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ESTIMATING MONTHLY AND STATE-LEVEL NO_x, SO₂, VOC, AND CO₂ EMISSIONS USING THE MSCET DATABASE

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ABSTRACT

This paper describes the Month and State Current Emission Trends (MSCET) database. It describes the methodology used to estimate NO_x, SO₂, VOC, and CO₂ emissions and the data sources used by the methodology. Selected emissions results from the database are presented.

INTRODUCTION

The MSCET database is designed to estimate emissions at a monthly and state level. The sources of the emissions are separated into six general categories, on the basis of different data sources and methodologies. The six general categories are electric utility, transportation, industrial fuel, industrial processes, commercial/residential, and miscellaneous. For methodology purposes, the emissions themselves are separated into two groups, one group consisting of nitrogen oxides (NO_x), sulfur dioxide (SO₂), and volatile organic compounds (VOC), the other group consisting solely of carbon dioxide (CO₂). The reason for this separation is that NO_x, SO₂, and VOC emissions were benchmarked to the 1985 National Acid Precipitation Assessment Program (NAPAP) Emissions Inventory, while the CO₂ emissions were estimated directly from fuel consumption data. The methodology will be described as follows:**

- Electric utility emissions for NO_x, SO₂, VOC, and CO₂
- NO_x, SO₂, and VOC emissions for:
 - Transportation
 - Industrial fuel, industrial processes, miscellaneous, and commercial/residential
- Nonutility CO₂ emissions

Following the methodology discussion, some selected emission results are presented. These include annual national emission trends for the four pollutants, annual northeast trends for the four pollutants, and seasonal national emission trends with contributions from the six general categories.

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** For a more thorough discussion of the MSCET methodology, the interested reader is referred to the report referenced at the end of the paper.

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ELECTRIC UTILITY EMISSIONS

Electric utility emissions are treated as a separate category for two reasons. First, these utilities are a significant source of emissions, responsible for two-thirds of SO₂ and about one-third of NO_x emitted. Second, and most pertinent to the methodology issue, more reliable and detailed data exist for electric utilities, covering the period from 1975 to the present.

At present, it is impractical to measure combustion emissions directly by monitoring all gases produced, so electric utility emissions are estimated. The method MSCET uses to estimate these emissions is the consumption/emission factor (CEF) method. In this method, (1) data on fuel consumption are collected, (2) emission factors per unit of fuel consumption are assigned, and (3) the emission factors are applied to the consumption data to estimate emissions. The CEF methodology is reflected in equation 1 below:

$$E_{i,b,m,f,p} = C_{i,b,m,f} \times EF_{b,f,p} \times (1 - R_{i,b,m,f,p}) \quad (1)$$

where:

- E = pollutant emissions;
- C = fuel consumption;
- EF = emission factor: emissions per unit of fuel consumed;
- R = emissions reduction due to control: fraction removed;
- i = plant;
- b = individual boiler or prime mover technology within a plant: steam turbine, gas turbine, or internal combustion;
- m = month;
- f = specific fuel: bituminous, subbituminous, lignite, fuel oil no. 2, fuel oil no. 6, or natural gas;
- p = pollutant: NO_x, SO₂, VOC, or CO₂

The sources of the data for electric utility emissions are as follows:

- (1) EIA Form 759: *Monthly Power Plant Report* provides data on quantity of fuel consumed by specific fuel type and prime mover technology.
- (2) FERC Form 423: *Monthly Report of Cost and Quality of Fuels for Electric Plants* provides data on heat and sulfur content of delivered fuels.
- (3) EIA Form 767: *Steam-Electric Plant Operation and Design Report* provides consumption data for individual boilers by general fuel type.
- (4) EPA Report AP-42: *Compilation of Air Pollutant Emission Factors* provides the emission factors used.

NO_x, SO₂, AND VOC EMISSIONS FROM TRANSPORTATION

The emissions from the transportation sector are estimated by two sets of methodologies, one for on-highway emissions, and one for off-highway emissions. The off-highway methodologies are specific to each separate emission source group (ESG) (e.g. shipping, general aviation) and are not discussed in this paper. The on-highway emissions consist of emissions from the following sources: (1) light- and heavy-duty gas vehicles, (2) light- and heavy-duty diesel vehicles, and (3) passenger automobiles. The following equation demonstrates this methodology:

$$E_{s,j,m,y} = \sum_{i=1}^4 [V_{s,i,j,m,y} \times EF_{s,i,j,m,y}] \quad (2)$$

where:

- E = on-highway transportation emissions,
- V = vehicle miles traveled (VMT),
- EF = MOBILE4 emission factor (month-specific and state-specific)
- s = state,
- i = speed range,
- j = vehicle type,
- m = month, and
- y = year.

The vehicle miles traveled (VMT) were obtained from the U.S. Department of Transportation (DOT) publication *Highway Statistics* at a level of aggregation of state and year. This was disaggregated to speed type and vehicle type through factors provided by DOT to Cambridge Systematics Inc. These data were then further disaggregated to month level by use of fuel consumption data in *Highway Statistics*. The emission factors were obtained from the EPA model MOBILE4.

NO_x, SO₂, AND VOC EMISSIONS FROM NONUTILITY STATIONARY SOURCES

This methodology estimates the emissions from industrial fuel, commercial/residential, and miscellaneous sources as well as from various industrial processes. The following equation was used to estimate the NO_x, SO₂, and VOC emissions:

$$E_{i,m,s,y} = EM_i \times S_{i,s,y} \times G_{i,y} \times M_{i,m,s,y} \quad (3)$$

where:

- E = emissions,
- EM = 1985 NAPAP emissions,
- S = state share,
- G = growth rate,
- M = monthly activity index,
- i = emission source group (ESG),
- s = state,
- m = month, and
- y = year.

Sources for the data used in equation 3 are as follows:

- (1) EM, the 1985 NAPAP emissions, were derived from the EPA 1985 NAPAP Emissions Inventory and are an aggregation of various SCC codes to the ESG codes used in MSCET.
- (2) State shares were derived from the 1985 NAPAP inventory.

(3) Growth rates were derived from EPA *National Air Pollutant Emission Estimates*.

(4) M, monthly activity indices, were derived from differing sources depending on the general category, as follows:

(A) For the commercial/institutional and residential fuel combustion sectors, state-specific heating degree data were used.

(B) For the commercial/institutional coal sector, data from *Quarterly Coal Report* were used.

(C) For the industrial fuel combustion sector, data from *Monthly Energy Review* were used.

(D) For the industrial process and miscellaneous sectors, the following data were used:

(a) Production data in *Survey of Current Business* (Department of Commerce)

(b) Production data from the Federal Reserve Board

(c) 1985 NAPAP seasonal allocation factors

(d) Equal distribution among all months.

CO₂ EMISSIONS

The methodology for estimating CO₂ emissions from electric utilities was discussed under the electric utility section. This following is a discussion of the MSCET modelling of CO₂ emissions for nonutility sources.

The methodology for estimating CO₂ emissions is different from the methodology used for NO_x, SO₂, and VOC because CO₂ is not included in the 1985 NAPAP Emissions Inventory, so the CO₂ emissions from MSCET are not benchmarked to 1985 as are the other nonutility emissions. Also for this reason, the MSCET CO₂ emission estimates are not disaggregated to ESG code, as are those for NO_x, SO₂, and VOC. The CO₂ emissions were calculated using the following formula:

$$E_{m,s,y,f} = EF_f \times SEDS_{f,s,y} \times M_{m,f,y} \quad (4)$$

where:

E = emissions,

SEDS = *State Energy Data Report* energy consumption,

EF = emission factor,

M = monthly fractional fuel use (from *Monthly Energy Review*),

s = state,

m = month,

y = year, and

f = fuel.

The *State Energy Data Report* provides the SEDS data by state, year, and fuel type. The emission factors were obtained from a number of sources, and the monthly fractional fuel use was obtained from the *Monthly Energy Review*.

SELECTED RESULTS FROM MSCET

The following graphs present the progression from national annual emission trends to regional and seasonal emissions possible with the MSCET database. A couple of points of explanation are in order. First, the

northeast region consists of the following states: ME, NH, VT, MA, CT, RI, DE, MD, PA, NY, NJ, VA, WV, OH, IN, MI, IL, WI, and MN. Second, the seasonal emissions are given as annual rates (i.e., the rates shown are four times the seasonal total).

Figure 1 presents the MSCET national NO_x , SO_2 , VOC, and CO_2 emission trends for the period 1975 to 1990. The plot shows the first three emissions declining until about 1982. Since then, only VOC has shown a decline. CO_2 had its first peak in 1979 and its minimum in 1983. It has since risen to a new peak in 1989 where it remained in 1990.

Figure 2 presents MSCET emission trends for the Northeast. Of the acid rain precursors, SO_2 is the prominent pollutant in the region, followed by VOC and NO_x . Over the period 1975 to 1990, NO_x and VOC declined, although they increased slightly in 1984. SO_2 declined until 1984 when it rose slightly, declining in 1985 and remaining relatively constant until 1988 when it rose slightly, remaining constant until 1990. CO_2 declined from 1975 to 1983, rose in 1984, and increased until 1988, when it leveled off.

As Figure 3 demonstrates, the major contributor of NO_x emissions is the transportation sector. This sector shows major seasonal variation, with a peak in summer and a minimum in winter. The seasonal variation is about 0.5 Mt (2 Mt/yr annual rate). In the mid-1980s, the electric utility sector becomes the dominant sector. The counter-cyclical seasonal patterns of transportation and commercial residential fuel combustion tend to cancel each other when aggregated for the region.

As Figure 4 demonstrates, only the electric utility sector and the commercial/residential sector show any significant seasonal variability in SO_2 emissions. The electric utility sector is the dominant source of SO_2 emissions, which decline until 1983 and then rise in 1984.

As Figure 5 shows, the dominant contributor of VOC emissions is the transportation sector, with the large seasonal variation of 7 Mt/yr (annual rate). This seasonal variation declines sharply in 1989 because of the lower volatility of motor fuel sold. Also in the mid-1980s, the industrial process sector becomes the dominant VOC source.

Figure 6 presents the MSCET CO_2 seasonal emissions. The electric utility sector is the dominant source of CO_2 emissions, rising overall from 1975 to 1990. Emissions of CO_2 from the industrial sector show an overall decline over the period. Transportation CO_2 emissions show a slight increase, and commercial/residential emissions reach minimum in 1983 before increasing slightly until 1990.

REFERENCES

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Kohout, E., et al., *Current Emission Trends for Nitrogen Oxides, Sulfur Dioxide, and Volatile Organic Compounds by Month and State: Methodology and Results*, Argonne National Laboratory Report ANL/EAIS/TM-25 (August 1990).

Figure 1: National Annual Emission Trends

Figure 2: Northeast Annual Emission Trends

Figure 3: National NO_x Seasonal Emission Trends

Figure 4: National SO₂ Seasonal Emission Trends

Figure 5: National VOC Seasonal Emission Trends

Figure 6: National CO₂ Seasonal Emission Trends

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