Efforts to Improve Spatial and Temporal Emissions Allocation Procedures

Gregory Stella

Emission Factors and Inventories Group
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711
stella.greg@epa.gov

Bernd Haneke, William Hodan, Mark Saeger

Pacific Environmental Services, Inc.
5001 S. Miami Boulevard
Research Triangle Park, NC 27709-2077
bhhaneke@mactec.com wmhodan@mactec.com

ABSTRACT

The need for regional emissions inventories to support multistate modeling programs is increasing in response to proposed revisions to the PM and Ozone NAAQS and the requirements of the Regional Haze rule. Many of the important sources associated with fine particulate matter and regional haze are area sources. Many of these area sources, such as open burning in rural areas and some dust sources, have not been considered to be high priority issues in previous air quality management programs. Others, such as residential wood combustion and agricultural field tilling, have been of interest on local scales only. The historical methods used to resolve county level, annual total emissions from these types of sources introduce significant uncertainty in many air quality modeling studies that extend over multi-state regions. This paper discusses coordinated EPA/Emissions Inventory Improvement Program (EIIP) research and development efforts to prioritize the specific spatial and temporal resolution needed to improve these regional analyses and to implement improvements for both base year and future year scenarios. Work described in this paper related to temporal allocation factors is sponsored by EPA, and the work related to spatial allocation factors is sponsored through the Emissions Modeling Committee of the EIIP.

The goals of the project are to:

- Review the origins and application of current temporal and spatial allocation factor files to identify important source categories that may benefit from improved allocation factors,
- Search out new sources of information that have potential for use in creating more current allocation factors,
- Update the temporal allocation factor files with improved information,
- Create spatial allocation factors files that represent the likely distribution of important spatial allocation surrogates in future years.

INTRODUCTION

Emissions estimates are typically derived from base calculations that rely on annual activity rates. Frequently, emissions estimates are adjusted to represent a typical summer season day or winter season day by application of a factor that accounts for the inherent seasonal variability of selected sources. Air quality models, however, must operate on hourly temporal scales to simulate complex chemical reaction dynamics. Temporal allocation of emissions is necessary for point, area, and mobile sources. Many large point sources, such as refineries or electric generating stations can be assumed to operate continuously. Other point sources and most area sources, however, operate on different temporal schedules. Some operate eight hours per day, and others may operate for 12 hours a day. Some activities are dominant on weekdays and others on weekend days. Temporal allocation profiles are used to generate the daily and hourly emissions variability required by the models. Many of the temporal allocation profiles used in current emissions processors are best judgement estimates that were developed many years ago. Improvements in temporal allocation of emissions may improve the simulation of chemical reaction dynamics in air quality models. The focus of this work is on Temporal Allocation Factor Files (TAFF) assignments for area sources.

Emissions estimates for area sources and non-road mobile sources are developed using county-level activity data. All air quality models suitable for regional-scale analyses are based on a grid system that divides the region into regularly spaced grid cells. Therefore, county-level emissions estimates must be assigned to the appropriate grid cells before they can be used as input to the regional air quality models. This step is accomplished by use of spatial allocation factors. The spatial allocation factors are related to the distribution of surrogate parameters that are directly related to the emissions activity. For example, activities that are related primarily to people can be allocated to grid cells in proportion to the distribution of population, or housing units. While the existing spatial distribution surrogates can be generated from information published by the Census Bureau and other sources, the use of those same distribution functions for future year scenarios neglects the effects of population growth and urban sprawl. It is desirable to have access to revised spatial allocation factors that may be more representative of spatial distributions in future years for use in evaluating control scenarios on expected future air quality.

This work is ongoing and, therefore, we will report on only a select few direct results in this paper. The purpose of the paper is to inform the emissions estimation community of the work, and to present anticipated schedules for the availability of improved temporal and spatial allocation factor files.

METHODOLOGY

Review of Existing Temporal Allocation Files

A review of the assignment of the existing temporal allocation factors to Source Classification Codes (SCC) in the 1996 NEI inventory was completed. This analysis revealed that all of the profiles were derived form either the National Acid Precipitation Assessment

Program (NAPAP), or the Southern Oxidant Study (SOS). Many other SCCs were simply assigned a flat temporal profile implying that the source is on continuously. The distribution of TAFF assignments by SCC record is summarized in Table 1.

Table 1. Current Assignment of TAFFs to SCCs Based on the 1996 NEI

Total Number of Records:	74,736
Number of Records per SCC:	12
Total Number of Unique SCCs (Calculated):	6,228

Code	Number of Records	Total Number of SCCs	Percentage of Total TAFFs	Number of Point Source SCCs	Number of Area Source SCCs	Number of Mobile Source SCCs
ECON	8,027	668	11	668	0	0
NAPAP	18,480	1,540	25	11	918	611
FLAT	26,548	2,206	35	1,096	835	275
A8	20,768	1,735	28	1,735	0	0
A6	229	20	0	20	0	0
B8	480	40	1	0	40	0
OTHR	204	17	0	17	0	0
Total:	74,736	6,226	100	3,547	1,793	886

Explanation of Codes:

ECON: Profiles assigned from economic data (Bureau of Economic Analysis, Bureau of Labor Statistics).
NAPAP: Profiles assigned from 1985 National Acid Precipitation Assessment Program (NAPAP) TAF file.
FLAT: Flat profiles assigned (all seasons, all days and all hours equally distributed).
A8: 8-digit profiles created from the Southern Oxidant Study (SOS) Point Source, Continuous Emission Monitoring (CEM), Lake Michigan Ozone Study (LMOS), Acid-Modes data were averaged and assigned to appropriate SCCs.
A6: 8-digit profiles created from SOS Point Source, CEM, LMOS, Acid-Modes data were averaged to the six-digit level and assigned to all 8-digit SCCs.
B8: 8-digit profiles taken from SOS Area Source data.

Other Codes from Report Not Used in the Database:

B6: 8-digit profiles created from SOS Point Source, CEM, LMOS, Acid-Modes and TNRCC data were averaged to the 6-digit level and assigned to all 8-digit SCCs in the respective 6-digit family.
T6: 8-digit profiles created from Texas Natural Resources Conservation Commission (TNRCC) data were averaged to the 6-digit level and assigned to all 8-digit SCCs in the respective 6-digit family.
T8: 8-digit profiles created from TNRCC data were assigned to appropriate SCCs.

Selecting High Priority Area Source Sectors for TAFF Development

Review of Table 1 reveals that nearly all of the area source categories are currently assigned to the flat profile or a TAFF that was developed during the NAPAP program in the late 1980s. The flat profile assumes continuous operation; that is equal activity in all seasons, operations on 7 days per week in each season, and operation for 24 hours on all days of the week. The NAPAP profiles generally attempt to distribute emissions to seasons, days and hours in a more realistic way, but in many cases these profiles are based on assumptions and are not necessarily based on measurement or observation. For example, residential fuel combustion categories are associated with TAFF profiles that allocate emissions primarily to winter months, and TAFF profiles used for recreational boat activities assign most of the emissions to weekend days. Even in these cases, however, a single profile is applied in all regions of the country, which ignores seasonal differences in activity that result from climate or micro-scale weather patterns.

A set of ranking criteria was used to prioritize sources relative to one another. These criteria included total emissions magnitude, coverage of SCC to TAFF assignments, and the percentage of TAFF profiles that assume a uniform seasonal distribution of activity. The emissions magnitude ranking was done on a regional basis to select those categories that represent significant emissions magnitude in all regions of the country. Emissions were summed for all states included in each of the Regional Planning Organizations. Three emissions parameters were used: NO_x and VOC emissions were used to represent ozone precursors, SO_2 and NH_3 were used to represent PM precursors, and PM-2.5 was represented separately as a measure of primary fine particulate emissions magnitude. Area source categories were grouped into sectors. For example, the emissions totals for all fuel types were lumped into a sector category to represent residential fuel combustion, and all waste management SCC categories were lumped into a sector named Waste Disposal, Treatment and Recovery activities.

The results of the prioritization process identified four source sector groupings that were high in more than one of the emissions categories in all regions and were assigned a large percentage of flat seasonal profiles. Upon review of the prioritization results, two more categories were identified as high priority sectors because of their relative ranking and anticipated role in future air quality management activities. These categories are:

- Agricultural crops,
- Commercial/Institutional Fuel Combustion,
- Residential Fuel Combustion,
- Waste Disposal, Treatment, and Recovery,
- Agricultural Livestock (added after review), and
- Construction Activities (added after review).

As mentioned above, TAFF assignments for many of the individual SCCs included in these groups represent a flat seasonal profile, and are applied uniformly in all regions of the country. In the initial phase of this work, analyses will be completed to either justify the use of a flat profile for individual SCCs in these groups, or identify information sources that will be useful to develop more specific TAFF profiles for SCCs and/or regions.

Review of Existing Spatial Allocation Factor Files

Table 2 summarizes the assignment of Spatial Allocation Factor Files (SAFF) to SCCs in one of the widely used emissions processing systems. The number of SAFFs is limited by the availability of both data and the resources that are required to periodically adjust these files for routine application in all regions of the country. The factors in Table 2 that are likely to change significantly with time are those related to population, housing, agricultural land area, and highways. As seen in Table 2 a large percentage of the area emissions categories are allocated using the population, housing and agricultural land spatial surrogates. In general, very good information is available from Census data generated by the Census Bureau and the Census of Agriculture to develop SAFFs for these categories from current information. The spatial distribution of these activities is expected to change with time in response to urban and suburban growth. Therefore, using these current SAFFs to represent future conditions in modeling exercises designed to predict the effects of various control strategies may not accurately represent future emissions distributions. The objective of the work on SAFF development will focus on generating SAFFs for population, housing and agricultural land area in future years. Initially, it is assumed that distributions of on-road mobile sources can be addressed in future years using transportation demand models that estimate activity for specific roadway links. The other SAFFs are assumed to be largely fixed and use of the existing distribution files will not seriously affect future year analyses.

PRELIMINARY RESULTS

TAFF Profile Development

TAFF profiles have been developed for fertilizer application and agricultural burning activities. Data for the fertilizer application TAFF profiles was obtained primarily from the Carnegie-Mellon University's NH_3 Inventory. Data for agricultural burning activities was obtained primarily from the U.S. Department of Agriculture publication "Usual Planting and Harvesting Dates for U.S. Field Crops," and from the Western Governor's Association's "Agricultural Burning Smoke Management Program Survey."

To date, 10 draft fertilizer application profiles have been developed. In addition, 28 draft agricultural burning profiles have been developed. Most of the TAFF profiles that were developed have provided resolution at the seasonal level. Not enough information was obtained to create profiles at a higher data resolution. Information has been obtained from the State of Washington that indicates that agricultural burning is only allowed during certain hours of the day. It is anticipated that the acquisition of similar data from different States will allow for the development of hourly profiles for agricultural burning.

PES has been collecting data to develop TAFF profiles for other categories, including construction, livestock, residential and commercial fuel combustion, and waste disposal, treatment and recovery facilities. It is anticipated that ongoing projects at PES dealing with residential and commercial fuel combustion will be able to provide enough data to develop seasonal TAFF profiles for these source categories. Preliminary information regarding construction activities has been obtained from the U.S. Census Bureau's Census of Construction

Table 2. Current SAFF Assignments Used in the SMOKE Emissions Modeling System

Spatial Surrogate Assignment File	Number of Area and Mobile SCCs Assignments	Emissions Magnitude By SAFF (tpy)						
		VOC	NO_x	CO	SO_2	PM-10	PM-2.5	NH_3
Population	1614	2,404,142	2,983,207	11,827,277	1,481,235	650,309	1,276,803	38,112
Urban Population	45	*	*	*	*	*	*	*
Rural Population	349	422,435	392,570	9,491,351	24,332	937,485	2,334,290	43,677
Housing	210	161,041	961,074	14,404,650	161,054	920,074	1,031,062	4,046
Agriculture	181	60,407	919,038	512,542	138,372	1,455,035	1,092,532	1,048,339
Major Highways	3	*	*	*	*	*	*	*
Urban Primary Roads	180	*	*	*	*	*	*	*
Rural Primary Roads	135	*	*	*	*	*	*	*
Urban Secondary Roads	45	*	*	*	*	*	*	*
Rural Secondary Roads	90	*	*	*	*	*	*	*
Airports	27	36	185,198	1,018,384	13,208	39,620	29,503	3,628
Land Area	17	2,654	34,565	0	215	241	171	0
Ports	72	29,079	1,006,626	138,194	61,455	45,690	40,044	1,439
Railroads	59	1,038	1,136,609	128,968	114,237	30,247	27,826	738
Water Area	25	57,314	68,332	2,254,474	20,291	41,117	37,829	248

Note: Emissions assigned to SAFFs are area and non-road emissions from NEI99 v.1. On-highway emission sources use the other 6 SAFFs, and have not been assigned to the NEI99 v.1

Industries. We are in the process of supplementing project-related results data with information obtained from other sources, primarily Internet searches.

SAFF Profile Development

PES has been coordinating efforts to develop SAFFs with the Emission Modeling Committee and EFIG. PES has contacted a number of State and local agencies in search of spatial allocation data and methods for future year emissions allocation. Of the contacts that were made, one agency was able to provide spatial allocation data and documentation. The Arizona Department of Environmental Quality put PES in contact with the Maricopa Association of Governments (MAG). MAG is a council of local governments that serves as a regional agency for the metropolitan Phoenix, AZ area. MAG is responsible for analysis, discussion and resolution of issues involving transportation, air quality, environment, regional development and social services. MAG supplied PES with a gridded surrogate file that was used for the 2015 modeling runs for their CO Maintenance Plan. The data contains 15 categories (columns) of data with the fraction of county totals in each cell. The 15 categories are listed below:

1. Occupied Housing
2. Industrial Employment
3. Non_Industrial Employment
4. Land Use _ Undeveloped Total
5. Land Use _ Developed Total
6. Residential Construction
7. Land Use _ Agricultural Stockyards
8. Land Use _ Agricultural Other
9. Commercial Construction
10. Land Use _ Non_Developable Forest
11. Land Use _ Railroad
12. Land Use _ Water
13. Land Use _ Golf Course
14. Total Construction
15. Land Use _ Airports

The spatial surrogate SCC cross-reference table used in conjunction with the gridded file when running the GRDEM module of the emission preprocessor (EPS2.0) was also supplied. There are still some questions concerning how the data was developed and whether there was any redistribution of future populations at the grid level according to land use surrogates. PES is following up with contacts at MAG to gather more information on how the future spatial surrogate tables were assembled. It appears that the standard method of developing future emission estimates uses population projections that do not account for shifts in population, but rather grows the population over the entire area. This method of projection does not account for new spatial distribution in future years. Changes in land use, the sprawl of population from urban areas into suburban and rural areas etc. causes shifts in the emissions from a given area over time.

It is the goal of the Emissions Modeling Committee to develop a methodology for assembling SAFFs that can be used for the entire United States. Collection of existing spatial allocation data and methods has only turned up one set of files as discussed above. To supplement the existing data and design a methodology applicable to the entire United States, it may be productive to use existing socioeconomic and other projection methodologies to develop a standard operating procedure for future spatial allocation factor development.

A projection methodology used in Utah is one example of an existing socioeconomic projection methodology that could be used to develop future spatial data sets taking into account new spatial distributions. The Wasatch Front Regional Council (WFRC) maintains future year projections of demographic and economic data for use as part of the transportation planning process. The Salt Lake and Ogden, Utah areas have a 30-year history of developing projections at the Traffic Analysis Zone (TAZ) level. The State uses the Utah Process Economic and Demographic (UPED) model to produce regional totals of population. The population trends are then used to develop county controls. The county controls, in turn, are used by local planning officials to develop TAZ level projections based on land availability, current land use, zoning, etc. Another projection method used by the WFRC is the Stratified Iterative Disaggregation (SID) method which creates projections for each TAZ using density specific growth rates and then sums the TAZs to county and regional totals using the Governor's Office of Planning and Budget (GOPB) county and regional totals as a control. The current projection methodology uses the knowledge gained in the 30-year history of the program to build on the past efforts while incorporating current information and refined techniques to create reliable projections.

The Federal State Cooperative Program for Population Projections (FSCPPP) uses State agencies in cooperation with the Census Bureau to improve population projections by incorporating local trends and knowledge into the census estimates. While the Census Bureau uses a consistent methodology across the United States to produce population projections, States use methodology and techniques that meet their specific needs. Much of the census projection data generated by State agencies is available at the county level, and possibly smaller sizes for some States and areas.

Information on future housing and agriculture estimation techniques are other elements that the committee agreed were critical elements in the development of future spatial allocation factors. The continued effort to develop SAFFs will include an investigation of housing and agriculture estimation techniques as well as population projections.

REFERENCES

1. Assessment Of Emissions Inventory Needs For Regional Haze Plans. Final Report prepared by Pacific Environmental Services, Inc. for The Mid-Atlantic Regional Air Management Association and the Southeast States Air Resource Managers. January 2001.

2. Regional Haze and Visibility in the Northeast and Mid-Atlantic States. Final report prepared by North East States for Coordinated Air Use Management. January 2001.

3. U.S. Environmental Protection Agency, Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume 1, Stationary Point and Area Sources. Section 1.4 Natural Gas Combustion, p. 1.4-6, 2000.

4. Methodology for Estimating Fugitive Windblown and Mechanically Resuspended Road Dust Emissions Applicable for Regional Scale Air Quality Monitoring. Final Report prepared for the Western Governors' Association. Principal Investigator Richard Countess. April, 2001.

5. Preliminary Work Plan for Emissions Inventory Improvement for Regional Haze Planning. Final Interim Report prepared by the Mid-Atlantic Regional Air Management Association for the Mid-Atlantic/Northeast Visibility Union. August 2001. URL: **http://www.marama.org/visibility/rhworkplan.pdf**