
File View Emissions PM Settings Analysis Results	Websites Exit Help
😂 🖬 🚳 Retrieve FEPS Heat, PM2.5, and Carbon Mono	xide Emissions Rates Ctrl+H
Title [Do not use any commas in the title or more than 72 characters]	Number of isopleths for VSMOKE-GIS
Emission and Heat Release Rates	Tatal Cassible Heat
Acres burned during this hour 100	Emission Rate (megawatts) 581.6
Particulate Matter	1
Background concentration (micrograms / cubic meter) 20	Total Source Emission Rate (gm / sec) 698.5
Carbon Monoxide	
Surface 70	Background Concentration 2

5. The screen shown on the next page appears. Results from the last FEPS run are populated in the table. If this is the desired run, simply select the desired hour to model (typically the hour with the highest PM_{2.5} emission rate), confirm those data and press "Use Answers." If a new FEPS run is necessary, press the "Execute FEPS" button and the FEPS program will appear. Pages 1-4 of this document provide instructions for FEPS. If you do run FEPS from here, you will need to retrieve your results after returning to VSMOKE.



6. The main VSMOKE input screen appears next. FEPS populates the values into the VSMOKE form, as shown on the next page. Illustrated first is the **top** of the VSMOKE form. The default values for background concentration levels of PM_{2.5} and CO are acceptable, although if you know the site-specific information, you can use those values. In this case, the background concentration of PM_{2.5} was set to $10 \,\mu g/m^3$ (as opposed to the default value of 20). The default background concentration for CO of 2 ppm was maintained. When available, you should use the actual atmospheric pressure rather than the pressure at sea level. The Help file for VSMOKE (<u>http://webcam.srs.fs.fed.us/tools/vsmoke/VSMOKE_Interface.pdf</u>) has a table that can be used to approximate atmospheric pressure at varying elevations.

VSMOKE and VSMOKE-GIS Input Values				Ē	
File View Emissions PM Settings Analysis Results	HYSPLIT	Websites	Exit	Help	
Image: Second state Image: Second st	S results are circled.		Number of for VSM0	of isopleths DKE-GIS 5	
Emission and Heat Release Rates	7	otal Sensib	le Heat	\bigcirc	
Acres burned during this hour 129.0	E	Emission Rat	e (megawa	atts) (504.3	
Particulate Matter					
Background concentration (micrograms / cubic meter)	se site-specific	informati	Emission on, if	Rate 773.098	
Carbon Monoxide	avan	able			
Surface Temperature (F)				tion 2	
Atmospheric Pressure 1000 (millibars)		otal Source	Emission	Rate 9024.028	
Meteorology	Click on the table wit	Help mer	u to loca d values.	ite a	

7. Next, the **bottom** view of the VSMOKE input screen is illustrated. This is where you put in your meteorological information, as well as information for plotting the smoke plume in ArcMap. Although the FEPS file populates some of this information, make sure that the values correspond to the selected specific weather forecast. You can also use the Region 8 guidelines to conduct several runs using different meteorological data, and compare their results.

The bottom portion of the VSMOKE form is shown below, with results from the FEPS file highlighted.

Meteorology Transport windspeed 10 Mixing H (miles per hour) above gr	eight (feet 2700 Relative Humidity (%) 48 round level)								
Calculate Stability Class with VSMOKE Time Zone 5 Year (ex. 2004) 2011 Month 12 Day 05 Hour of simulation (enter 14.5 for 2:30 pm) 11 Surface (10 meter) Wind Speed (miles per hour) 0paque Cloud Cover (values between 0 and 10) 0 Cloud Cover Ceiling Height (feet above ground level) 3000									
Inputs used only in VSMOKE-GIS Check if time period is before sunset (daylight) Wind Direction (degrees) 270	Stability Class for 3 (Slightly unstable) VSMOKE-GIS Stability class will be calculated based on the other met data from VSMOKE, so your may need to re								
Status	run the model with the calculated value.								

The weather forecast may not contain "Time Zone", "Opaque Cloud Cover", "Cloud Cover Ceiling Height", and "Stability Class for VSMOKE-GIS".

a. Find the time zone by clicking on the Websites menu. Valid numbers for the continental United States are: Eastern daylight time = 4.0, Eastern Standard Time = 5.0, Central Daylight Time =

5.0, Central Standard Time = 6.0, Mountain Daylight Time = 6.0, Mountain Standard Time =

- 7.0, Pacific Daylight Time = 7.0 and Pacific Standard Time = 8.0
- b. Estimate cloud cover from the forecast; opaque cloud cover is a scale where "0" equals clear, and "10" equals overcast.
- c. A NWS website shows the cloud cover ceiling height linked from the Websites menu.
- d. VSMOKE calculates the stability class, so you can make an educated guess the first time you run the model based on information found in a section of the help files under Estimating Stability Class/Field. This value is <u>only</u> used by VSMOKE-GIS, so you can re-run the model with the value calculated by VSMOKE if different than what was originally entered.
- 8. Fill all fields on the VSMOKE input form, then save the results. Then, click on Analysis, Execute VSMOKE and VSMOKE-GIS to run VSMOKE, as shown below.

🖉 VSMOKE and VSMOKE-GIS I	nput Valı	ues for C	:\vsmkgs\te	st.txt		
File View Emissions PM Settings	Analysis	Results	HYSPLIT	Websites	Exit	Help
28 🖪 🔿 📕 💌	Execut	e VSMOKE	and VSMOKE-G	IS Ctrl+E		
Title [Do not use any commas in t	he title or m	ore than 72	2 characters)		Number of for VSM0	of isopleths IKE-GIS 5
-Emission and Heat Release R Acres burned during this hou	ates ¶ 129.0			Total Sensil Emission Ra	ole Heat ite (megawa	atts) (504.3

9. View results, first in a tabular format, and then in ArcMap if running VSMOKE-GIS. First click on "Results", then "VSMOKE Tabular Results…" as shown below.

🐺 VSMOKE and VSMOKE-GIS Input Val	ues for C	:\vsmkgs\te	st.txt		
File View Emissions PM Settings Analysis	Results	HYSPLIT	Websites	Exit	Help
	VSMOK	E Tabular Resu	ts Ctrl+T		
	VSMOK	E Report,	Ctrl+R		
Title Do not use any commas in the title or m	nore than 72	2 characters)		for VSMC	of isopleths IKE-GIS 5
Emission and Heat Release Rates Acres burned during this hour 129.0			Total Sensil Emission Ra	ble Heat ite (megawa	atts) 504.3

- 10. Results are displayed in a new window that has four separate tabs (Concentrations, Visibility, Plume, and Stability/DI/LVORI).
 - a. The first tab, "Concentrations", shows the predicted downwind concentrations of both $PM_{2.5}$ and CO, color coded in accordance with the Air Quality Index (AQI).

Copy Show	Graph	Close			
Distance from fire	y Plume Stabilit <u> PM2.5</u> (ug/m3) 1 858 26	y, DI, and LVORI	Distance from fire 247 mi	<u>PM2.5</u> (ug/m3) 150.75	<u>CO</u> (ppm)
413 ft	1,605.27	18.76	3.11 mi	137.86	3.25
518 ft 656 ft	1,369.30 1,154.04	16.26 13.99	3.92 mi 4.94 mi	126.38 114.86	3.12
823 ft 1037 ft	967.85 808.60	12.02 10.34	6.21 mi 7.82 mi	102.83 91.03	2.88
0.25 mi	668.37	8.85	9.85 mi	80.12	2.64
0.39 mi	447.89	6.52	15.61 mi	62.06	2.44
0.49 mi 0.62 mi	366.98 301.28	5.67 4.97	19.65 mi 24.74 mi	54.95 48.98	2.37 2.31
0.78 mi 0.98 mi	254 73 224.16	4.48 4.16	31.14 mi 39.21 mi	44.01 39.89	2.25
1.24 mi 1.56 mi	200.09	3.90	49.36 mi 62.14 mi	36,48	2.17
1.96 mi	165.09	3.53			

b. The second tab gives the predicted downwind visibility impacts.

Сору	Show Graph	Close			
Concentrations	/isibility Plume Stab	ility, DI, and LVORI			
Distance from fire 317 ft	<u>Crossplume</u> <u>Visibility</u> (<u>miles)</u> 0.09	<u>Contrast</u> <u>Ratio</u> (<u>miles)</u> 0.00	<u>Distance</u> <u>from fire</u> 2.47 mi	<u>Crossplume</u> <u>Visibility</u> (miles) 15.37	<u>Contrast</u> <u>Ratio</u> (<u>miles)</u> 0.74
422 ft	0.11	0.00	3.11 mi	15.75	0.78
528 ft	0.13	0.00	3.92 mi	15.89	0.81
634 ft	0.15	0.01	4.94 mi	15.91	0.84
845 ft	0.18	0.02	6.21 mi	15.92	0.86
1056 ft	0.21	0.03	7.82 mi	15.92	0.88
0.25 mi	0.26	0.06	9.85 mi	15.92	0.89
0.31 mi	0.34	0.10	12.40 mi	15.92	0.90
0.39 mi	0.59	0.16	15.61 mi	15.92	0.92
0.49 mi	4.65	0.24	19.65 mi	15.92	0.92
0.62 mi	7.79	0.32	24.74 mi	15.92	0.93
0.78 mi	9.91	0.39	31.14 mi	15.95	0.94
0.98 mi	11.59	0.47	39.21 mi	16.06	0.94
1.24 mi	12.91	0.55	49.36 mi	16.29	0.95
1.56 mi	13.95	0.62	62.14 mi	16.63	0.95
1.96 mi	14.76	0.68			

c. The third tab shows calculated plume rise

Сору	Show Gra	oh Cla	ose				
Concentrations	Visibility P	lume Stability, E)l, and LVORI				
Distance from fire 317 ft	<u>Plume</u> <u>Height</u> (feet) 623	<u>Horizontal</u> Dispersion Coefficient (feet) 76	<u>Vertical</u> Dispersion <u>Coefficient</u> (feet) 49	<u>Distance</u> <u>from fire</u> 2.47 mi	<u>Plume</u> <u>Height</u> (feet) 2,700	<u>Horizontal</u> <u>Dispersion</u> <u>Coefficient</u> <u>(feet)</u> 1,732	<u>Vertical</u> <u>Dispersion</u> <u>Coefficient</u> (feet) 1,653
422 ft	726	91	57	3.11 mi	2,700	2,117	2,122
528 ft	847	109	67	3.92 mi	2,700	2,588	2,727
634 ft	987	131	81	4.94 mi	2,700	3,161	3,505
845 ft	1,151	158	98	6.21 mi	2,700	3,859	4,506
1056 ft	1,342	191	119	7.82 mi	2,700	4,708	5,796
0.25 mi	1,564	233	147	9.85 mi	2,700	5,739	7,455
0.31 mi	1,824	283	185	12.40 mi	2,700	6,989	9,592
0.39 mi	2,126	346	233	15.61 mi	2,700	8,504	12,342
0.49 mi	2,479	422	296	19.65 mi	2,700	10,336	15,883
0.62 mi	2,700	516	376	24.74 mi	2,700	12,549	20,441
0.78 mi	2,700	631	480	31.14 mi	2,700	15,218	26,309
0.98 mi	2,700	772	613	39.21 mi	2,700	18,430	33,863
1.24 mi	2,700	945	784	49.36 mi	2,700	22,287	43,588
1.56 mi	2,700	1,157	1,004	62.14 mi	2,700	26,911	56,107
1.96 mi	2,700	1,415	1,288				

d. To view the stability class that was calculated by VSMOKE, click on the last tab, "Stability, DI, and LVORI"; if it is different than what was entered, rerun VSMOKE with the proper stability class in order to display results in VSMOKE-GIS.

Copy Show Graph Close
Concentrations Visibility Plume Stability, DI, and LVORI
Analysis period is during the day
Use Time of Day in VSMOKE-GIS
STABILITY CLASS = 2 (Moderately unstable)
Use Stability in VSMOKE-GIS
Dispersion Index: 23 - fair
Low Visibility Occurrence Risk Index (LVORI): 2 - close to the base line
The base line risk of having low visibility is about 1 in 1000 accidents.

AQI Code	PM _{2.5} Concentration (µg/m ³)	CO Concentration (ppm)	Description
Green	< 39	< 4.5	Good
Yellow	39 - 88	4.5 – 9.4	Moderate
Orange	89-138	9.5 – 12.4	Unhealthy for Sensitive People
Red	139 – 351	12.5 – 15.4	Unhealthy
Purple	352 - 526	15.5 - 30.4	Very Unhealthy
Maroon	527 +	30.5 +	Hazardous

11. Tabular results display, and the draft report created by VSMOKE appears. Click on "Results", then "VSMOKE Report…". The report appears in a separate screen. Click "Edit, Copy" to copy the report and

then paste it into a Word document for editing. Once you have created a report, you can go back to your tabular results and click on the "Copy" button to copy any of the results into the report.

	VSMOKE Report	×
	Edit Close	
l	Copy Op not use any commas in the title or more than 72 characters) Prepared by: Date: 12/15/2011	~
	The smoke dispersion modeling analysis (using VSMOKE and/or VSMOKE-GIS) for this project was performed for 129.0 acres to be burned on 12/05/2011 at the time period of 1100 hours. This time period has daytime dispersion characteristics to disperse the pollutants from the fire. The location of the fire is at approximately 35.339 degrees latitude and -83.346 degrees longitude (459873.536 meters east and 1256928.872 meters north using US Albers projection). The emission rate of PM2.5 (fine particles) this hour was 773.098 grams/second, and carbon monoxide was 9024.028 grams/second. The heat release rate was 504.3 megawatts. Both emission rates and the heat release rates were calculated using the Fire Emission Production Simulator (FEPS) model. The estimated background concentration of fine particles and carbon monoxide of the air carried with the winds into the fire are 20 micrograms/cubic meter and 2 parts per million, respectively. The proportion of the smoke subject to plume rise was -0.75 percent, which means 75 percent of the smoke is being dispersed gradually as it rises to the mixing height, and 25 percent is dispersed at ground level.	i =
	The meteorological conditions used in this model run were:	
	 Mixing height was 2700 feet above ground level (AGL). Transport wind speed, and surface wind speed were 10 and 5.9 miles per hour, respectively. There were no clouds in the sky. Surface temperature was 57.7 degrees Fahrenheit, and the relative humidity was 48 percent. The calculated stability class from VSMOKE was slightly unstable. 	
	The VSMOKE model produces three types of outputs that estimate: a.) The ability of the atmosphere to disperse smoke and the likelihood the smoke will contribute to fog formation, b.) Downwind concentrations of particulate matter and carbon monoxide, and c.) Visibility conditions downwind of the fire.	
	The Dispersion Index (DI) is an estimate of the ability of the atmosphere to disperse smoke to acceptably low average concentrations downwind of one or more fires. This value could represent an	~

12. To view the results in ArcMap, minimize the VSMOKE program so that ArcMap again appears then select the plume button to show the plume.



13. Here is an example of a VSMOKE-GIS plume.



The VSMOKE-GIS plume extends out approximately 30 miles. In this example, observe that AQI Code Orange or worse concentrations are predicted approximately one-quarter to one-third of that distance, or 10 miles from the burn unit.

Running HYSPLIT

Fire Management Officers (FMOs) in Region 8 are using HYSPLIT more often to evaluate smoke dispersion the morning of a planned burn. The R8 Air Resources Team works with HYSPLIT developers at NOAA-Air Resources Laboratory (ARL) to improve the accuracy of HYSPLIT's projection of $PM_{2.5}$ concentrations. The instructions included here are designed to provide FMOs with an easy-to-use method of developing parameters to input into HYSPLIT for each prescribed fire project. Note that ARL requires that proper citations be used in all reports referencing HYSPLIT results; these citations are given at the end of this document.^{1/}

- 1. Use the instructions found on pages 1-4 of this document to obtain your emission and heat release rates using FEPS.
- 2. Create Your HYSPLIT Inputs in the "VSMOKE and HYSPLIT Interface". The interface is configured to not only use the FEPS results to conduct a VSMOKE screening analysis; it will also calculate the user inputs to the HYSPLIT model.
 - a. Open up the "VSMOKE and HYSPLIT Interface" form, either through ArcMap or by the smoke.exe icon (found on your desktop or at c:\vsmkgs) and click on "HYSPSLIT". Enter the coordinates of the burn unit. The following screen appears.



- 3. After you click on the "Calculate HYSPLIT Emissions and Plume Rise for Ready Version", HYSPLIT input values appear, including the total $PM_{2.5}$ emissions in micrograms, the average height of the plume in meters, and the time and duration of the active fire phase in UTC.
- 4. At this point, you can close the "VSMOKE and HYSPLIT Interface."
- 5. Open the HYSPLIT atmospheric dispersion model. You may have an icon for your desktop; otherwise, click on the *Start* menu and find HYSPLIT as shown below.



6. Retrieve today's forecast data for your geographic region (most recent is typically 06 UTC). For most of Region 8, the SE forecast will be appropriate, but some areas in VA will need the NE forecast. Click on "HTTP Data File" to start the download.

2		FTP/HTTP	Processed Forecast Data from	ARL	×
Meteorology	<u>T</u> rajectory	Al Ab re	l data files are deri breviations indicate solution (1 or 3 hr), sigma, s=SS0.7), and	ived from various forecast mod : spatial resolution, temporal , vertical coordinate (P=press forecast duration.	els. ure,
		**	FTP Password:	mpitrolo@hysplit	
ARL Data FTP	rorecast - sys		Meteorolo	gical File Selection	
Convert to ADI	Innorded	m	C gfsf	1-deg 3P +192h (0.7 Gb)	
CONVERT TO ARE ,	Appended		C gfslrf	1-deg 12P +384h (1.3 Gb)	
			C gfs0p5f	0.5 d 3S +84h (2.6 Gb)	
			C namf	12-km 3P +84h (1.6 Gb)	
			C namsf	12-km 1S +48h (2.7 Gb)	
			C namsf.AK	12-km 1S +48h (1.5 Gb)	
			C namsf.HI	2-km 1S +48h (1.4 Gb)	
			C namsf.FW	1-km 1S +36h (2.2 Gb)	
			C namsf.NEtile	12-km 1s +48h (0.3 Gb)	
			C namsf.NWtile	12-km 1s +48h (0.3 Gb)	
			namsf.SEtile	12-km 1s +48h (0.3 Gb)	
			C namsf.SWtile	12-km 1s +48h (0.3 Gb)	
			C namsf00.CONU	S 4-km 1S +6h (2.0 Gb)	
			C namsf06.CONU:	S 4-km 1S +12h (2.0 Gb)	
			C namsf12.CONU	S 4-km 1S +18h (2.0 Gb)	
			C namsf18.CONU:	S 4-km 1S +24h (2.0 Gb)	
			C rapf	20-km 1P +18h (0.2 Gb)	
			Year (YYYY): 2017	Month (MM): 10 Day (DD): 18	1
			Forecast Cycle (UTC): C 00 @ 06 C 12 C 18	
			RAP only Cycle (UTC): C 03 C 09 C 15 C 21	
			Output path: C:/	/hysplit4/working	
		Quit	Help	TP Data File HTTP Dat	ta Para

Be aware that it can take approximately 5 minutes for the data file to download if you directly connect to a USDA Forest Service network and up to 15 minutes if you are using a wireless connection.

7. Retrieve the Setup_FEPS file produced by the HYSPLIT user interface by going to the **Advanced** tab and navigating through the "Configuration Setup" to "Concentration".

_				
	<u>A</u> dvanced	A and	SASEM 4	Climate
-			run da	Chan.
	Configuration Set	tup 🕨	Trajecto	ry

On the next screen press **Retrieve** and then search for the Setup_FEPS file in the "C:\hysplit4\working" directory. Press **OK** when finished and then **Save**.



Be sure to redo this step (retrieving the Setup file) each time the run involves a new FEPS file....browse and select the "Setup_FEPS" file. Do not just assume it is selecting the newest file just because it is showing up in the pathname. The same applies to the next step where you will retrieve a "Control_FEPS" file.

8. Next, setup the HYPLIT run by selecting the "<u>C</u>oncentration" dropdown menu followed by "Setup Run."



- a. **Retrieve** the Control_feps file from the "C:\hysplit4\working" directory.
- b. Check that the HH value for the "Starting Time" is the same as the meteorology file. For example, if you download the hysplit.t06z.namsf.SEtile then the HH value should be set to a value of 6.
- c. Save

Concentration Setup	
Starting time (YY MM DD HH): 09 04 08 5	
The number of starting locations: 4 ====> Setup starting locatio	ns
Total run time (hrs) Direction Top of model (m agl)	
24 © Fwrd O Back 10000.0	
Vertical: © 0:data C 11: 05 C 2:isen C 1:ens C 4:sigma C 5:di	ivg
Add Meteorology Files Clear Selected Files: 1	1
C:/nysplit4/working/	
Pollutant, Deposition and Grids setup	
Quit Help Save as Retrieve Save	

Be sure to redo this step (retrieving the Control file) each time the run involves a new FEPS file....browse and select the "Control_FEPS" file. Do not just assume it is selecting the newest file just because it is showing up in the pathname.

9. Run the HYSPLIT model to predict PM2.5 concentrations. Click on "Concentration, Run Model"



Select "Run Using Setup File" option. The following message may appear; if so, click "Run Using Setup File".

4	Advanced Configu	ation Namelist File Found	!! 🗖 🗖 💌
	SETUP.CFG namelist fi	Le found! Created from the Adv	anced-Configuration Menu.
	Cancel Run	Delete file then Run	Run using SETUP file

Progress of the modeling appears in the Simulation Log. When the run is complete, press Exit to move to the next step.

SIMULATION LOG		
SETUP.CFG		^
Calculation Started Percent complete: Percent complete:	please be patient 4.2 8.3	
Percent complete: 1	2.5	
Percent complete: 1	6.7	
Percent complete: 2 Percent complete: 2	0.8 5.0	
Percent complete: 2 Percent complete: 3	9.2 3.3	
Percent complete: 3 Percent complete: 4	7.5	
Percent complete: 4	5.8	
	Exit	
<		> ~

10. Display the concentration contours. Click on Concentration \rightarrow Display \rightarrow Concentration \rightarrow Concentration

<u>C</u> oncentration		<u>A</u> dvanced										
				🝷 🕜 🛛 🕮 <u>R</u> ead 🖕								
5 Quick Start	•			÷	ab	-	Α	-		: 🔛	1	Pi I
Setup Run		Help	3			•	1		-	•	4	•
Run Model							İ					
Display	•	Concentration	•	Γ	0	lo1	ito	ur	s			

To display hourly results in Google Earth, set up the Concentration Display page as shown below. The UserSet values represent the upper limits of current hourly $PM_{2.5}$ AQI categories. To continue, press the **Execute Display** button. Do not be alarmed when windows on your screen flicker as the display executes – it just means that the display-writing software is working!



If you are interested in creating 24 hour concentrations to compare to the 24 hr PM_{2.5} standard, select "cdump24hr" and enter <u>35:255126000</u> in the space after "User Set" (or, in place of the 34, you can enter the PM_{2.5} level where it plus background = 35). All other settings are as shown for displaying hourly results.

¹EPA has not set an hourly AQI for PM2.5. Values used in this example were taken from: Wildfire Smoke: A Guide for Public Health Officials, Revised July 2008. <u>http://www.arb.ca.gov/smp/progdev/pubeduc/wfgv8.pdf</u>.

- 11. To Display smoke plumes (color-coded by PM_{2.5} concentration) in Google Earth:
 - a. Start Google Earth.
 - b. Open the HYSPLITconc.kmz file found in C:\hysplit4\working" directory. If you want to save the kmz file, then save it using a new file name before you execute another modeling run. Each time you run Hysplit and create a new display the program writes it to the same HYSPLITconc.kmz file name.
 - c. The R8 Air Resource Team recommends that you rename the kmz file using the name of the fire, and save it to a separate folder, such as the folder that contains all other information for that particular burn.
 - d. Remember that you can "play" the results with the time slider bar or advance through the images beginning at midnight and continuing until the end of the modeling simulation (48 hours or less).

Troubleshooting: If the program hangs up or stops responding, exit and start over.

Following the steps outlined above should provide not only the dispersion pattern but also a conservative projection of concentration levels in micrograms per cubic meter, the same parameter upon which that the PM_{2.5} National Ambient Air Quality Standard (NAAQS) is based. Although the air quality standards for PM_{2.5} are on a 24-hour and an annual basis, hourly PM_{2.5} values are used to evaluate health risks using the Air Quality Index (AQI)^{2/}. Below are the AQI levels.

$\begin{array}{c} PM2.5 \ Concentration \\ (\mu g/m^3) \end{array}$	AQI Code	Description			
< 39	Green	Good			
39 - 88	Yellow	Moderate			
89-138	Orange	Unhealthy for Sensitive People			
139 – 351	Red	Unhealthy			
352 - 526	Purple	Very Unhealthy			
> 527	Maroon	Hazardous			

Note that Code Orange or higher values for just a few hours could potentially cause an exceedance of the 24-hour NAAQS, which is currently set at 35 μ g/m³. Therefore, R8 Air Resource Team recommends that FMOs pay attention to the downwind concentration levels if they exceed 88 μ g/m³ as they review the dispersion patterns.

Reminders for FEPS, VSMOKE, and HYSPLIT

- FEPS results are used as inputs to both VSMOKE and HYSPLIT Ready.
- VSMOKE is used during the fire planning process, and can be run multiple times using different meteorology to determine the potential downwind impacts under various weather conditions.
- HYSPLIT Ready is used the day before or day of a prescribed fire to assist in making final Go/No-Go decisions. It uses actual forecast meteorology data to calculate predicted downwind concentrations from the prescribed fire. <u>At this time</u>, R8 Air Resource Team does <u>not recommended that HYSPLIT Ready be used.</u>

• HYSPLIT PC provides more refined predictions of downwind concentrations.

If you have any questions about the use of these smoke modeling tools, please contact the Air Specialist assigned to your forest.

CITATIONS

^{1/} Draxler, R.R. and Rolph, G.D., 2003. HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air Resources Laboratory, Silver Spring, MD.

Rolph, G.D., 2010. Real Time Environmental Applications and Display System (READY) website (<u>http://ready.arl.noaa.gov</u>). NOAA Air Resources Laboratory, Silver Spring, MD.

 $\frac{2}{2}$ The 1-hour PM_{2.5} AQI values are taken from "Wildfire Smoke: A Guide for Public Health Officials", July 2008 revision. <u>http://www.arb.ca.gov/smp/progdev/pubeduc/wfgv8.pdf</u>