Development of Managed Burning and Wildland Fire Emission Estimates for VISTAS

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ABSTRACT

The organization called Visibility Improvement - State and Tribal Association of the Southeast (VISTAS) is responsible for technical analyses and planning activities to support the 10 VISTAS states in the development of their individual State Implementation Plans for regional haze. In cooperation with state and local air quality agencies, VISTAS has developed a 2002 base year emissions inventory that will be used for emissions and photochemical modeling of fine particulate matter and visibility.

Emissions from managed burning and wildland fires are an important component of emission contributions to fine particulate matter and regional haze. This paper examines the development of a 2002 base year emission inventory for managed burning and wildland fires in the VISTAS states, as well as estimates for agricultural burning and land clearing of debris. The paper focuses on the data collection effort, the determination of fuel loading for each type of fire, the assignment of emission factors to various fire types and the overall emissions from each fire type. Fire emission estimates were calculated for individual fires and then composited as an annual emissions inventory. Records for the individual fire were provided to the VISTAS emissions modeling team. We discuss the assumptions that were required in migrating the inventory from a fire-by-fire inventory to an annual inventory. The paper also discusses the QA/QC aspects of inventory preparation and looks at the differences in temporal profiles from the 2002 data submitted by state and federal forestry officials compared to the previously available default assumptions used in the SMOKE emissions model.

INTRODUCTION

Many portions of the country are working on evaluating emission estimates and model results for regional haze modeling. The majority of this work is being performed by regional planning organizations. In the Southeastern U.S., the Visibility - State and Tribal Association of the Southeast (VISTAS) is responsible for technical analyses and planning activities to support the 10 VISTAS states in the development of their individual State Implementation Plans for regional haze. In cooperation with state and local air quality agencies, VISTAS has developed a 2002 base year emissions inventory that will be used for emissions and photochemical modeling of fine particulate matter and visibility.

In many regions of the U.S. one of the important sources to consider for regional haze modeling is fires, both prescribed (managed) and wildfires. VISTAS has developed emission estimates for prescribed and wildfires as well as estimates for agricultural burning and burning for land clearing purposes.

FIRE EMISSION ESTIMATES

Data Requested

In early 2003, VISTAS requested that State forestry personnel in each of the 10 VISTAS states provide information necessary to calculate fire emissions from wildfires, prescribed burning, agricultural fires and land clearing of debris. Specifically, VISTAS requested the following information:

Wildfires:

- Number of acres burned
- Date of fire – Actual days were preferred with information on the month that the fire actually occurred being the minimum information provided
- Type of material burned (pine, oak, etc.)
- Fuel loading (tons/acre)
- Location of fire – Latitude/longitude information was preferred, but if not available, the minimum acceptable information was the county in which the fire was located. For fires that spanned counties, VISTAS requested a breakdown of the acres per county.

Prescribed fires:

- Number of acres burned
- Date of fire – Actual days were preferred with information on the month that the fire actually occurred being the minimum information provided
- Type of material burned (short needle conifer, long needle conifer, logging slash debris, hardwood, palmetto, etc.)
- Fuel loading (tons/acre)
- Location of fire - Latitude/longitude information was preferred, but if not available, the minimum acceptable information was the county in which the fire

was located. For fires that spanned counties, VISTAS requested a breakdown of the acres per county.

In addition to the data elements detailed above, VISTAS requested an estimate regarding the percentage of the fire that occurred in the flaming, smoldering and actual fire stages.

Agricultural burning:

- Number of acres burned
- Date of fire – Actual days were preferred with information on the month that the fire occurred being the minimum information provided.
- Type of material burned (crop type)
- Fuel loading (tons/acre)
- Location of fire - Latitude/longitude information was preferred, but if not available, the minimum acceptable information was the county in which the fire was located. For fires that spanned counties, VISTAS requested a breakdown of the acres per county.

Land clearing of debris:

- Number of acres burned
- Date of fire – Actual days were preferred with information on the month that the fire occurred in being the minimum information provided.
- Type of material burned (grass, wood debris, etc.)
- Fuel loading (tons/acre)
- Location of fire - Latitude/longitude information was preferred, but if not available, the minimum acceptable information was the county in which the fire was located. For fires that spanned counties, VISTAS requested a breakdown of the acres per county.

Data Supplied

Data returned from the State forestry contacts varied by State both in the types of fire information returned (e.g., wildfires, prescribed, agricultural or land clearing) and in the detail provided. Some States provided information on each fire by latitude and longitude while others provided only the county location. In other cases very detailed information was provided on the fire date (including reported date, control date and fire out date, for example) while others only provided the month the fire occurred. For States that only provided the month in which the fire occurred, we set the date to the first of the month. Some States provided fairly detailed information on the fuel type and loading while others provided no data at all on the fuel type (or loading). No States provided estimates on the smoldering or flaming stages of the fire. Finally most States provided information in electronic format; however several only provided hard copy. For those that provided hard copy data, we scanned the data and inserted it into spreadsheets. The spreadsheets were reviewed against the original materials to ensure that the data were translated correctly.

VISTAS also requested information from Federal agencies on fires on Federal lands. The following Federal agencies were requested to submit data:

- Forest Service;
- Fish and Wildlife Service;
- National Park Service;
- Bureau of Land Management; and
- Bureau of Indian Affairs.

Data for wildfires was provided by all Federal agencies. However, prescribed burning data were only provided by the U.S. Forest Service. No other Federal agencies provided prescribed burning data to VISTAS.

Tables 1 and 2 provide an overview of the data supplied by State and Federal agencies for fires for VISTAS. Prescribed fire and Silviculture were combined under the same source classification code (SCC) in the data summaries.

Table 1. Fires data provided by state agencies by fire type

State	Agriculture	Prescribed	Silviculture	Land Clearing	Wildfires
AL	✓	✓		✓	✓
FL	✓	✓	✓	✓	✓
GA	✓		✓	✓	✓
KY					✓
MS		✓			
NC					✓
SC	✓	✓		✓	✓
TN					✓
VA					✓
WV					✓

Data Manipulation/Augmentation

Once all the data had been provided by the State and Federal agencies, MACTEC compiled the data into a master database containing common pieces of information necessary to identify the fire location and date as well as the data necessary to calculate emissions. That database was used to calculate fires on a fire-by-fire basis for all data submitted. Opportunities to improve the inventory methods are discussed at the end of this section.

Table 2. Fires data provided by federal agencies by fire type

Agency	Agriculture	Prescribed	Silviculture	Land Clearing	Wildfires
USFS		✓			✓
FWS					✓
NPS					✓
BLM					✓
BIA					✓

Prior to inserting data into the master database however, separate databases for each State and Federal submittal were developed. The first step in completing these databases was to ensure that sufficient location information was available so that the emissions could eventually be summed at the county level for the annual inventory.

For those data submittals that provided only latitude and longitude, we imported the data into a geographic information system (GIS) program and used the GIS program to add information on the State and county where the fire was located. In many cases this involved converting the data on latitude and longitude. Data on latitude and longitude were submitted in both hours:minutes:seconds format as well as decimal degrees. All data were converted to decimal degrees. For some of these records, the data either 1) fell outside of the State that the submittal was for or 2) fell in the ocean. Fires that fell outside of the State, in the ocean, or in the wrong State were dropped. This resulted in less than three percent of the acreage submitted for any State being deleted. Some State agencies submitted section, township and range data. Converting these data to latitude/longitude was beyond the current scope of work. In this initial 2002 inventory we simply used the county information provided to locate these fires.

For data submitted with only State and county information, we placed the fires at the county centroid location. For that work we used a file on the EPA website that listed the location of the county centroid in decimal degrees. All records where the location information was the county centroid were marked in the database.

Once the location information was completed for all data, we then proceeded to augment the fuel loading information in the database. The general approach used for augmenting fuel loading was as follows:

- State-supplied data – if provided, these values were always used

- Federal agency-supplied data – if provided, values were used. If federal record is redundant of state fire record, state data used.
- National Fire Danger Rating System (NFDRS) Model value assigned fuel loading
- Material burned type (a NFDRS value was assigned if the material burned could be easily matched to a NFDRS fuel model)
- State specific defaults calculated where no material burned type was provided
- Values for fires other than wildfires or prescribed burns were obtained from the Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources.

Values for fuel loading were then assigned to each individual fire (either State or Federal) based on this priority scheme. If the State supplied a value for fuel loading (even if the value was for the whole State) that value was used for all fires of that type (e.g., wildfires, prescribed fires, etc.). Similarly, if the Federal agency supplied fuel loading data for the fire, it was always used. Where no State or Federal value was provided but a NFDRS fire model designation was provided, the default value for that fire model designation was used for the fuel loading. If the data included the type of material burned and it could be matched with a similar material described by the vegetation type of a NFDRS fire model category, then the fuel loading for that NFDRS category was used. If the material could not be matched or was not provided, then an average State fuel loading based on a State-wide average of different NFDRS fuel models was used. Finally, for some fire types (e.g., agricultural burning or land clearing of debris), AP-42 fuel loadings were utilized. For those fire types, AP-42 was the primary source of fuel loading information unless information was provided by the State. In a few cases, we also used values from the 1999 NEI based on the NEI documentation.

The default values for the NFDRS fuel models were provided by Bruce Bayle, USFS (Bayle, 2003). NFDRS classifies fuel models using an alphabetic system that describes the general type of material that is consumed in the fire. Table 3 shows the list of NFDRS fuel models and the vegetative types associated with each model.

Table 3. NFDRS fuel model designations and vegetation types

NFDRS Fuel Model	Vegetation
A	Annual grass and forbs
B	Mature chaparral
C	Open timber/grass
D	Southern rough
E	Hardwoods (winter)
F	Intermediate brush
G	Closed, short-needle conifer (heavy dead)
H	Closed, short-needle conifer (normal dead)
I	Heavy slash
J	Medium slash
K	Light slash
L	Perennial grass
N	Sawgrass

O	Pocosin
P	Southern plantation
Q	Alaskan black spruce
R	Hardwoods (summer)
S	Alaskan tundra
T	Sagebrush/grass
U	Western, long-needle conifer

The information provided by Bayle was in the form of fuel loadings, by size class of fuel, for each NFDRS fuel model. Data on the fuel size class were provided for one hour, 10 hour, 100 hour, and 1000 hour fuels. The one hour fuel designation means that the fuel is of a size that will burn in the first hour of the fire. Similar meanings can be assigned to the other size class categories. In addition, information was provided on live woody and live herbaceous materials. Totaling the fuel loading for each size class (along with the live woody and herbaceous material) provided an overall average fuel loading for each NFDRS fuel model type. These values were summed to provide the fuel loadings for each fuel model.

The summation of these values was performed using a weighting scheme provided by Bayle. For each respective southern fuel model, we used the following percentages to calculate a typical tonnage per acre:

Include 100% of the 1 and 10 hour fuels (1h + 10h).
Include 50% of the 100 hour fuels (100h).
Include 10% of the 1,000 hour fuels (1,000h).
Include 40% of the "live woody" fuels.
Include 10% of the "live herbaceous" fuels.

The above percentages represent an average/typical wildfire and average/typical weather conditions/environmental factors in the southeast.

The values calculated using this weighting scheme were then compared to the default State fuel loadings from Table 4 of the EPA report entitled "Data Needs and Availability for Wildland Fire Emission Inventories - Short-term Improvements to the Wildland Fire Component of the National Emissions Inventory" (EPA, 2003). A spreadsheet was prepared with the summarized fuel loading values provided by Bayle along with those from the EPA report. That spreadsheet was then reviewed by Bruce Bayle, Mark Clere (Fire Planning Specialist, National Forests in Florida, Tallahassee, FL), and Charlie Kerr (Fire Management Officer, Francis Marion & Sumter National Forests, Columbia, SC) to ensure that the data used were optimal for southeastern forests. Suggestions for modifying the values in the spreadsheet were made by the reviewers and implemented as the standard values for use with the different NFDRS fuel models. The assumptions were then reviewed and approved by all the state forestry agencies. Table 4 shows the initial values for each NFDRS fuel model calculated using the weighting scheme, the default EPA 2003 report values and the final values used based on the review of both the initial calculated values and the EPA 2003 report defaults.

Table 4. Fuel loading values (tons/acre burned) used to produce fire emission values for NFDRS classified fires

NFDRS Fuel Model	Vegetation	1h	10h	100h	1000h	live woody	live herb.	Average fuel loading	EPA wildfire fuel loading	EPA prescribed fuel loading	Bayle revised*
		All values in tons/acre burned									
A	Annual grass and forbs	0.2					0.3	0.23	0.5	0.5	0.5
B	Mature chaparral	3.5	4	0.5		11.5		12.35	19.5	19.5	12.35
C	Open timber/grass	0.4	1			0.5	0.8	1.68	4.7	4.7	2
D	Southern rough	2	1			3	0.75	4.275	15.6	10.6	4.275
E	Hardwoods (winter)	1.5	0.5	0.25		0.5	0.5	2.375			2.375
F	Intermediate brush	2.5	2	1.5		9		8.85	3.8	3.8	8.85
G	Closed, short-needle conifer (heavy dead)	2.5	2	5	12	0.5	0.5	8.45	73.5	25.6	8.45
H	Closed, short-needle conifer (normal dead)	1.5	1	2	2	0.5	0.5	3.95	27.5	15	3.95
I	Heavy slash	12	12	10	12			30.2	55.1	49.1	30.2
J	Medium slash	7	7	6	5.5			17.55	34	31.2	12
K	Light slash	2.5	2.5	2	2.5			6.25	14.4	13.1	6.25
L	Perennial grass	0.25					0.5	0.3	0.8	0.8	0.3
N	Sawgrass	1.5	1.5			2		3.8	5	5	3.8
O	Pocosin	2	3	3	2	7		9.5	46.1	45.1	9.5
P	Southern plantation	1	1	0.5		0.5	0.5	2.5	16.4	10.2	2.5
Q	Alaskan black spruce	2	2.5	2	1	4	0.5	7.25	57.6	48.8	7.25
R	Hardwoods (summer)	0.5	0.5	0.5		0.5	0.5	1.5	3.1	3.1	2
S	Alaskan tundra	0.5	0.5	0.5	0.5	0.5	0.5	1.55			1.55
T	Sagebrush/grass	1	0.5			2.5	0.5	2.55	4.5	4.5	2.55
U	Western, long-needle conifer	1.5	1.5	1		0.5	0.5	3.75	19.1	10.3	3.75

* Bayle revised values were the values used to produce the emission inventory.

When the type of material burned wasn't known, default values had to be calculated. Table 3 of the EPA 2003 report provides a State-wide method for calculating fuel loadings based on the fraction of total state acreage in each NFDRS model. These fractions were used with the Bayle revised fuel loading values discussed above to calculate a State default value for wildfires only when the type of material burned could not be determined. For example in KY, 0.001 of State land is classified as NFDRS model C (open timber/grass), 0.199 as L (perennial grass), 0.048 as P (southern plantation) and 0.752 as R (hardwoods [summer]). This yields a State default for wildfires (where the fuel type was not specified) of 1.69. These values were used whenever there was insufficient information to assign an actual value based either on the NFDRS model or the type of vegetation (material) burned. For prescribed fires, the initial values were calculated using the EPA 2003 report defaults. The States of AL, FL, GA, and SC asked VISTAS to revise their prescribed burning default values to use the Bayle state-wide default assumptions coupled with the State fractions from the EPA 2003 report following review of the initial estimates.

Once the fuel loading had been assigned to each fire, emission factors were assigned. Each fire was assigned a "fire model" designation for the purposes of assigning an emission factor to the fire. In the cases where the fires had designated NFDRS fire models already, the "fire model" designation was identical to the NFDRS letter designation. There were other designations that were assigned to other fire types (agricultural burning fires, etc.). In some cases the material burned type was used to assign the "fire model" emission factor assignment. Emission factors were assigned for all fire types.

The basis for the emission factors for many of these fires was Table 2 of the EPA 2003 report. For a few of the "fire models", the emission factors used differ slightly from Table 2 of that report. This is consistent with note 3 for Table 2 in the EPA 2003 report, which indicates emission factors for fuel models other than NFDRS types A, B, C, F, and L should be augmented by 17% and 8.5% for wildfires and prescribed fires respectively. Accordingly, the values for those fuel models were augmented by those percentages

Once all of the data required to calculate emissions were acquired or assigned, we then put all of the State data into a master database. The master database contains the following data fields:

StateFIPS	State FIPS code
CountyFIPS	County FIPS code
SCC	Source Classification Code
Date	Date of Fire
Acres	Number of Acres burned
Latitude	Latitude in decimal degrees
Longitude	Longitude in decimal degrees
LatLongIsCountyCent	True/False field indicating whether the latitude and longitude value is the county centroid – value is "True" if it is

FireType	Type of fire - prescribed and silviculture burning were both assigned the prescribed burning SCC, waste burning and land clearing of debris burning were both assigned the waste burning SCC
Material	Type of material burned if known
Fuel Loading	Fuel loading value in tons/acre
Default Fuel Loading	True/false field indicating if the fuel loading value is a default value – "True" if it is
Default Material	True/false field indicating if the material field value is a default value – "True" if it is
Fuel Loading Source	Source for the fuel loading value
Emission Factor Code	Code used to look up emission factor values in the emission factor table - NFDRS fuel model if available
Pollutant	Pollutant for emissions
Emissions	Emissions value in tons
Emission Factor	Emission factor in lbs/ton of material burned
Agency	Agency that submitted data
DataSource	Who supplied the data (State or Federal or other)
StateFederal	One character indicator field that indicates if the record is a State (S) or federal (F) data record.

The master database file contains the raw fire-by-fire information used to estimate most (but not all) emissions in versions 1 through 3 of the VISTAS base year area source inventory. Duplicate state and federal fire records were removed from the inventory to avoid double counting fires. Due to removal of duplicate records, summing emissions for the individual fires in the master fire database will not provide the same annual values found in the inventory in all cases.
The replacement process used to allocate fire emissions from either the master fire database or the 1999 NEI version 2 is described below and illustrated in Figures 1 through 3.

For wildfire, if both state and federal agencies submitted wildfire activity data, records were checked to remove duplicate records. Activity data submitted by the states was used to calculate emissions for each county. If fire data were not available from all federal agencies in that state, then in the counties with unrepresented federal forested land, 1999 NEI Version 2 default assumptions were used. Mississippi did not submit wildfire data. For MS, the 1999 NEI version 2 values were maintained, again to avoid double counting or underestimating. MS data in the master fire database file will not match the annual emission inventory values.

For prescribed fire, records supplied by the fire contacts for the States of AL, FL, GA, MS, and SC included prescribed fire on Federal lands. For those States, the prescribed fire emission values in the master fire database match the NIF version. Federal data was not used for those States. The remaining states did not submit prescribed fire data. Even

if Federal prescribed fire data were available, the 1999 NEI version 2 prescribed fire inventory data were used to avoid double counting.

Figure 1. General approach to estimating emissions for fires (applies to wildfires and prescribed fires)

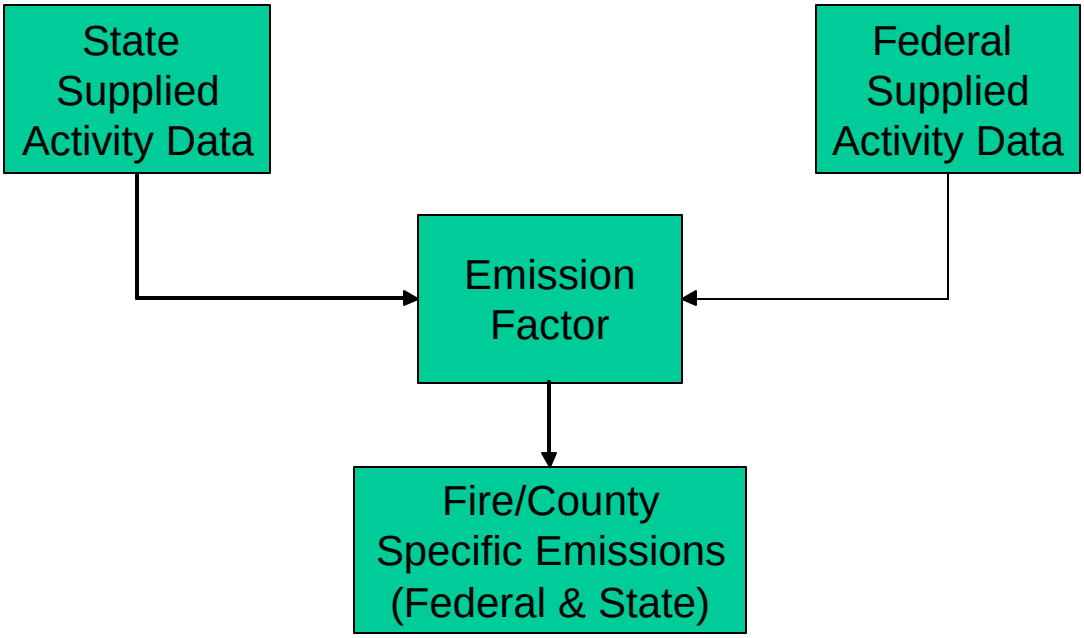


Figure 2. Approach used for calculating fires if federal data were missing.

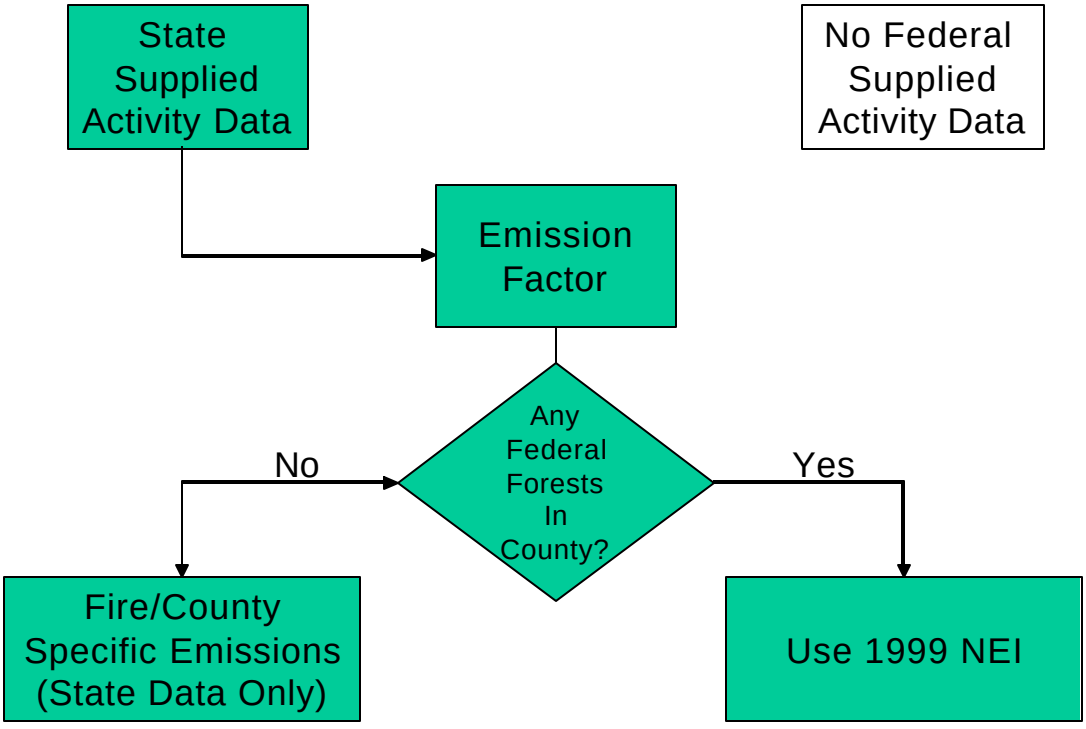
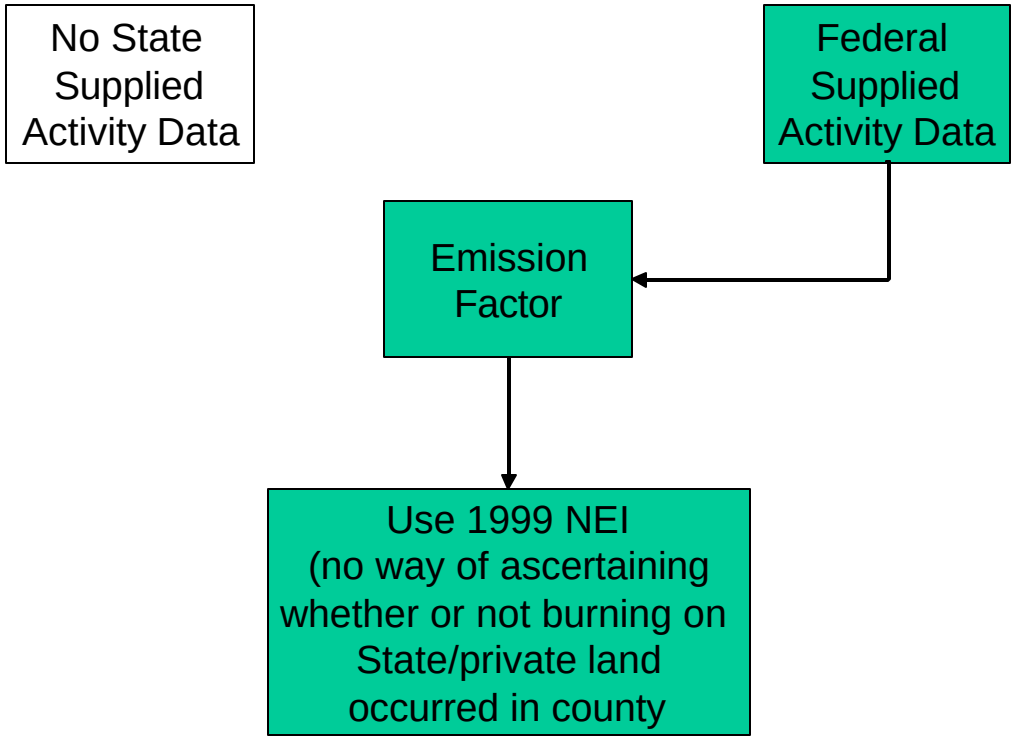


Figure 3. Approach used for calculating fires if state data were missing.



RESULTS

Table 5 presents the results of the emission estimates for the 2002 wildfires for each State and pollutant.

Table 5. Emissions by State and pollutant for wildfires in 2002 in the VISTAS region (all values in tons/year).

Fire Type	State	CO	NH3	NOX	PM10-PRI	PM25-PRI	SO2	VOC
Wildfires	AL	16,132	73	346	1,568	1,345	95	759
Wildfires	FL	46,457	209	997	4,517	3,874	273	2,186
Wildfires	GA	100,389	452	2,154	9,761	8,372	590	4,724
Wildfires	KY	8,960	40	192	871	747	53	422
Wildfires	MS	30,429	126	869	2,826	2,543	33	4,173
Wildfires	NC	23,006	103	494	2,237	1,918	135	1,083
Wildfires	SC	22,551	101	484	2,193	1,881	133	1,061
Wildfires	TN	4,458	20	96	433	372	26	210
Wildfires	VA	16,650	75	357	1,619	1,388	98	783
Wildfires	WV	6,735	30	144	655	562	40	317
Total		**275,766**	**1,230**	**6,133**	**26,680**	**23,002**	**1,476**	**15,718**

Table 6 shows similar information for prescribed burning for 2002 by State and pollutant.

Table 6. Emissions by State and pollutant for prescribed burning in 2002 in the VISTAS region (all values in tons/year).

Fire Type	State	CO	NH3	NOX	PM10-PRI	PM25-PRI	SO2	VOC
Prescribed	AL	359,596	1,618	7,715	34,964	29,987	2,115	16,922
Prescribed	FL	701,932	3,157	15,059	68,250	58,535	4,129	33,032
Prescribed	GA	473,461	2,130	10,157	46,035	39,482	2,785	22,281
Prescribed	KY	2,940	8	55	412	371	2	140
Prescribed	MS	11,360	51	244	1,105	947	67	535
Prescribed	NC	2,543	7	47	357	321	1	121
Prescribed	SC	165,951	746	3,560	16,136	13,839	976	7,809
Prescribed	TN	580	2	11	81	73	0	28
Prescribed	VA	6,547	103	708	6,247	5,622	25	319
Prescribed	WV	30	0	1	3	3	0	1
Total		**1,724,940**	**7,822**	**37,556**	**173,590**	**149,181**	**10,101**	**81,188**

One of the benefits of developing fire-by-fire estimates prior to summarizing the emissions for the annual inventory was the ability to evaluate temporal information about the fire types. Figure 4 shows the difference in monthly temporal profiles between the actual wildfire data collected from the States and the default wildfire profile used in the SMOKE emissions model for VISTAS Phase I air quality modeling. The default profile places the majority of emissions in the June-December timeframe while the actual 2002 wildfire profile places the majority of the emissions in the spring.

Figure 4. Actual wildfire acreage burned by month compared to the default monthly profile from SMOKE.

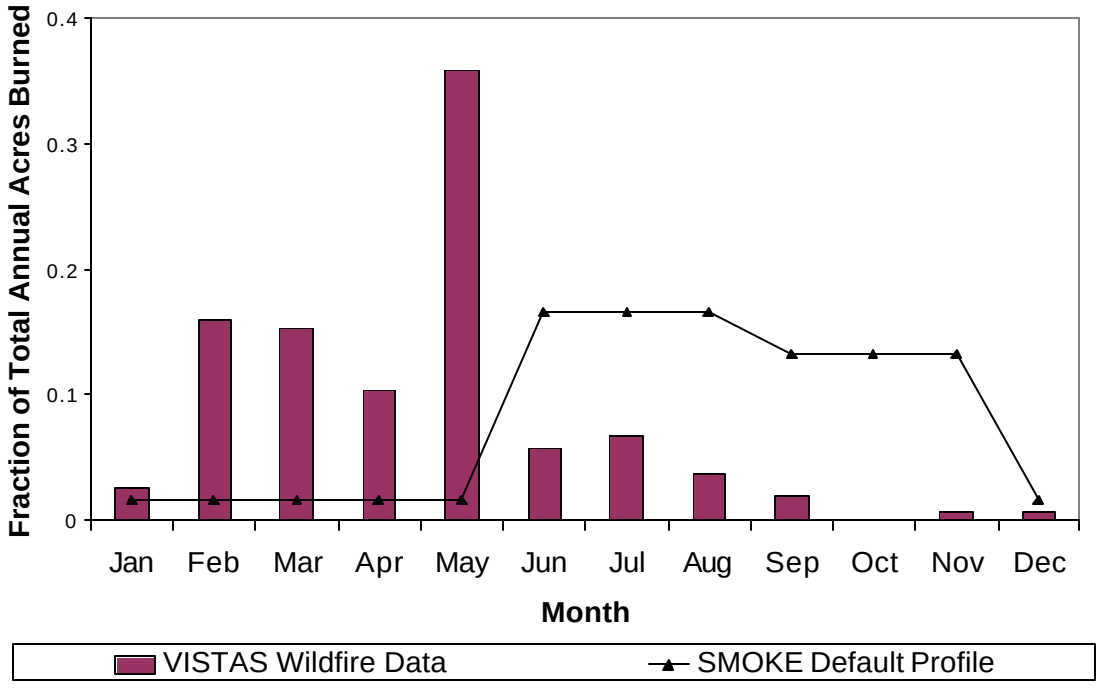


Figure 5 shows similar information for prescribed burning in the VISTAS region. While the primary months for burning are different for prescribed fires in both the default and actual data, the results still show that use of the default profile would place the majority of emissions in the last spring to late summer timeframe while the actual data shows that the bulk of emissions in 2002 occurred in the winter months (Jan-Mar). While only five states submitted prescribed burning data, for the purposes of comparison, the percentage contribution of prescribed fire in the remaining states is small and does not affect the comparison in Figure 6.

Figure 5. Actual prescribed fire acreage burned by month compared to the default monthly profile from SMOKE.

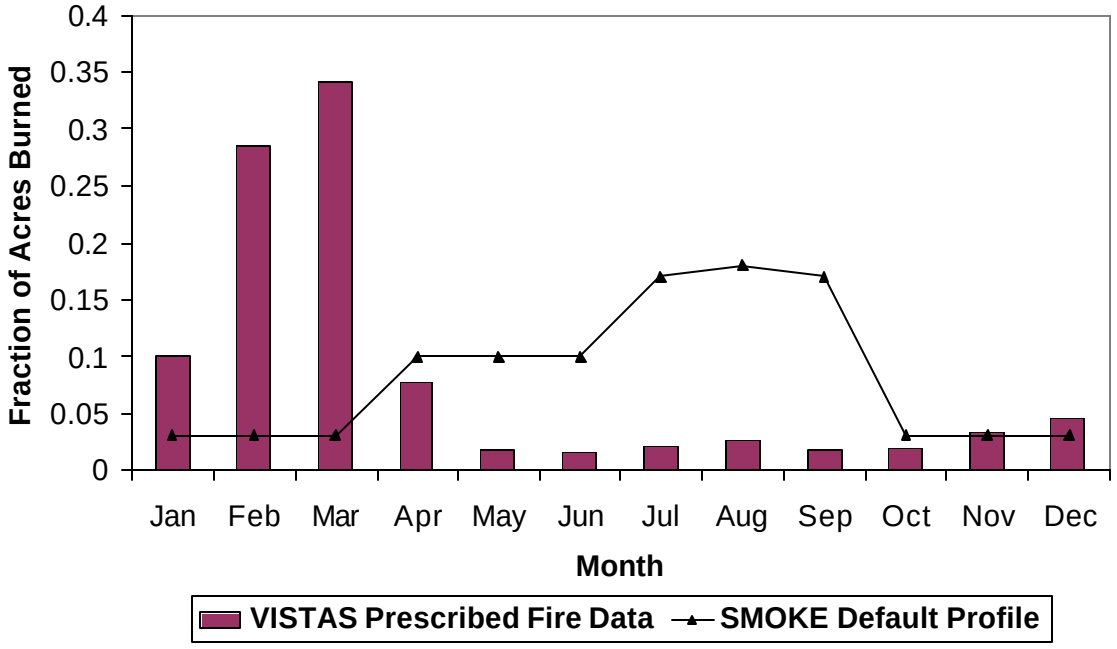


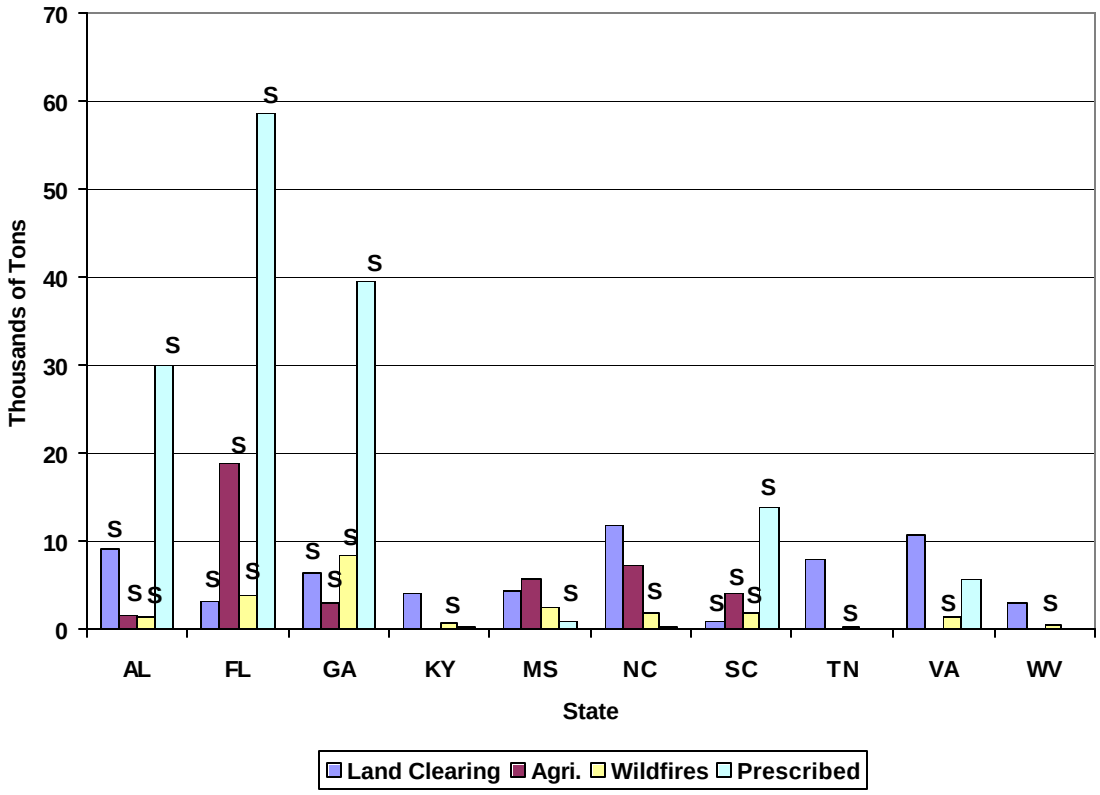
Figure 6 shows the emissions of PM2.5 for the various fire types for each VISTAS State. In the figure, an "S" above the bar indicates that the data used to calculate the emissions were supplied by the State. From this figure it is clear that for 2002, prescribed fires dominated the emissions with the majority of emissions coming from three States: AL, FL, and GA.

Future opportunities to improve this initial 2002 inventory include:

- Convert section, township and range data submitted by state agencies to latitude/longitude.
- If only county identifier, apply GIS land use coverage to restrict fire emissions to forested areas of the county.
- Initially, fires were represented as area sources. For VISTAS' 2002 annual modeling fires are being converted to point source files.

- For selected large fires, meteorological data could be combined with fire size and fuel loading to improve temporal distribution of emissions over life of the fire.

Figure 6. PM2.5 emissions by State and fire type in the VISTAS region.



CONCLUSIONS

VISTAS performed a data collection effort as part of their 2002 base year emission inventory effort to better characterize fire emissions from wildfires, prescribed burns, agricultural burning and land clearing of debris. The data collected was used to develop fire-by-fire emission estimates for both State and Federal lands. Fuel loading, burn dates, acres burned and other attributes were collected where possible and missing data were developed using default information. The results of the emission estimates showed that monthly temporal profiles for prescribed and wildfires were significantly different than the default values used by the SMOKE model.

The data also show that prescribed fires are significantly higher emission contributors for 2002 than wildfires with the majority of prescribed fire emissions coming from three States.

REFERENCES

Bayle, B., 2003, U.S. Forest Service, personal communication.

U.S. Environmental Protection Agency, 2003, "Data Needs and Availability for Wildland Fire Emission Inventories - Short-term Improvements to the Wildland Fire Component of the National Emissions Inventory." June 5, 2003, prepared under EPA Contract No. 68-D-02-064, Work Assignment No. I-08 for Tom Pace.