Using Smoke Modeling Tools for Prescribed Fire Planning and Implementation

A Quick Set of Instructions

(Revised December 2011)

Fire Management Officers (FMOs) in Region 8 are increasing their use of smoke modeling 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 HYSPLIT.

- FEPS is used to estimate emission and heat release rates from the prescribed fire event. FEPS results are used as inputs to both the VSMOKE and the HYSPLIT models.
- VSMOKE is a simple screening model that is used during the prescribed fire planning process. The FMO enters various meteorological conditions into VSMOKE to simulate certain scenarios and assess the worst-case downwind concentration from the proposed burn.
- HYSPLIT
    - The Ready version of HYSPLIT is a web-based model that uses forecast met data to estimate predicted downwind pollution concentrations. Because HYSPLIT uses forecast met data, it can be used by FMOs to make Go/No Go decisions the day before or the day of the proposed prescribed burn.
    - The PC version of HYSPLIT provides a more refined prediction of downwind concentrations. The Air Resources Team can conduct this modeling for field personnel.

This document will outline the steps necessary to run FEPS, VSMOKE and HYSPLIT. Since both VSMOKE and HYSPLIT use emission and heat release rates from FEPS, instructions for running that program will be presented first. Then, instructions for running VSMOKE for planning purposes will be given starting on page 4. Finally, beginning on page 12, the instructions for running HYSPLIT (both the Ready and the PC versions) will be given.

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

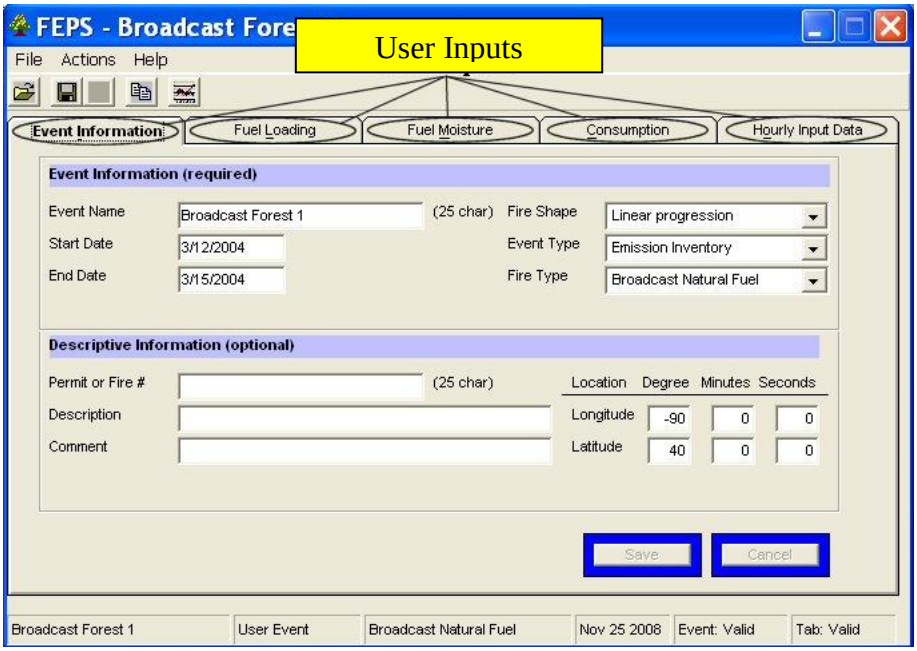
- Bill Jackson (828-257-4815): North Carolina, Cherokee, Francis Marion - Sumter, Savannah River, and Chattahoochee-Oconee, George Washington-Jefferson, Daniel Boone, and Land Between the Lakes
- Judy Logan (501-321-5341) : Ouachita, Ozark-St. Francis, Kisatchie, Texas
- Anthony Matthews (850-523-8520): Florida, Alabama, and Mississippi
- Melanie Pitrolo (828-257-4213): Any Forest
- Daniel Stratton (850-523-8566): Any Forest

Using FEPS to Create Your Emissions and Heat Input Files to be Used in VSMOKE and HYSPLIT

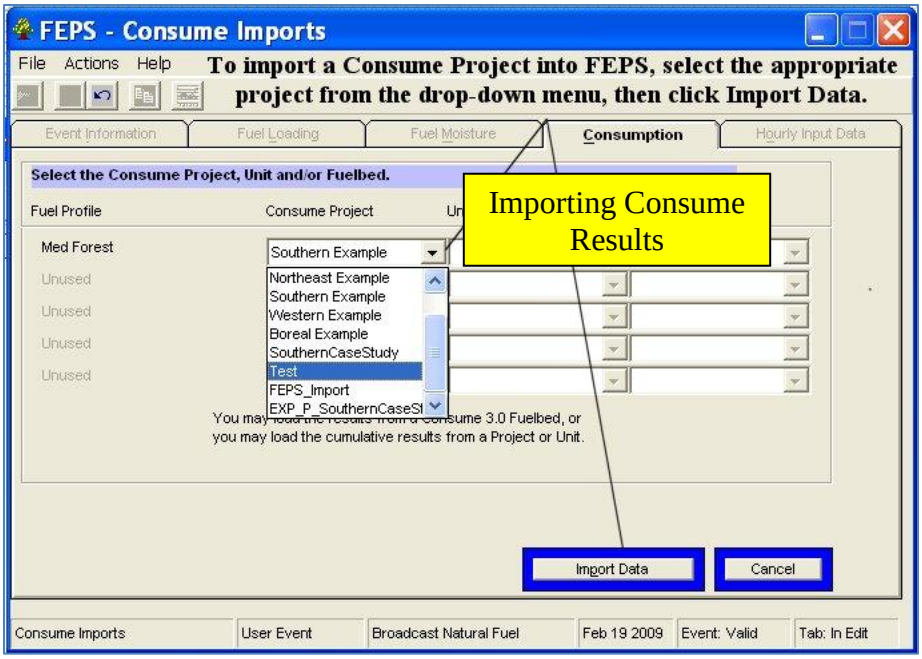
To estimate downwind concentrations resulting from your prescribed fire event, you must first calculate your hourly emission rates and heat release rates from your fire. You do this using the Fire Emissions Production Simulator (FEPS). The paper, "Using FEPS Results as Inputs to Smoke Dispersion Models: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

1. Open FEPS, either from the VSMOKE form or from your 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

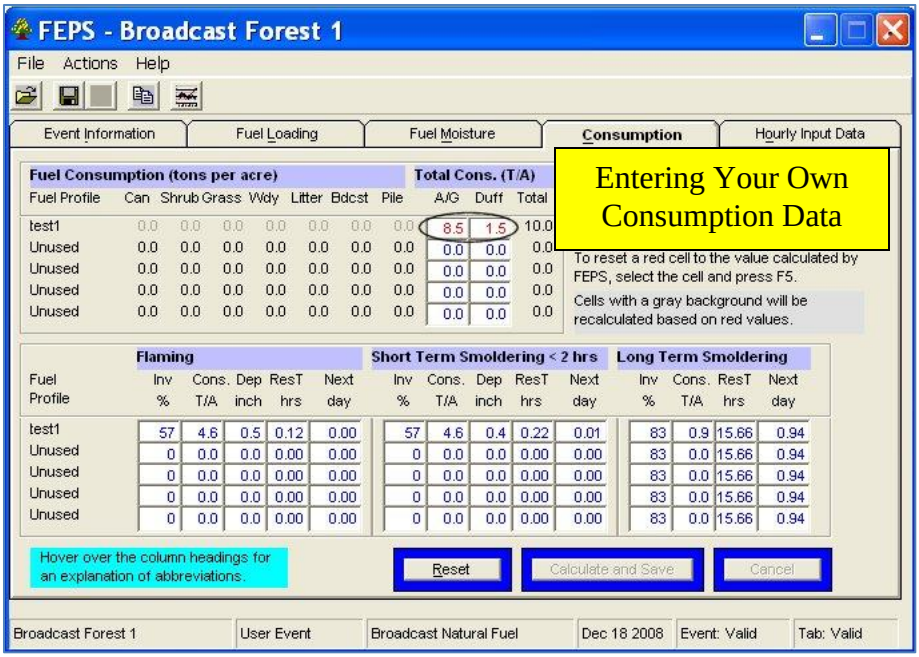
tabs will appear. Enter your event information (start and end date) in the left side of the form, then click save.



2. To obtain consumption information, there are three options. You can have FEPS calculate your consumption, you can import consumption information from the CONSUME software program, or you can directly enter in your consumption based on your best professional judgment.
    a. If you are using FEPS to calculate your consumption, go to the Fuel Loading tab and enter in your fuel profile name and select your fuel bed type. Then, in the Fuel Moisture tab, pick your fuel moisture. In the Consumption tab, select "calculate and save".
    b. If you are not using FEPS to calculate your consumption, go to the Fuel Loading tab, clear out the fuel bed information, and then name your fuel profile. Next, go to the Fuel Moisture tab and set your fuel moisture at "Very Dry". Then go to the Consumption tab to either import or type in your 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 your CONSUME project. Note that the Unit and Fuelbed may be selected as well.

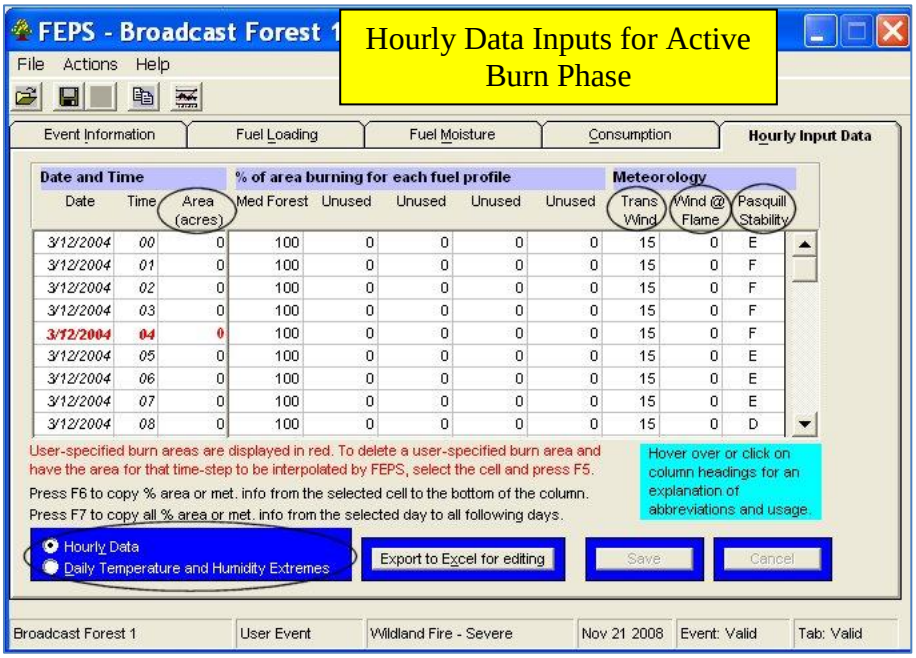


ii. If you know what your consumption will be, either from field measurements or by your best professional judgment, you can manually enter that information into FEPS as shown below.

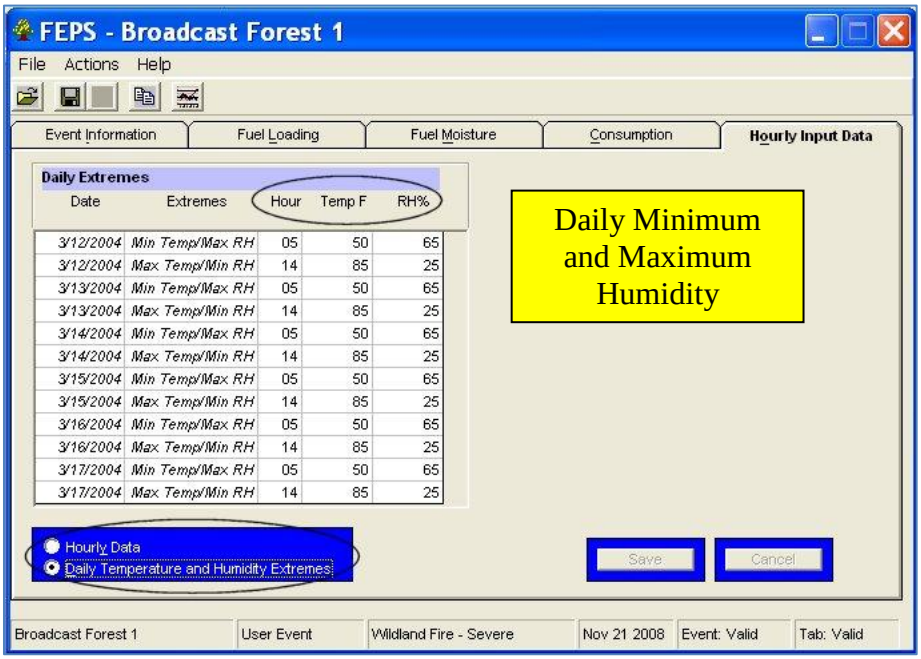


3. After entering your consumption information for your prescribed fire event, go to the Hourly Input Data tab. You will need to enter the hourly meteorology data, along with the fire spread information, for each hour of the active burn phase. There are two views within this tab, the "Hourly Data" and the "Daily Temperature and Humidity Extremes".
   a. Below is the "Hourly Data" view. You must enter in the hourly information for the active burn phase, including the rate of spread of the fire, the transport and mid-flame (not surface) wind speeds, and the stability class. Note that in the absence of site-specific met data, mid-flame wind

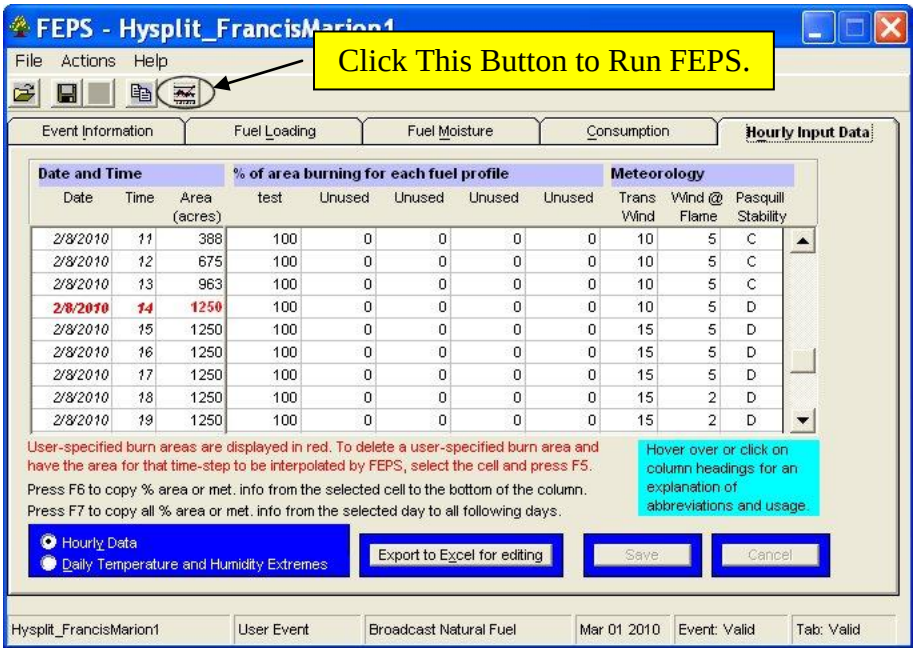
speeds are assumed to be 40% of the surface wind speed values (e.g, a surface wind speed of 5 miles per hour is assumed to have a mid-flame wind speed of 2 miles per hour).



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



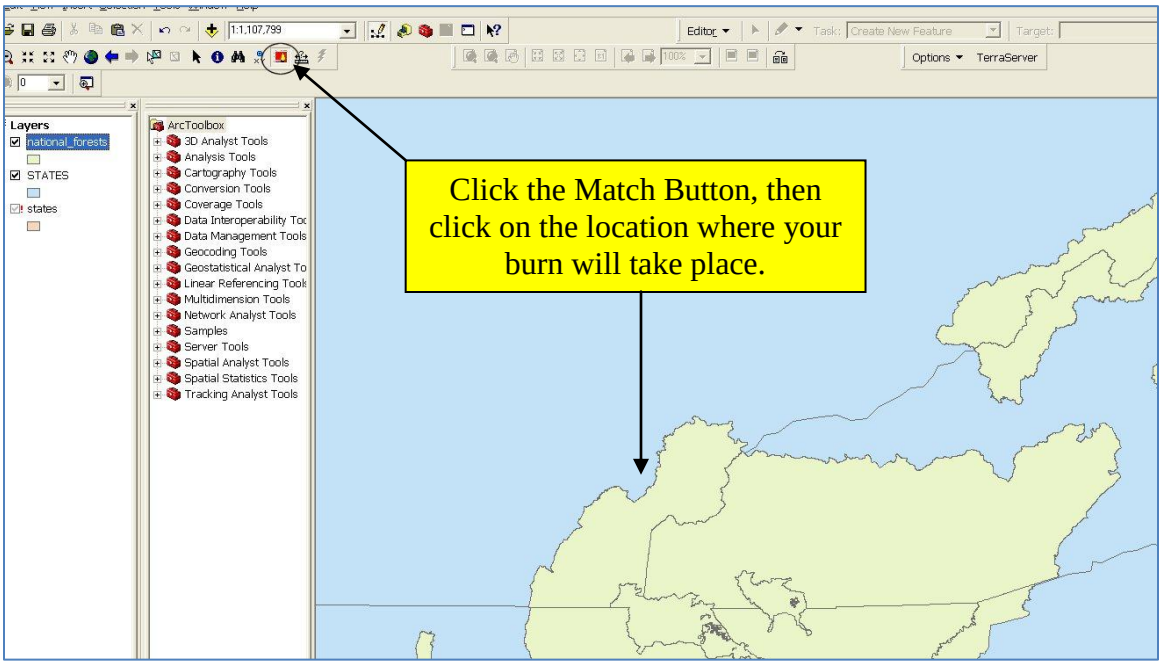
4. Run FEPS by clicking on the button below and to the right of the Help menu. After clicking on this button, you can exit the program. Your results are ready to be used in either VSMOKE or HYSPLIT.



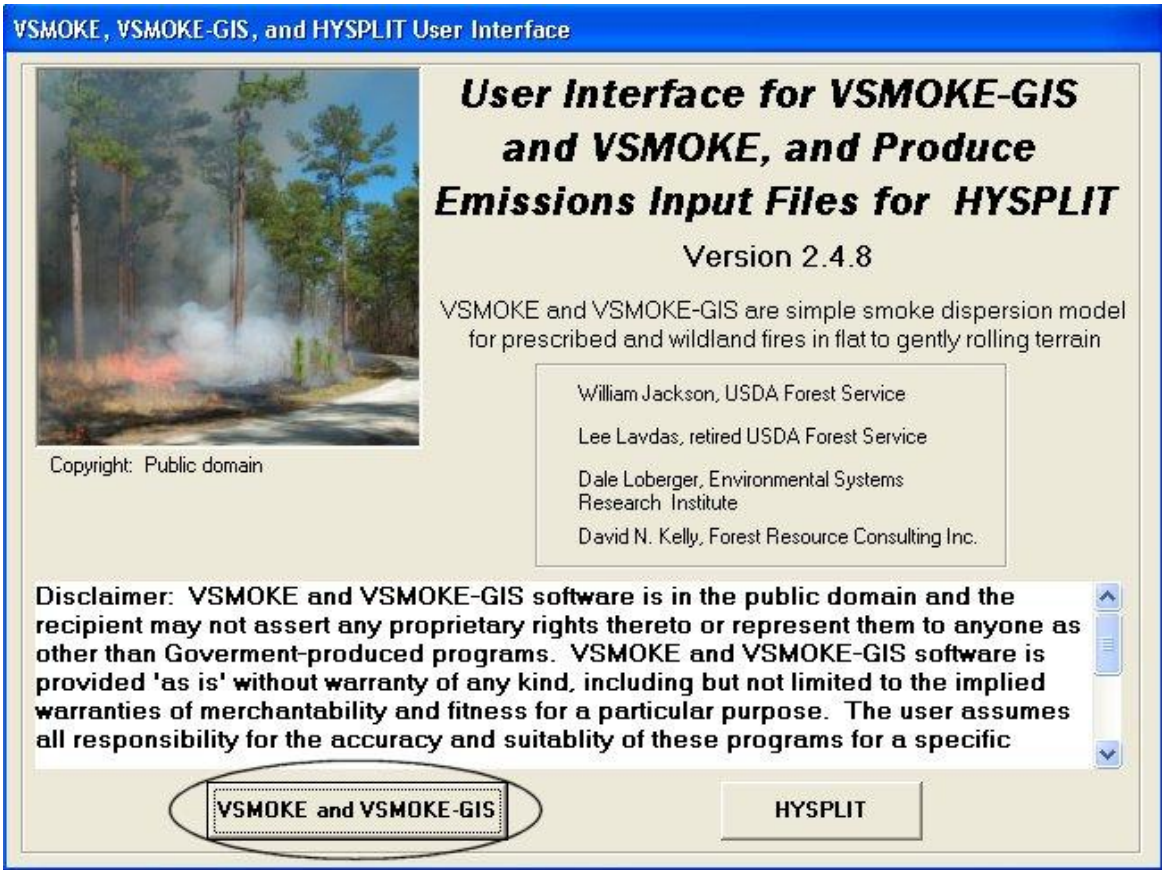
Running VSMOKE or VSMOKE-GIS

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

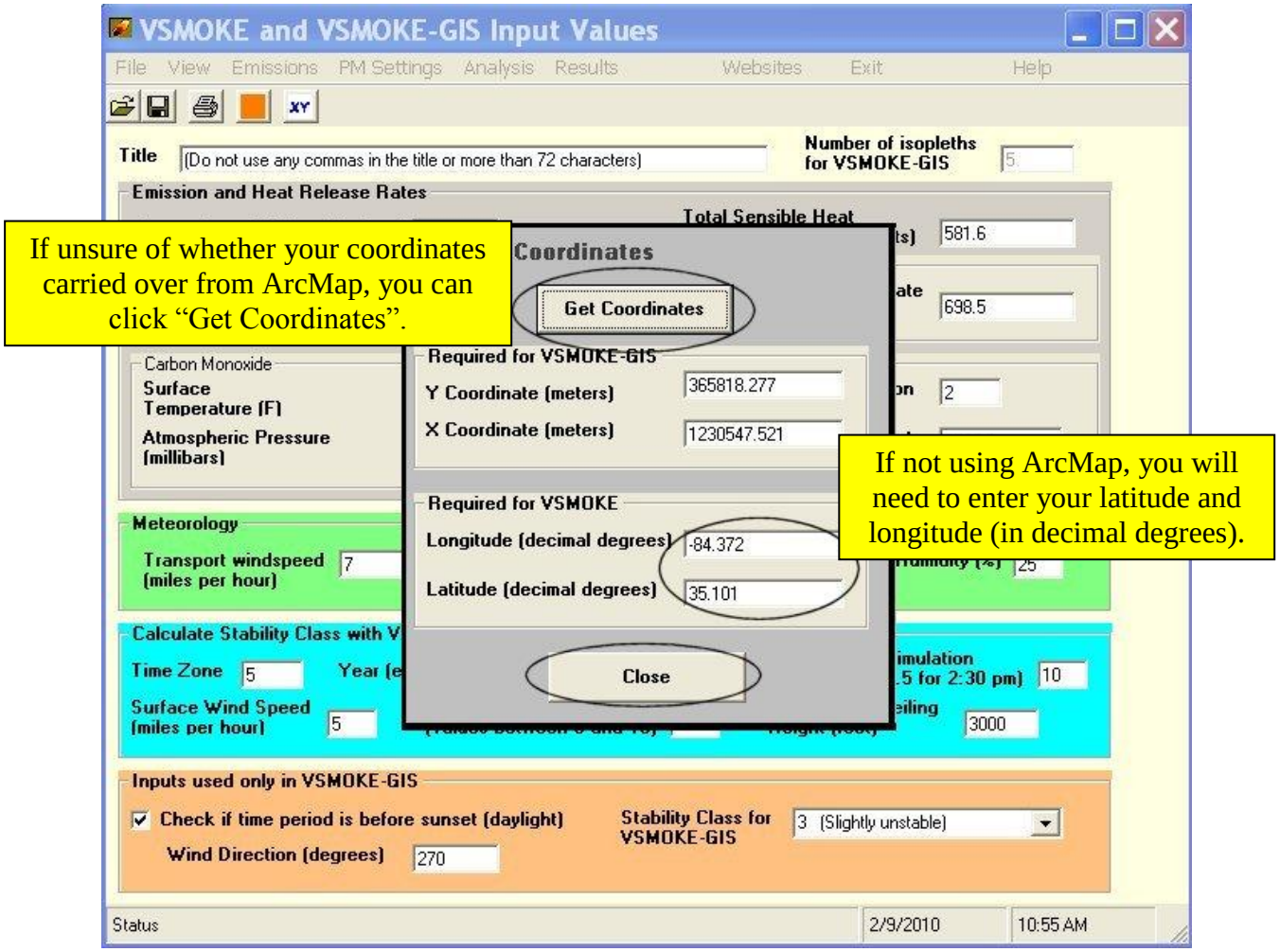
1. Navigate to the c:\vsmkgs folder. Click on the **c:\vsmkgs\vsmoke.mxd** file. This opens the ArcMap project. (It is possible you have an icon on your desktop named **vsmoke.mxd**. If so, simply double click on it to open the ArcMap project.) Once the ArcMap project is open, you can add any layers that you may want in the VSMOKE project, i.e. forest boundary, burn units, etc. At that point, you can click on the match button  as shown on the screen capture on below, and then click on the location on the map where your burn will take place.



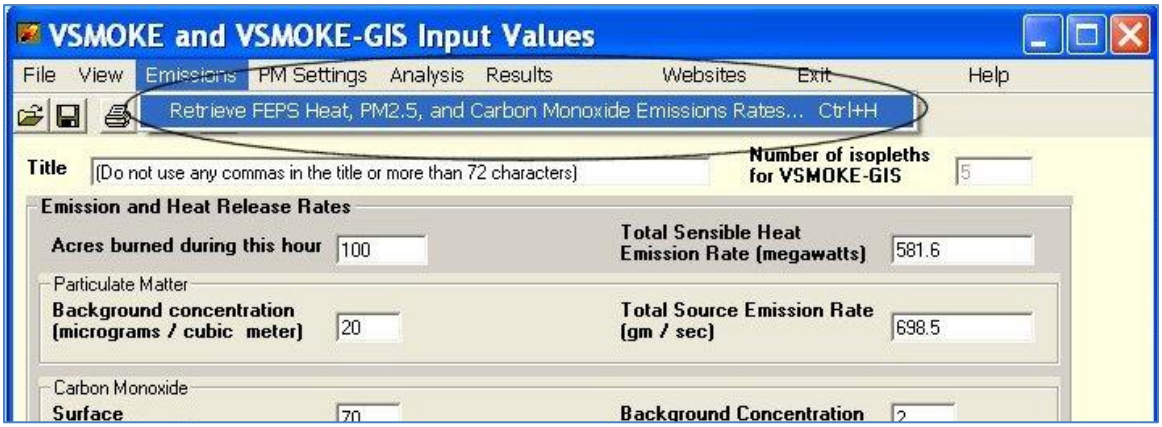
2. After either clicking on the map, or opening VSMOKE from the Windows Start Menu, the VSMOKE dialogue box will open. You will see the screen that is shown below. Click on "VSMOKE and VSMOKE-GIS".



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, you need to enter the latitude and longitude in decimal degrees. Click Close.

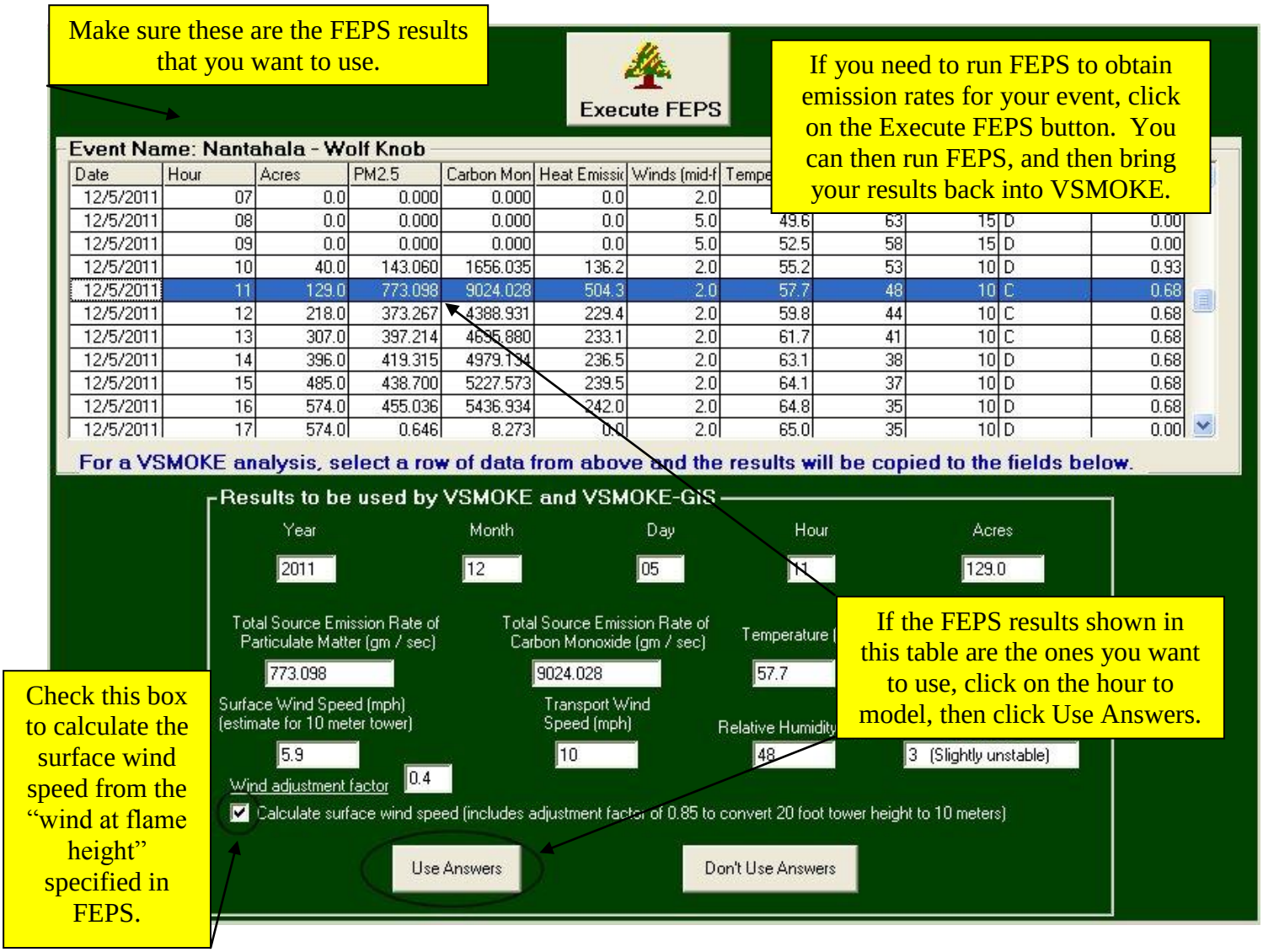


4. The main VSMOKE input screen appears. The first thing that you need to do is retrieve your FEPS results by clicking **Emissions**, then **Retrieve FEPS…Emission Rates**, as shown below.

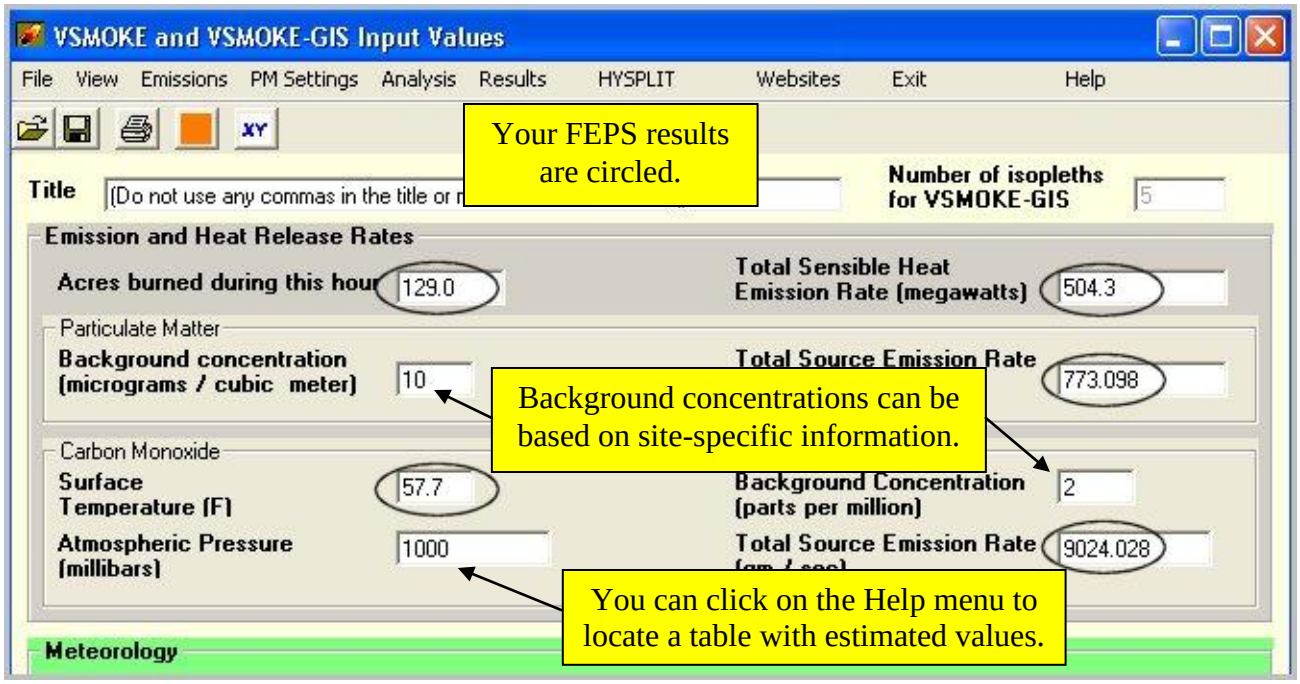


5. The screen shown on the next page appears. The results from your last FEPS run have already been populated in the table. If this is the run you want to use, then simply select the hour that you want to model (typically the hour with the highest $PM_{2.5}$ emission rate), confirm that you want to use those data and press "Use Answers". If you need to do a new FEPS run you can press the "Execute FEPS" button

and it will take you to the FEPS program. Pages 1-4 of this document provide instructions for FEPS. If you do run FEPS from here, you will need to retrieve your results again once back in VSMOKE.

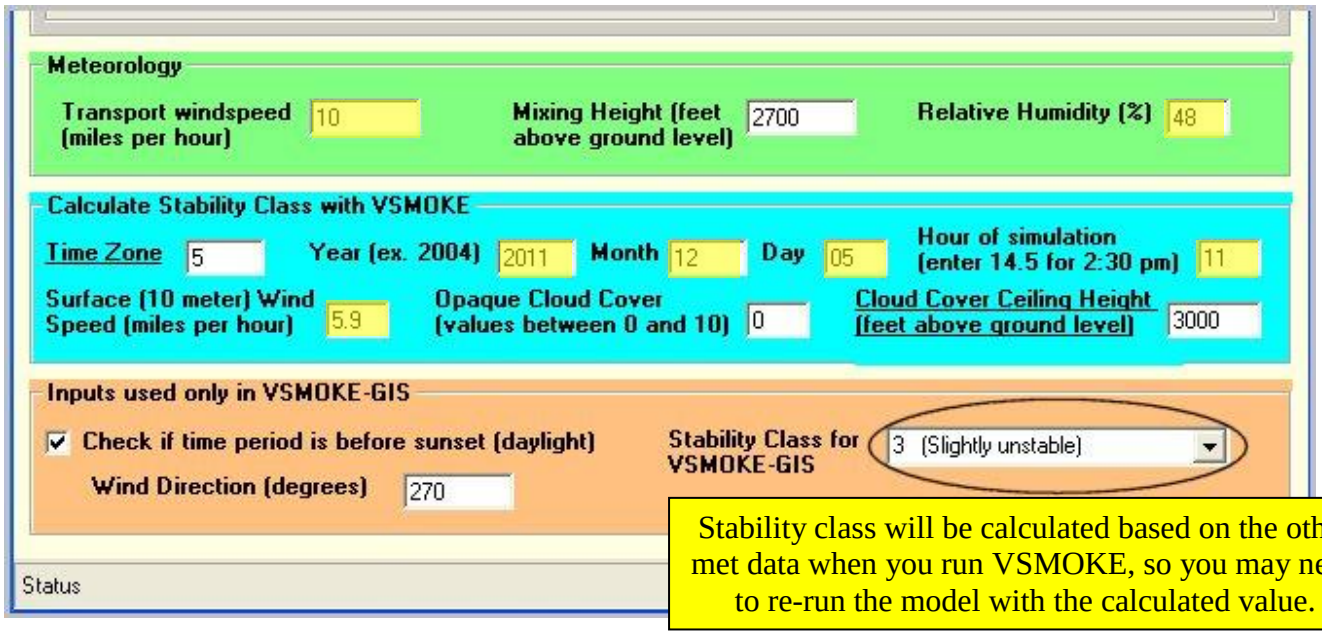


6. You will now be back at the main VSMOKE input screen. The values from FEPS have been populated into the VSMOKE form, as shown on the next page. First is shown the **top** of the VSMOKE form. The default values for background concentration levels of $PM_{2.5}$ and CO are okay to use, although if you 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. There is a table in the Help files that can be used to approximate atmospheric pressure at varying elevations. This table is under Emissions and Heat Release Rates/Atmospheric pressure in the Help files.



7. We will now focus our attention on the **bottom** part of the VSMOKE input screen. This is where you put in your meteorology information, as well as your information for plotting your plume in ArcMap. Although some of this information is populated based on your FEPS file, make sure that the values correspond to the specific weather forecast that you are using. You can also use the Region 8 guidelines to conduct several runs using different meteorology, and compare their results.

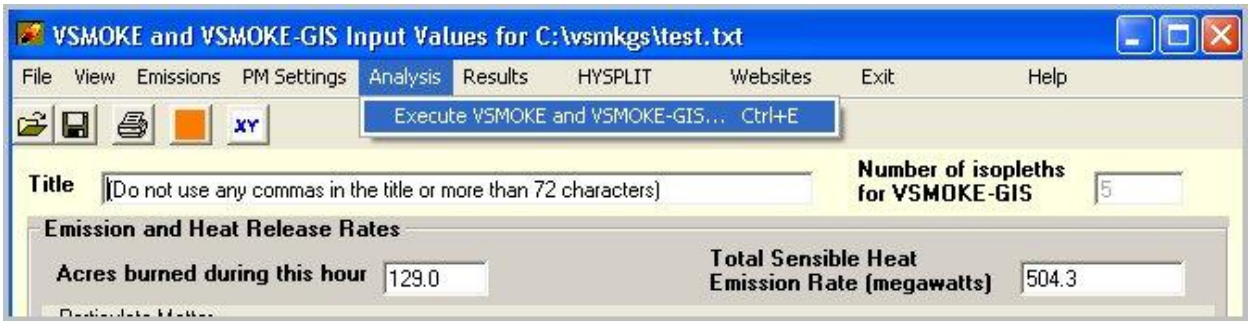
   The bottom portion of the VSMOKE form is shown below, with the results that are brought in from your FEPS file highlighted.



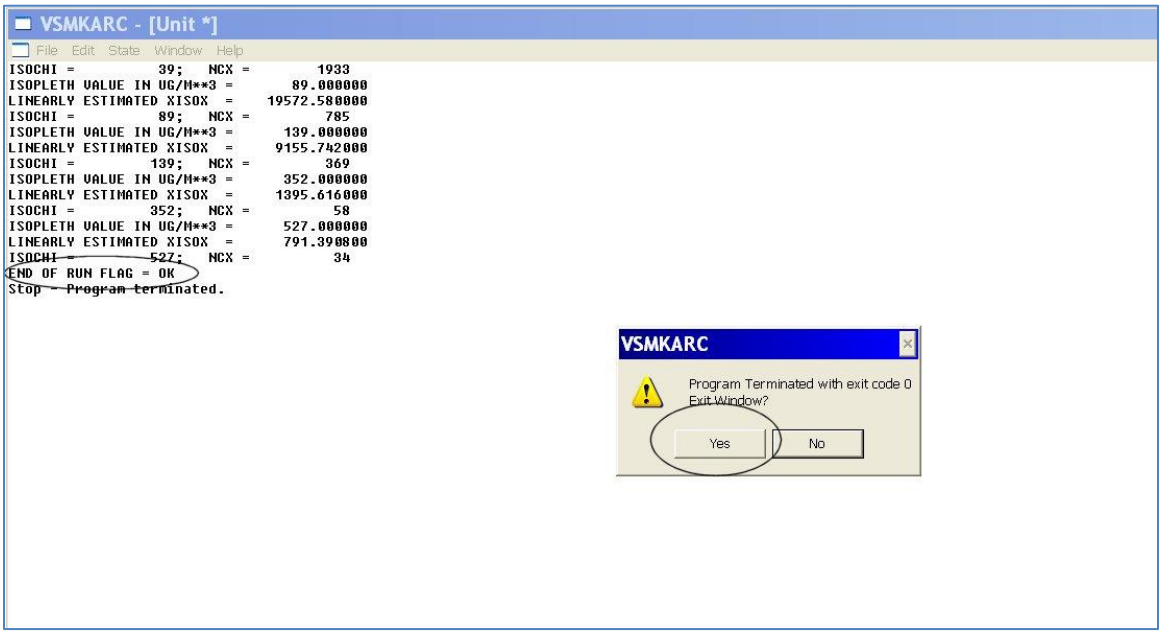
   Some of the values that you may not find on the weather forecast are **"**Time Zone", **"**Opaque Cloud Cover", "Cloud Cover Ceiling Height", and "Stability Class for VSMOKE-GIS".

a. Your time zone can be found 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. Opaque cloud cover is a scale where "0" equals clear, and "10" equals overcast, so you can estimate your cloud cover from your forecast.
c. The cloud cover ceiling height can be found on a NWS website that is linked from the Websites menu.
d. The stability class will be calculated by VSMOKE, 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 only used by VSMOKE-GIS, so you can re-run the model with the value calculated by VSMOKE if different than what was originally entered

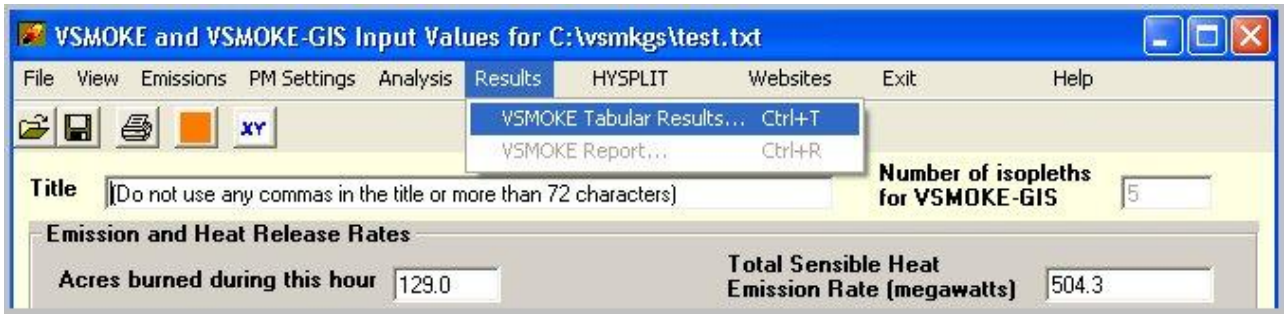
8. After entering all fields on the VSMOKE input form, save your results. Then, click on Analysis → Execute VSMOKE and VSMOKE-GIS… to run VSMOKE, as shown below.



9. When VSMOKE has completed the run, you will see the following screen. Make sure that the "End of Run Flag = OK", then click "Yes" to exit the window. If the run did not execute properly, then you will need to re-run the model.

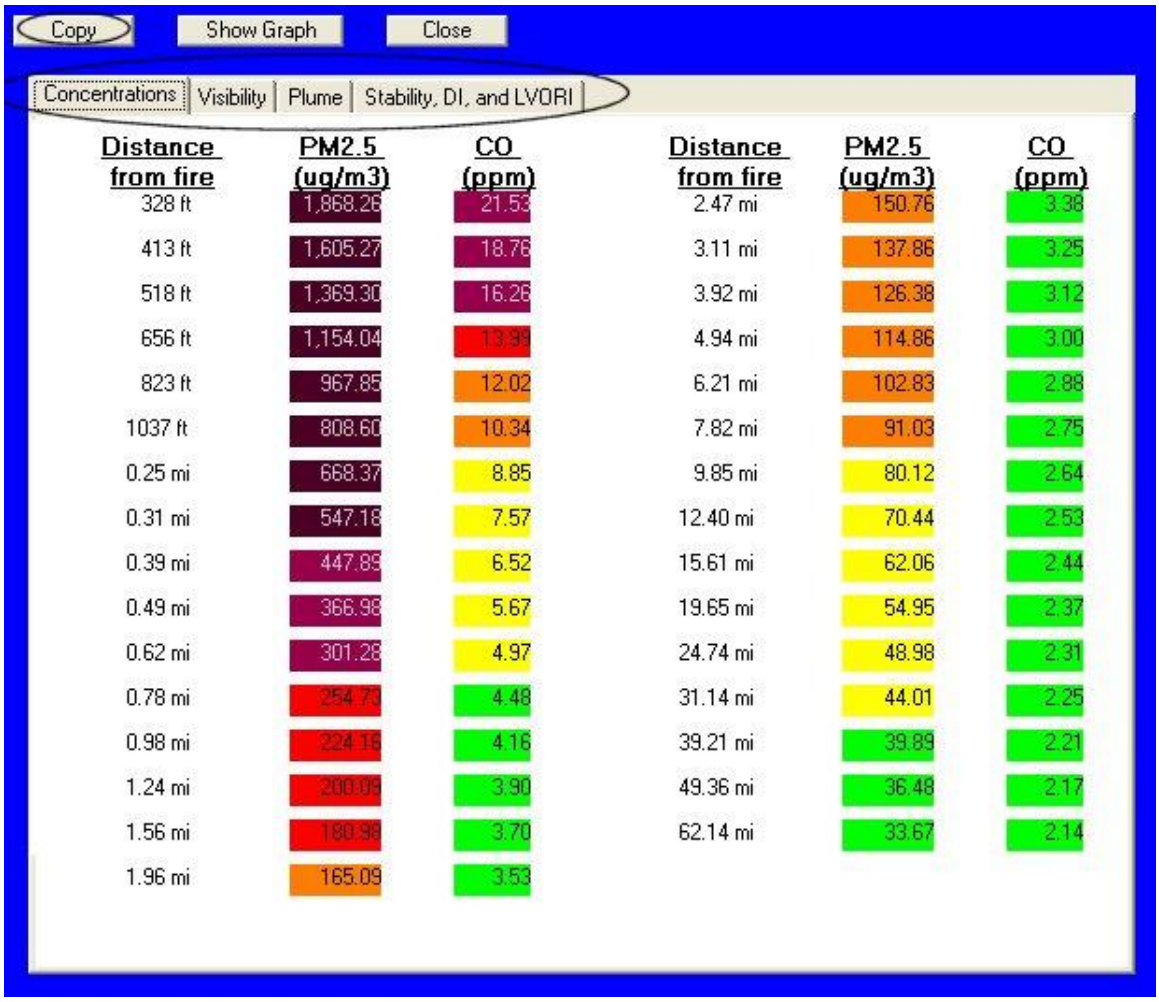


10. You may now view your results, first in a tabular format, and then in ArcMap if you were running VSMOKE-GIS. First click on "Results", then "VSMOKE Tabular Results…" as shown below.



11. Your results will be displayed in a new window that has four separate tabs (Concentrations, Visibility, Plume, 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).



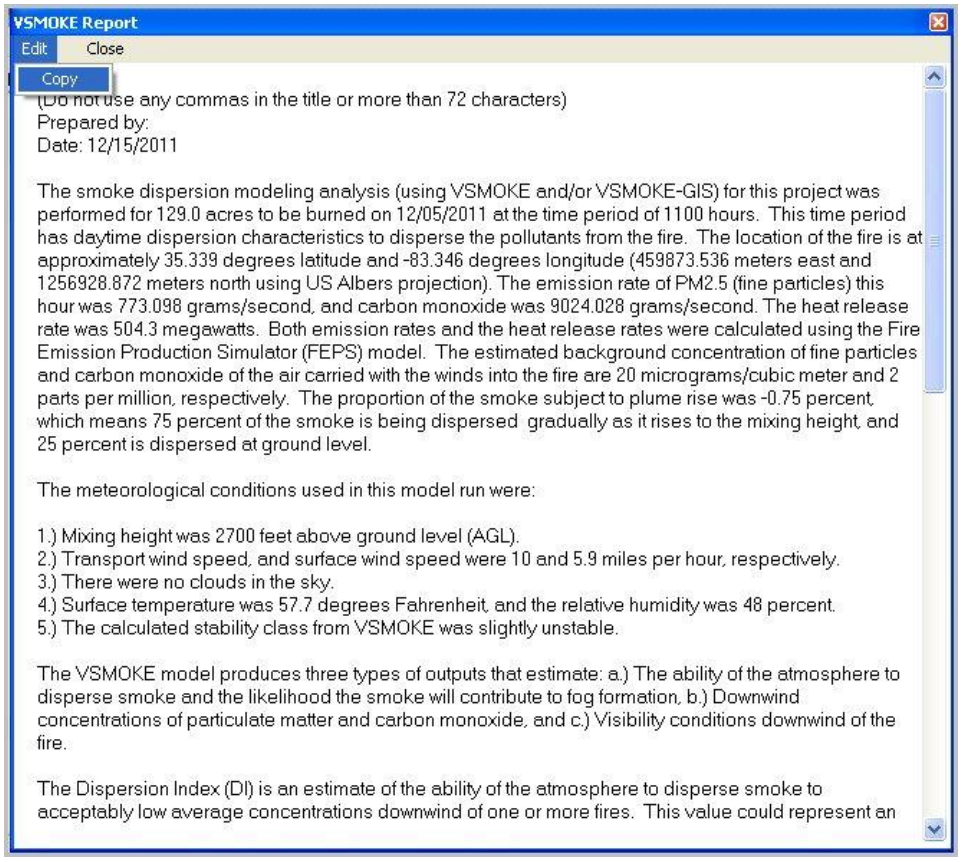
Distance from fire	PM2.5 (ug/m3)	CO (ppm)	Distance from fire	PM2.5 (ug/m3)	CO (ppm)
328 ft	1,868.26	21.53	2.47 mi	150.76	3.38
413 ft	1,605.27	18.76	3.11 mi	137.86	3.25
518 ft	1,369.30	16.26	3.92 mi	126.38	3.12
656 ft	1,154.04	13.99	4.94 mi	114.86	3.00
823 ft	967.85	12.02	6.21 mi	102.83	2.88
1037 ft	808.60	10.34	7.82 mi	91.03	2.75
0.25 mi	668.37	8.85	9.85 mi	80.12	2.64
0.31 mi	547.18	7.57	12.40 mi	70.44	2.53
0.39 mi	447.89	6.52	15.61 mi	62.06	2.44
0.49 mi	366.98	5.67	19.65 mi	54.95	2.37
0.62 mi	301.28	4.97	24.74 mi	48.98	2.31
0.78 mi	254.70	4.48	31.14 mi	44.01	2.25
0.98 mi	224.16	4.16	39.21 mi	39.89	2.21
1.24 mi	200.09	3.90	49.36 mi	36.48	2.17
1.56 mi	180.98	3.70	62.14 mi	33.67	2.14
1.96 mi	165.09	3.53			

AQI Code	*$PM_{2.5}$ Concentration ($\mu g/m^3$)*	*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

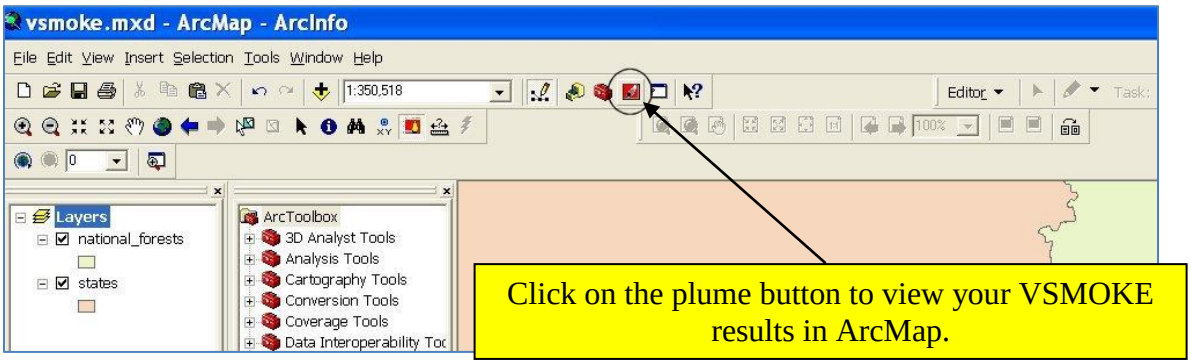
b. The second tab gives the predicted downwind visibility impacts, and the third tab gives the calculated plume rise.

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

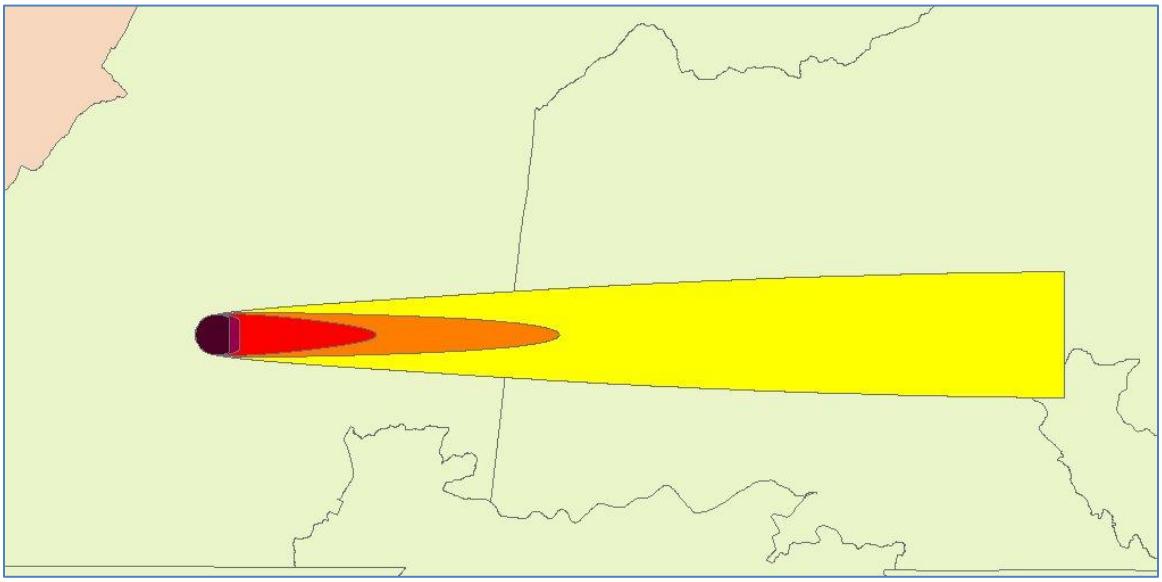
12. Once you view your tabular results, you can view the draft report that VSMOKE has created for this analysis. You click on "Results", then "VSMOKE Report…". The report appears in a separate screen, and you can click "Edit, Copy" to copy the report, and then paste it into a Word document for editing. Once you have created a report, you can go back to your tabular results and click on the "Copy" button to copy any of your results into your report.



13. To view your results in ArcMap, minimize the VSMOKE program so that ArcMap again appears. Select the plume button and the plume will appear on the map.



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



The VSMOKE-GIS plume extends out approximately 30 miles. In this example, you can see that AQI Code Orange or worse concentrations are predicted approximately half that distance, or 15 miles from the burn unit.

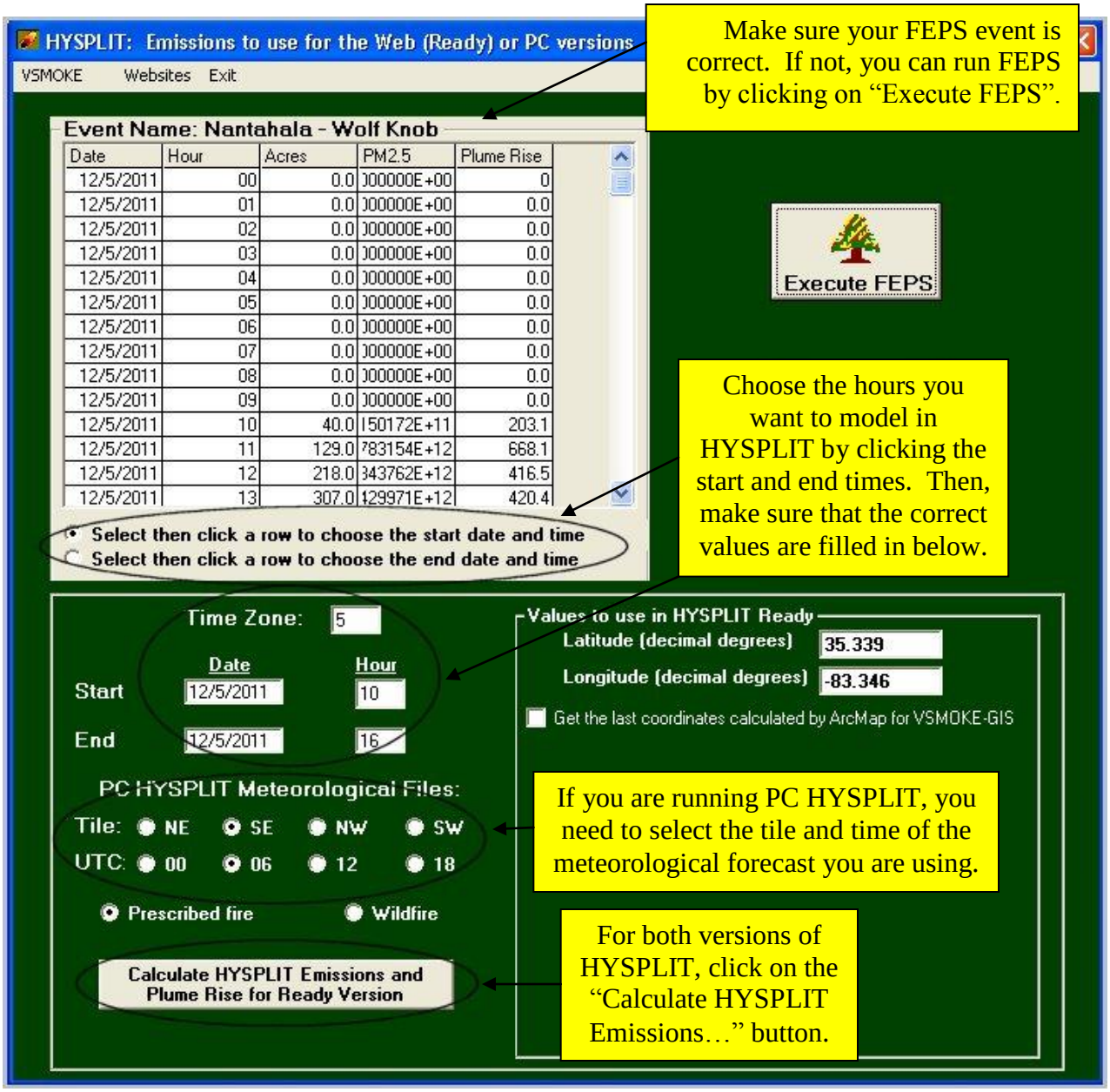
Running HYSPLIT Ready

Fire Management Officers (FMOs) in Region 8 are increasing their use of the READY-WEB version of HYSPLIT to evaluate smoke dispersion the morning of a planned burn. The Air Resources Team has been working 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 burn project. Instructions for running the PC version of the software will be given starting on page 18. 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/]

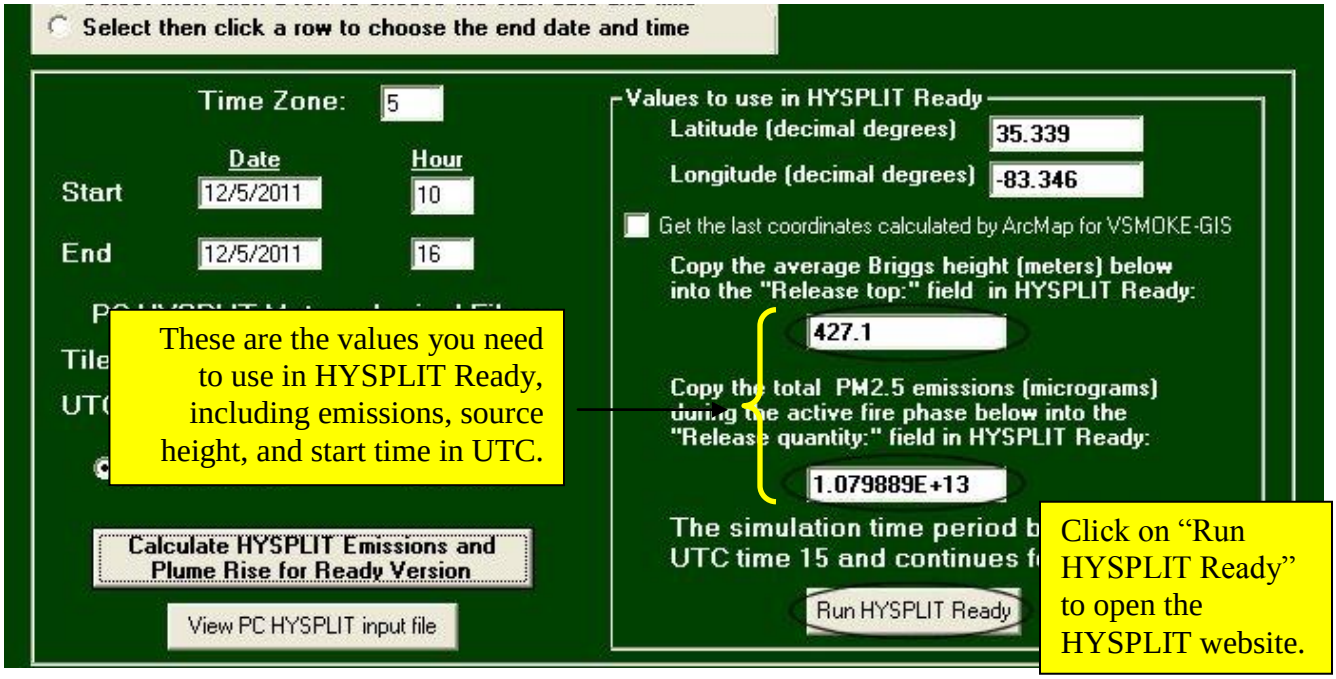
1. Use the instructions found on pages 1-4 of this document to obtain your emission and heat release rates using FEPS.

2. Create Your HYSPLIT Inputs in VSMOKE. VSMOKE has been configured to not only use the FEPS results to conduct a screening analysis, it will also calculate the user inputs to the HYSPLIT model.

    a. You will need to open up the VSMOKE form, either through ArcMap or by the smoke.exe icon (found on your desktop or at c:\vsmkgs) and click on "HYSPSLIT". You will then enter the coordinates of the burn unit. The following screen will appear.

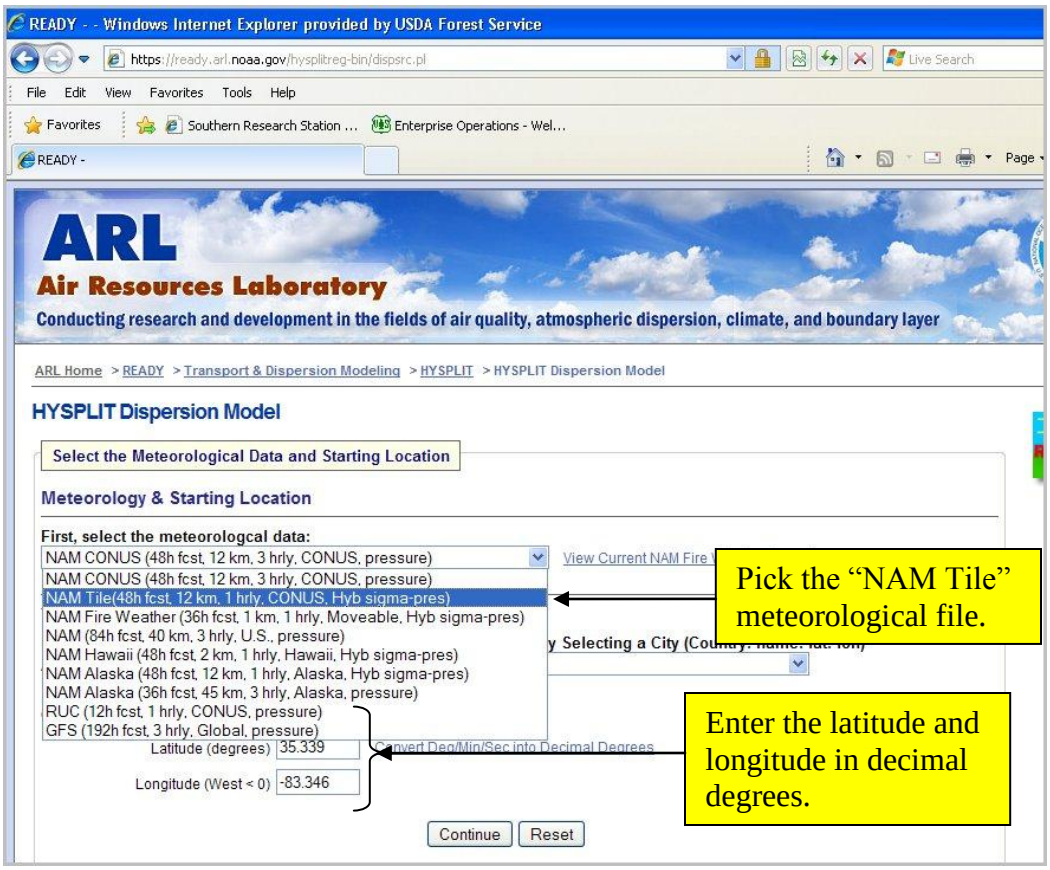


3. Once you click on the "Calculate HYSPLIT Emissions and Plume Rise for Ready Version", you will see the input values for HYSPLIT, including the total $PM_{2.5}$ emissions in micrograms, the average height of the plume in meters, and the time and duration of the active fire phase in UTC.

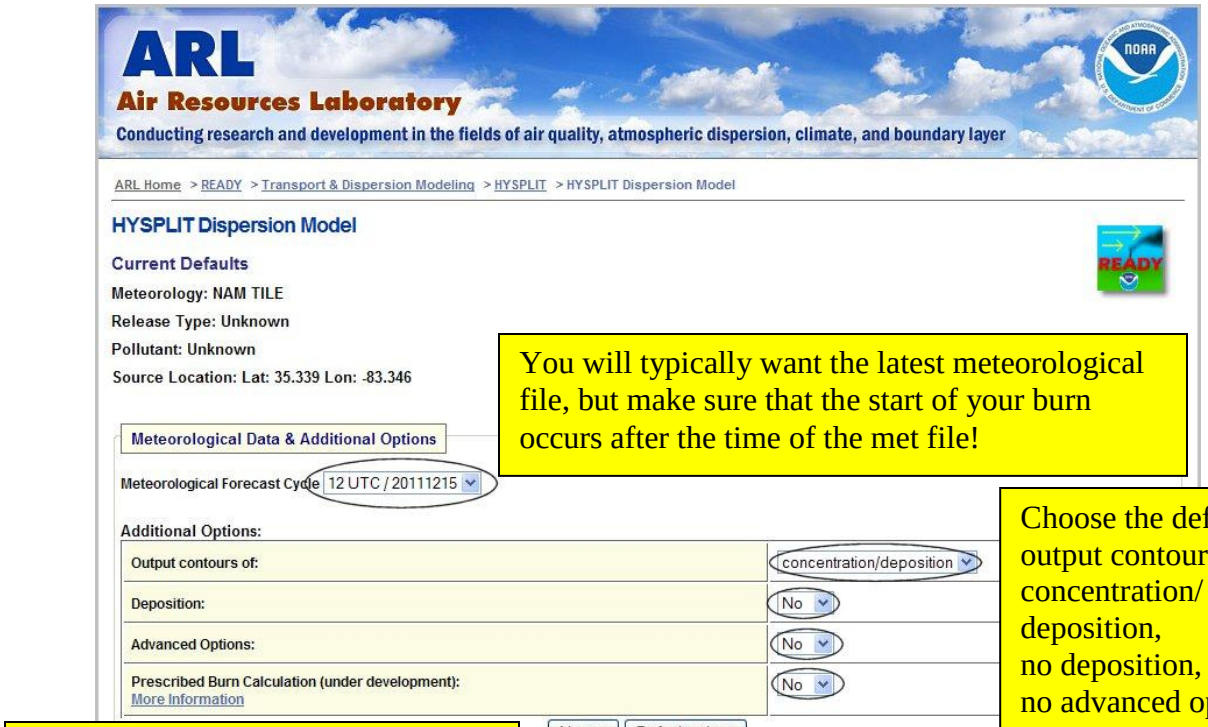


4. At this point, you can close VSMOKE. Make sure you write down the user inputs! Alternatively, you can keep the form open and copy/paste the values into HYSPLIT.

5. After opening up the HYSPLIT Ready website (http://ready.arl.noaa.gov/HYSPLIT.php), log in to your HYSPLIT account and request a forecast dispersion run. On the first screen, select the correct meteorological file (NAM Tile) and input your correct latitude and longitude.



6. On the next screen, use all of the default values.

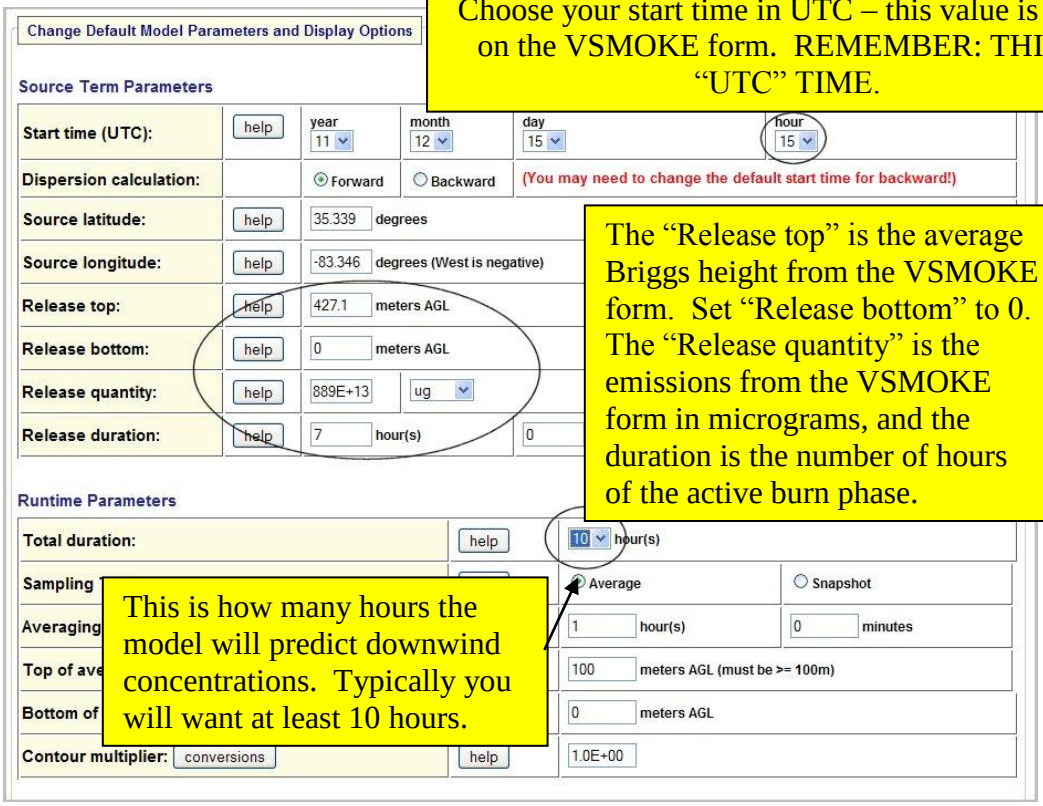


You will typically want the latest meteorological file, but make sure that the start of your burn occurs after the time of the met file!

Choose the defaults: output contours of concentration/ deposition, no deposition, no advanced options, and no prescribed burn calculation.

We are not currently recommending the prescribed burn calculator.

7. On the next screen, you will input the specific information about your burn. Below is the user inputs part of the screen.



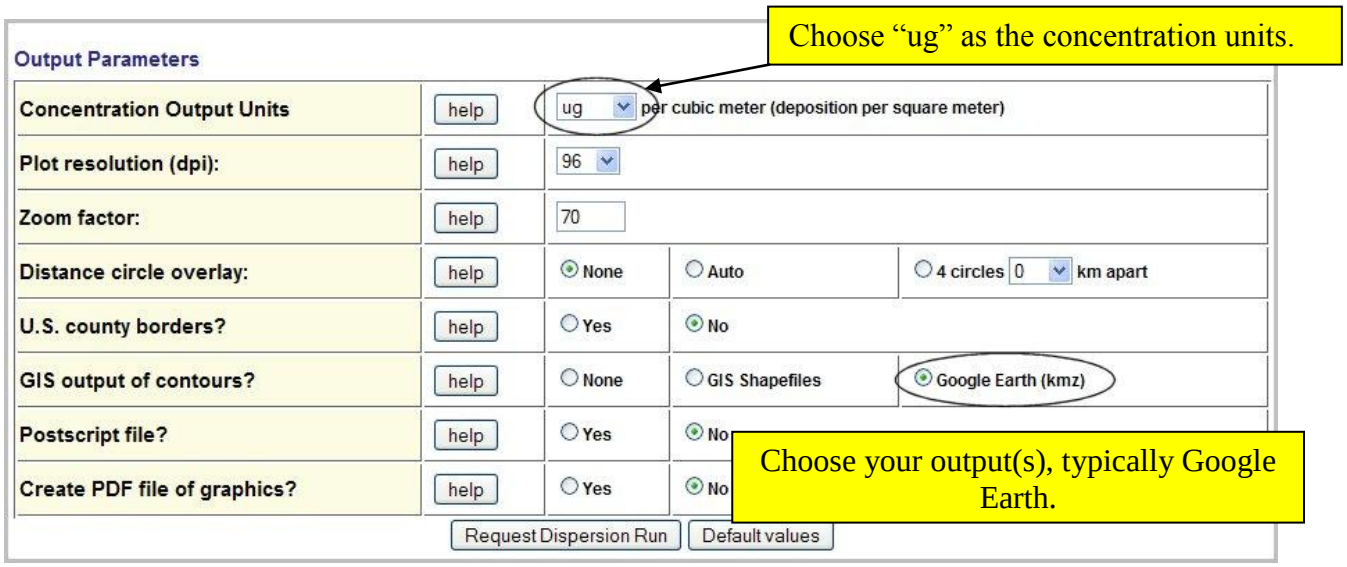
Choose your start time in UTC – this value is given on the VSMOKE form. REMEMBER: THIS IS "UTC" TIME.

The "Release top" is the average Briggs height from the VSMOKE form. Set "Release bottom" to 0. The "Release quantity" is the emissions from the VSMOKE form in micrograms, and the duration is the number of hours of the active burn phase.

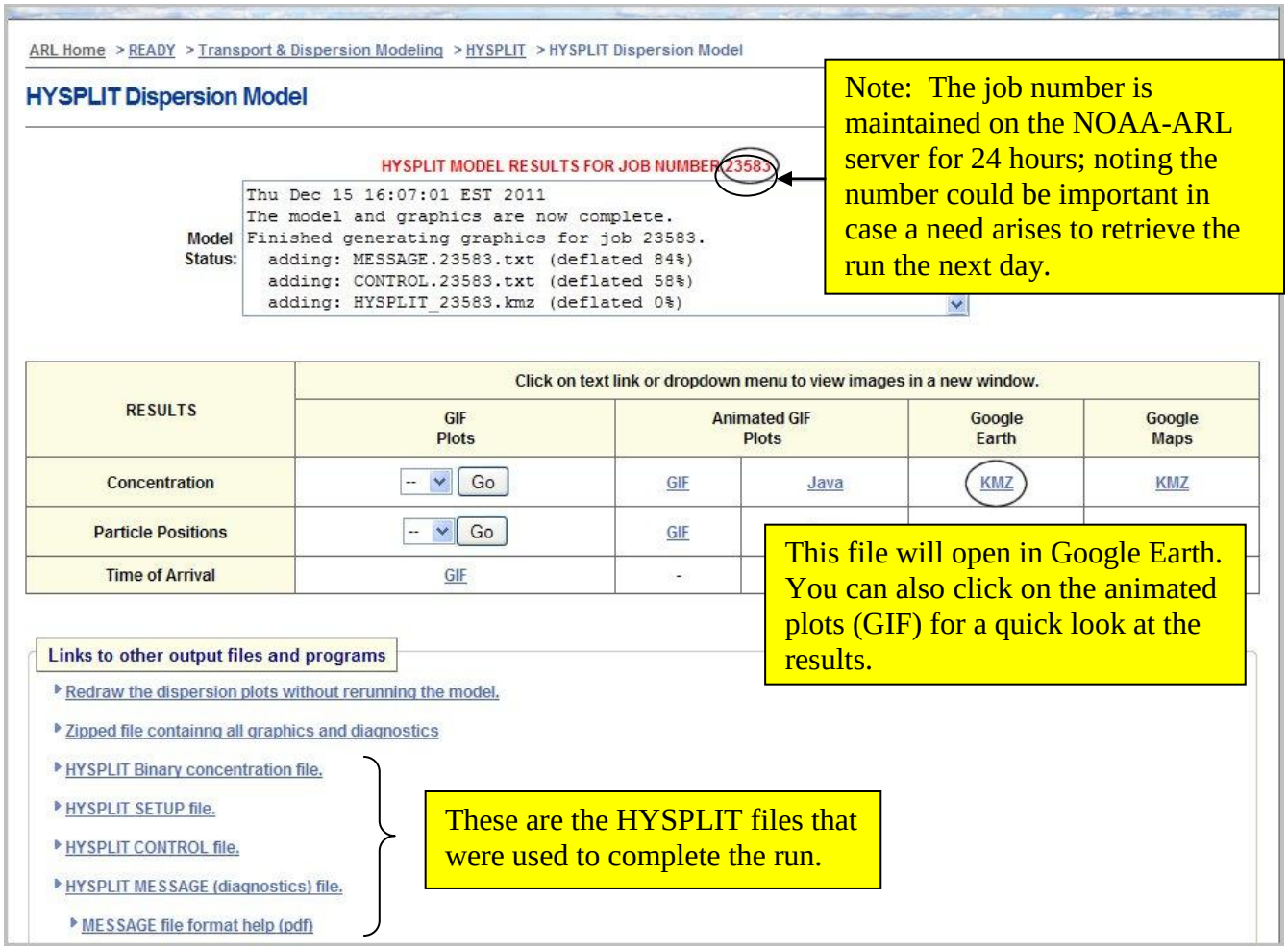
This is how many hours the model will predict downwind concentrations. Typically you will want at least 10 hours.

You can use all of the other default values as shown.

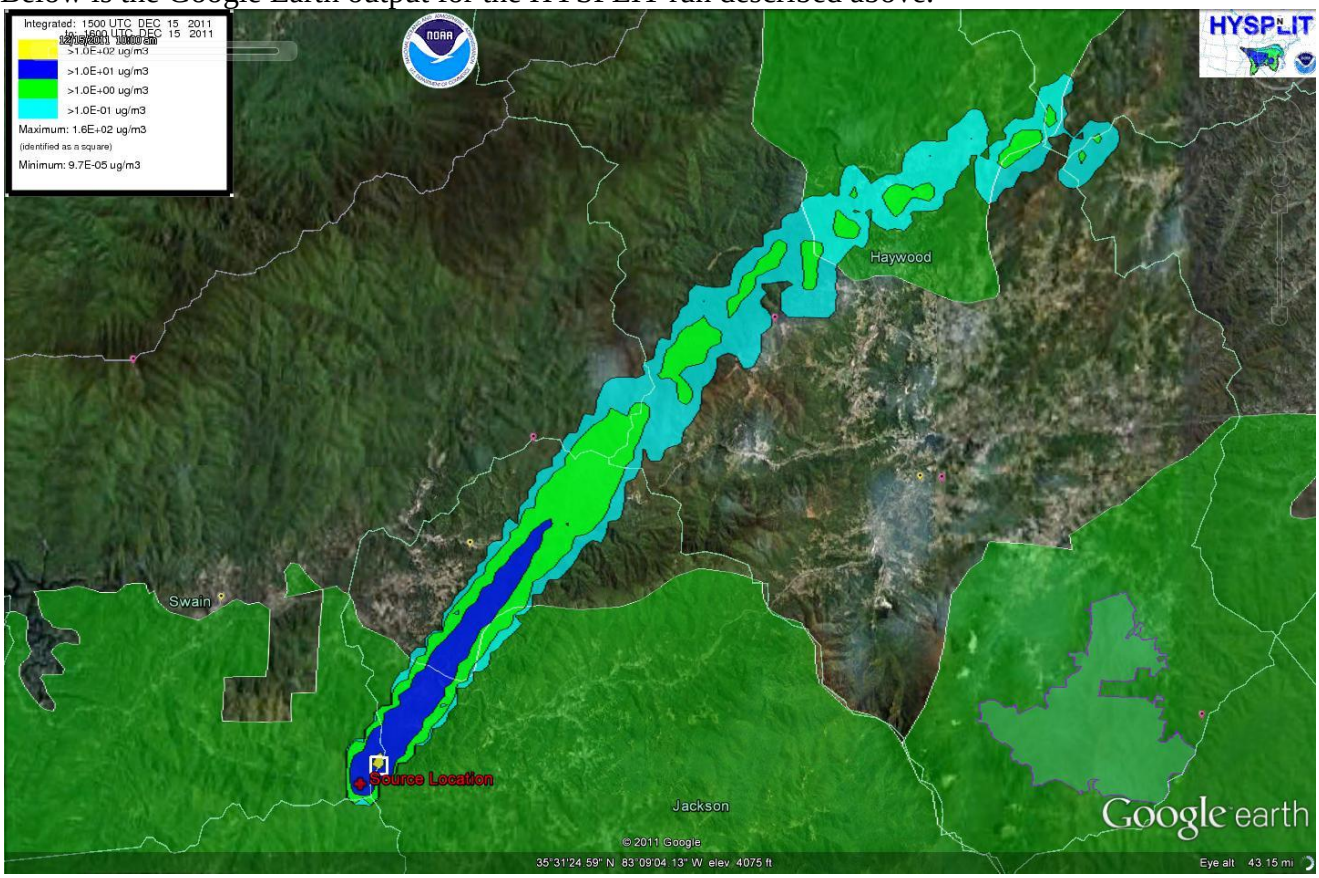
Here is the output options part of the screen.



8. Click on "Request Dispersion Run", and once the modeling run is complete you can click on the output files to view your results.



9. Below is the Google Earth output for the HYSPLIT run described above.



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.

PM2.5 Concentration ($\mu g/m^3$)	***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

In the Google Earth graphic above, the yellow areas close to the source depict where predicted hourly concentrations are greater than or equal to 100 µg/m^3, approximately equivalent to an AQI code of orange. The dark blue, green, and light blue areas show hourly concentrations are predicted to be equivalent to AQI codes of yellow and green. The maximum predicted downwind concentration (shown in the white squares) is 160 µg/m3 (1.6 E+02 µg/m^3); this value is code green and downwind concentrations are predicted to be good.

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 µg/m^3. Therefore, we recommend that FMOs pay attention to the downwind concentration levels if they exceed 88 µg/m^3 as they review the dispersion patterns.

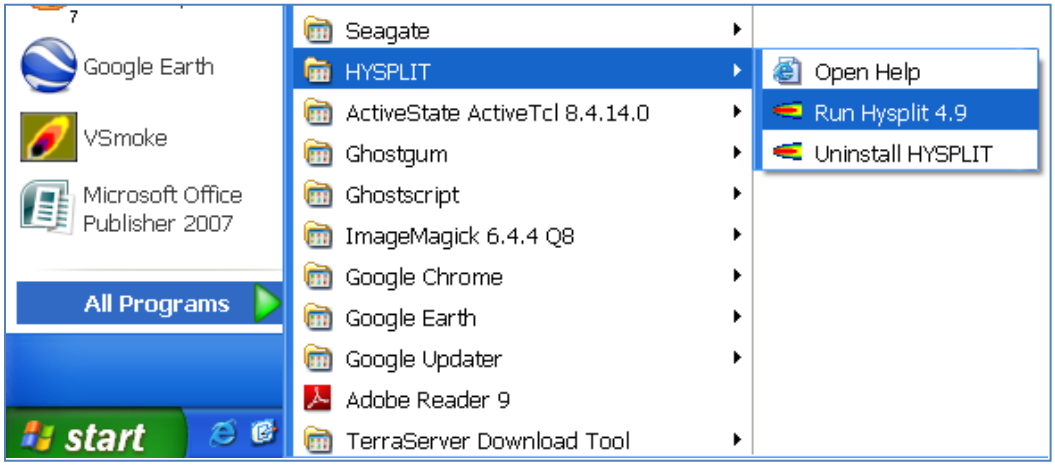
Running HYSPLIT PC

Below is a set of simple instructions for running the PC version of the HYSPLIT software. Typically, a member of the Air Resources Team will run this more refined model for larger or more complicated prescribed fire events. 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.

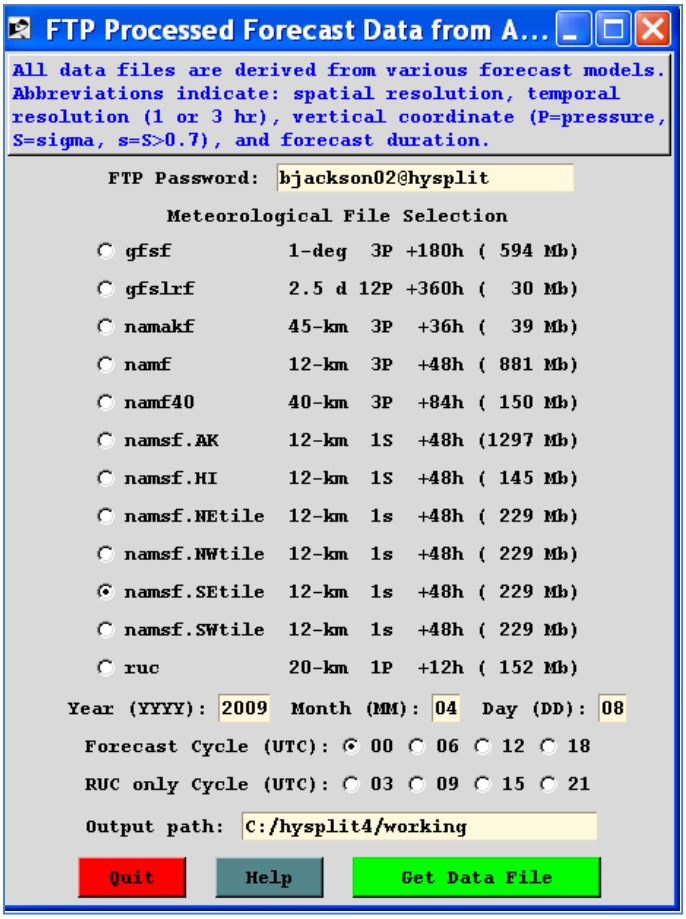
2. Use the instructions found on pages 12-13 of this document to create your input files for HYSPLIT PC.

3. Open the HYSPLIT atmospheric dispersion model. You may have an icon  on your desktop; otherwise, click on the *Start* menu and find HYSPLIT as shown below.



4. Retrieve today's forecast data for your geographic region starting at midnight (00). For most of Region 8 the SE forecast will be appropriate, but some areas in VA will need the NE forecast.

The screen should look something like this before you press the Get Data File button

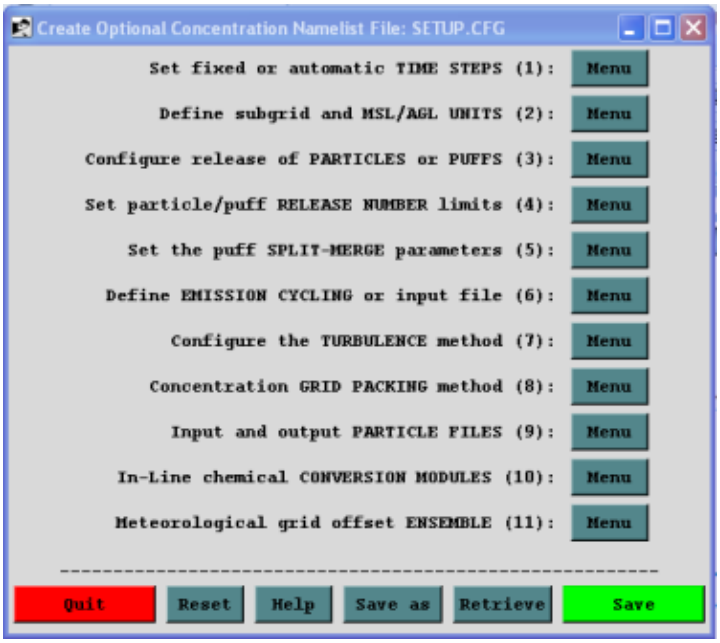


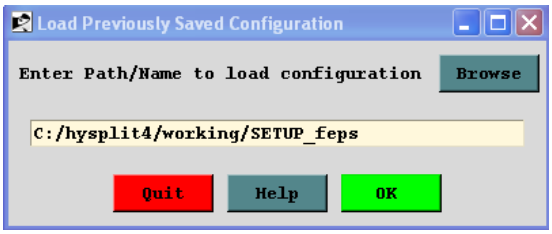
Be aware that it can take approximately15 minutes for the data file to download if you are directly connected to a Forest Service network, and up to 40 minutes if you are using a wireless connection.

5. 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".

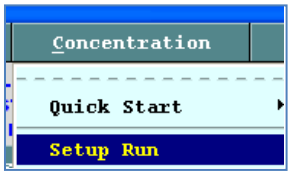
On the next screen press **Retrieve** and then search for the Setup_FEPS file in the "C:\hysplit4\working" directory. Press **OK** when finished and then **Save**.

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.

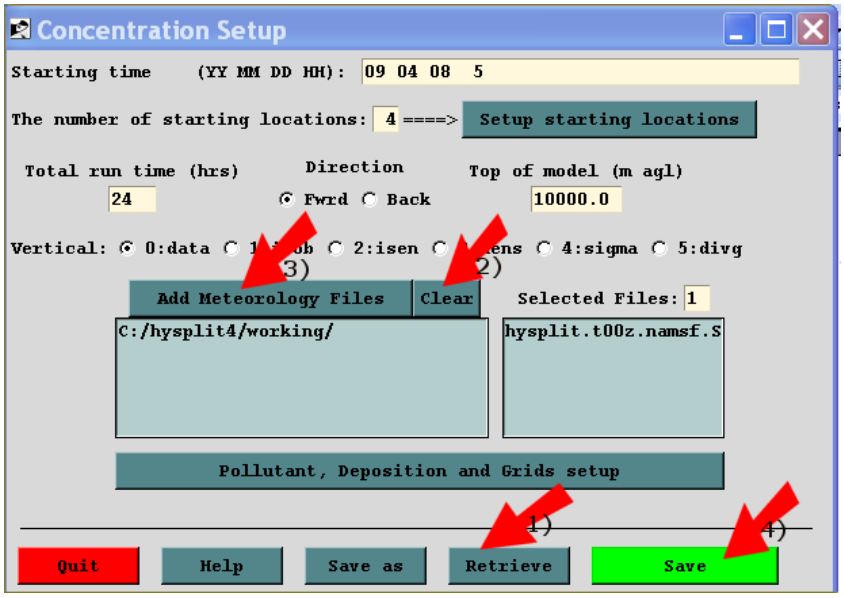




6. Next, setup the HYPLIT run by selecting the "Concentration" dropdown menu followed by "Setup Run."

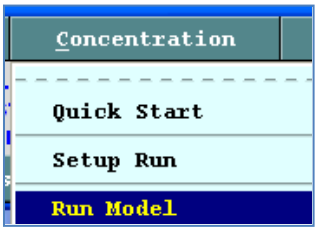


   a. **Retrieve** the Control_feps file from the "C:\hysplit4\working" directory.
   b. **Clear** the meteorological files.
   c. **Add Meteorology Files**: hysplit.t00z.namsf.SEtile
   d. Make sure the HH value for the "Starting Time" is the same as the meteorology file. For example, if you download the hysplit.t06z.namsf.SEtile then the HH value should be set to a value of 6.
   e. Save

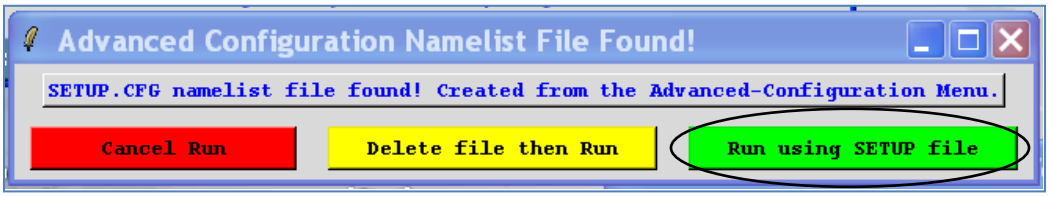


Be sure to redo this step (retrieving the Control file) each time the run involves a new FEPS file….browse and select the "Control_FEPS" file. Do not just assume it is selecting the newest file just because it is showing up in the pathname.

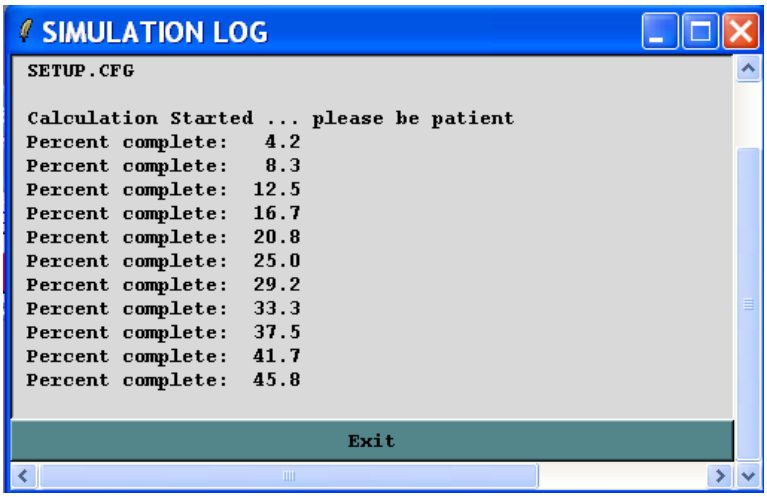
7. Run the HYSPLIT model to predict PM2.5 concentrations. Click on "Concentration, Run Model"



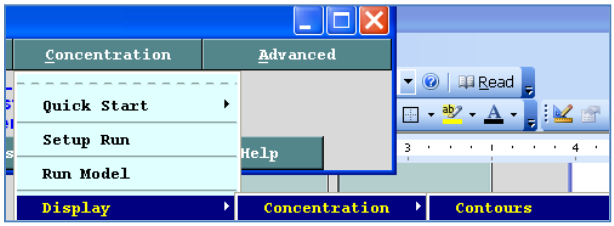
Select "Run Using Setup File" option. The following message may appear; if so click "Run Using Setup File".



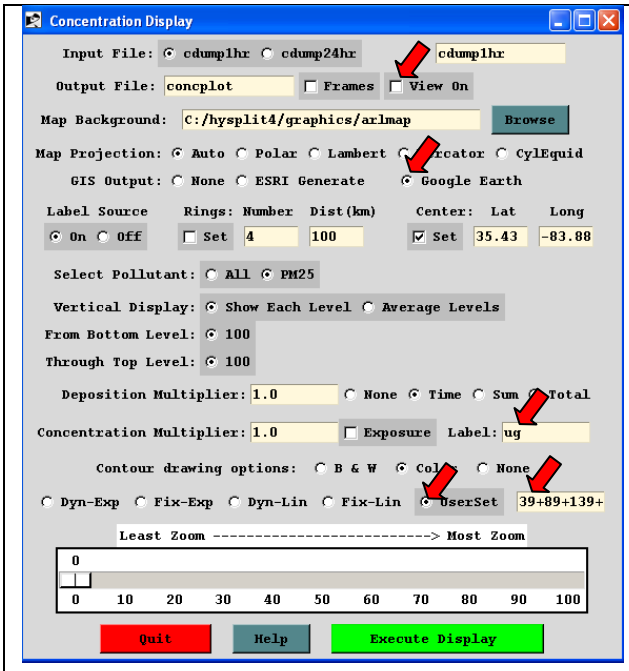
You will see the progress of the modeling in the Simulation Log. When the run is complete, press Exit to move to the next step.



8. Display the concentration contours. Click on **Concentration → Display → Concentration → Contours.**



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!



Enter the "UserSet" values in this order:
38::255255000+88::255126000+138::255000000+351::153000076

This configuration allows the output to display in the PM2.5 Hourly Air Quality Index (AQI) color codes of yellow, orange, red and purple.

$PM_{2.5}$ Hourly Air Quality Index (AQI)[1]
Moderate
Unhealthy for Sensitive Groups
Unhealthy
Very Unhealthy

If you are interested in creating 24 hour concentrations to compare to the 24 hr $PM_{2.5}$ standard, select "cdump24hr" and enter **35:255126000** 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.

9. 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. We recommend that you rename the kmz file using the name of your burn, 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.

[1]EPA 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. http://www.arb.ca.gov/smp/progdev/pubeduc/wfgv8.pdf.

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.
- HYSPLIT PC provides more refined predictions of downwind concentrations. Typically, an Air Specialist will conduct this modeling for field personnel.

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 (http://ready.arl.noaa.gov). NOAA Air Resources Laboratory, Silver Spring, MD.

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