Development and Evaluation of a Methodology for Determining Air Pollution Emissions Relative to Geophysical and Societal Change

Allen Williams and Zhining Tao
Illinois State Water Survey

Varkki Pallathucheril and Soo Jung Ha
University of Illinois, Department of Urban and Regional Planning

Kieran Donaghy
Cornell University, Department of City and Regional Planning

Geoffrey Hewings
University of Illinois, Department of Geography

Donald J. Wuebbles and Beth Bye
University of Illinois, Department of Atmospheric Sciences

1. INTRODUCTION

- The **principal objective of the project** was to develop an emissions inventory modeling system (EIMS) that can be used to predict future emissions inventories for different societal and climate change scenarios.

- **Future emissions are to be predicted** via simulations of econometric models, emissions development tools, and a vegetation model that are based on societal and climate change scenarios employing generally accepted growth factors.

- To **model anthropogenic emissions**, the 1999 National Emissions Inventory (NEI99) is mapped into two continuous-time regional econometric input-output models (CT-REIMs) whose sectors align with the North American Industry Classification System (NAICS), the REIMs are solved out 50 and 100 years to project future emissions, then the future emissions are mapped back into NEI99 format, which can be read by the emission process models.

- The **study areas** include the Chicago metropolitan area and the midwestern states.

- A **decision-support system** was developed to permit investigations of emissions inventories under a range of scenarios.

2. DEVELOPMENT OF THE EMISSIONS INVENTORY MODEL

The development of future emissions inventories in the present study is similar to traditional approaches, in which emissions (*EM*) are determined by emission intensity (*EMI*) and levels of emissions-producing activities:

$$EM = EMI \times activity,$$

where emission intensity (*EMI*) is in terms of pollutant emissions per emission activity, and ‘activity’ covers any form of economic and social actions that relate to emissions.

In this study we select economic activities (in terms of sectoral economic outputs), populations, energy usage, and vehicle miles traveled (VMT) as emissions-producing activities.

Modeling Strategy

1. Develop from two existing discrete-time REIMS two *continuous-time* versions to depict past, present, and future economic activities.

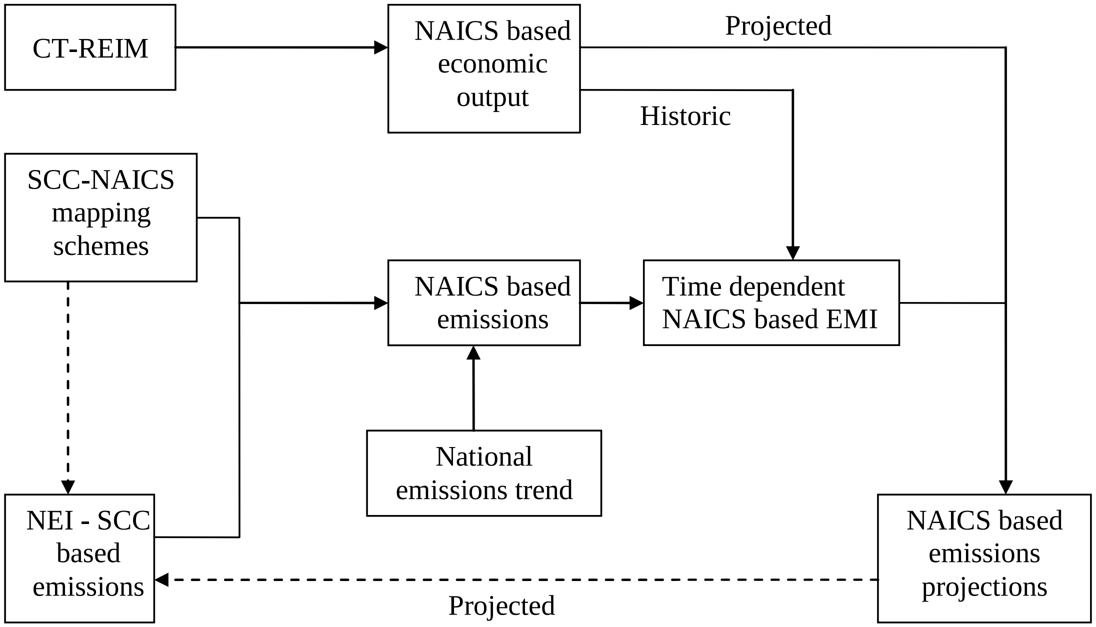
2. Develop emissions intensity factors (EMI) based on available data on emission inventories and economic/social activities.

3. Develop a mechanism to quantify changes in EMI related to shifts in energy and material usage, technological change, population change, and possible policy and regulation changes.

4. Survey historical and projected changes in emissions activities—e.g., energy, population, and VMT.

5. Develop future emission inventories based on the *EM=EMI* x *activity* relationship.

6. Map the activity-based emissions to process-based emissions that are catalogued by source classification code (SCC) to they can be input to emission process models, e.g., SMOKE, to generate speciated and gridded emissions at finer time resolution for air-quality models.



Schematic Overview of the Econometric-Emissions Modeling System

2.1 Continuous-Time Regional Econometric Input-Output Models (CT-REIMS)

The discrete-time REIM of the Chicago economy, developed by the Regional Economics Applications Laboratory of UIUC, was re-specificed as a continuous-time model and re-estimated with a system estimator (NL-quasi-FIML).

An explicit first-order exponential lag-adjustment procedure with negative feedback was imposed in the estimation to ensure stability in out-of-sample forecasting.

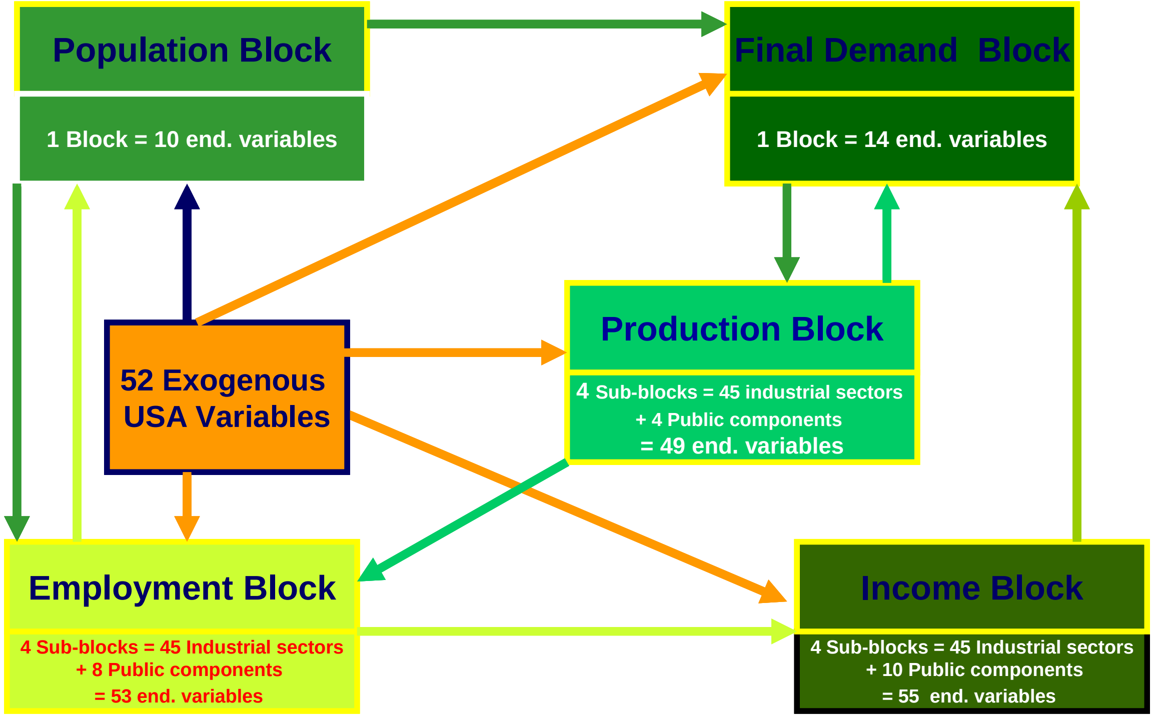
Equation blocs were first estimated separately and then together.

The following figure displays the structure of the Chicago model.

The in-sample fit of the CT-REIM for the economy of the Chicago metropolitan area is excellent with no variable having a proportional error in excess of 4%. Solutions of the model in simulations out of sample are also stable.

The model supports out-of-sample simulations for 30-, 50-, and 100-year periods at any frequency of temporal solution.

The Midwest model was developed similarly and also has good post estimation diagnostics.



Population Block

1 Block = 10 end. variables

Final Demand Block

1 Block = 14 end. variables

52 Exogenous USA Variables

Production Block

4 Sub-blocks = 45 industrial sectors
+ 4 Public components
= 49 end. variables

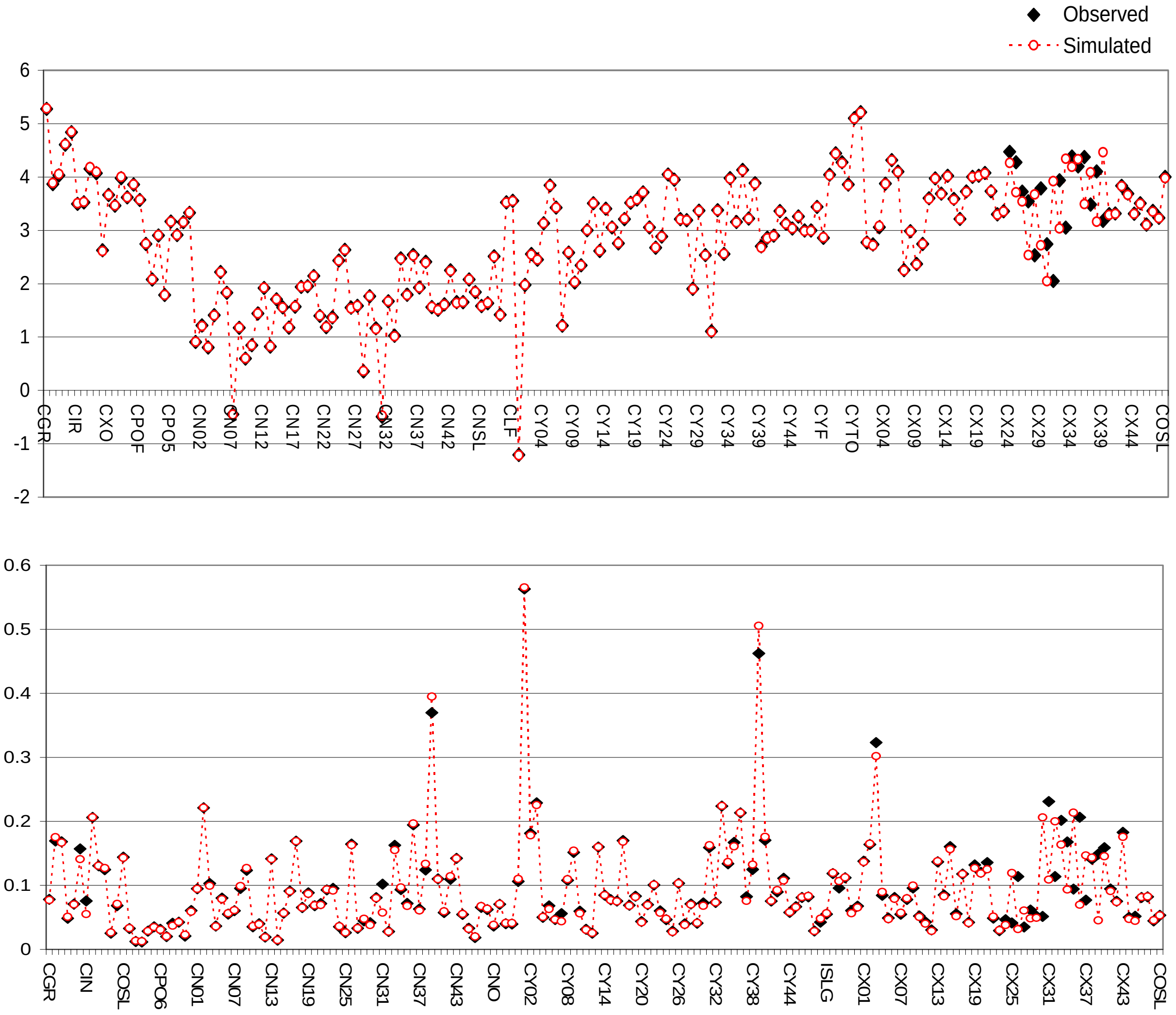
Employment Block

4 Sub-blocks = 45 Industrial sectors
+ 8 Public components
= 53 end. variables

Income Block

4 Sub-blocks = 45 Industrial sectors
+ 10 Public components
= 55 end. variables

Detailed CT-REIM structure for the Chicago Model



Comparison of Observed vs. In-Sample Solution Values of Endogenous Variables in the Chicago CT-REIM: Means (upper) and Standard Deviations (lower)

2.2 Emission Intensities

Emission intensities must be estimated from present emissions and levels of emission activities.

- ‘Present emissions’ are taken to be those in the NEI99, whereas

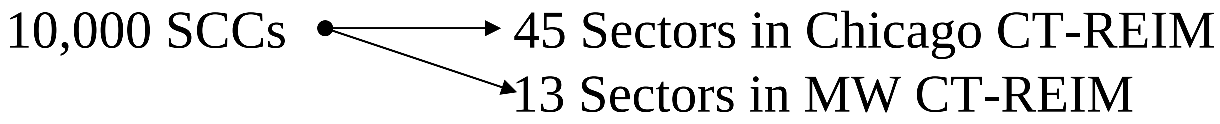
- ‘emission activities’ are represented by surrogates—e.g., sectoral economic output (for economic activity), vehicle miles traveled (for mobile emissions), and energy usage by households.

Sources:

Sectoral output – Chicago Federal Reserve Bank
VMT – http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.htm
Household energy usage – http://www.eia.doe.gov, http://www.census.gov

2.2.a SCC-NAICS Mapping (w/constant EMI)

NEI99 is organized and reported on the basis of the source classification code (SCC), reflecting specific actual emitting processes. The CT-REIM models use the North American Industry Classification system (NAICS) to represent economic activity. Thus SCC emissions must be mapped to emissions from NAICS activities.



10,000 SCCs

45 Sectors in Chicago CT-REIM

13 Sectors in MW CT-REIM

Solution strategy: construct look-up tables in which one column contains SCCs and the other contains NAICS codes.

In NEI99, all point sources and 16% of area sources have an SIC code (predating NAICS) associated with an SCC. 4% of area sources are related to household activities, hence population. The US EPA’s Economic Growth Analysis System (EGAS, http://www.epa.gov.ttn/chief/emch/projection/index/html), developed to generate activity growth factors in developing emission inventories, assigns 30% of area sources to a SIC. We assigned the remaining 50% on the basis of comparison of SCC and SIC coding. We then mapped SIC to NAICS codes.

We used VMT data to estimate the EMIs for two mobile source categories—light-duty and heavy-duty vehicles.

2.2.b Time-varying EMI

Reasonable emission scenario development must account for greater efficiencies in energy use and social concerns for a healthier environment, as well as rising emissions from increased energy use.

We constructed NEI99-like inventories for the period of 1970 to 2002 from the NEI AIR Pollutant Emissions Trends data (http://www.epa.gov/ttn/chief/trends).

We also compiled the emission activity data for the same period of time using results from the CT-REIM and historical records from USDOT, USDOE, and US Census Bureau. Based on our SCC-NAICS mapping, we calculated sectoral EMI for 1970-2002.

Subsequently we computed the average annual percentage change in EMI from each activity. *This average annual EMI change reflects, collectively, the pace of historical technological, economic, and policy changes*. By assuming the average EMI change rate continues into future, we can project a time-varying EMI for each activity: $EMI_t = EMI_0 \times (1 + \frac{rate}{100})^n$.

2.3 Emissions Scenario Development

Emission changes can result from changes in emission-producing activities, changes in emission intensities of those activities, or both. Depending on which type of change, or combination of changes one assumes, different emissions scenarios result. We consider scenarios with constant and changing EMIs.

2.4 Development of SCC-based Emissions Growth Factors

Once future emissions are estimated for each activity, we can develop activity-based growth factors and calculate SCC-based emissions by employing our SIC-NAICS look-up tables. We develop growth factors for each pollutant by sector, for each area considered, and for mobile and point sources.

2.5 Dynamic Global Vegetation Model

We investigated the effect of climate variation on vegetation distribution and biogenic emissions for the year 2050 with dynamic global vegatation models. The Integrated Biosphere Simulator (IBIS) and Agro-Ecosystem IBIS (Agro-IBIS) were used to simulate vegetation characteristics in response to the IPCC A1Fi climate scenario and to examine changes in the spatial distribution of biogenic emissions. The Agro-IBIS simulates both natural and managed vegetation. It contains a total of 16 vegetation biomes, each able to support a unique combination of plant functional types (PFT).

Current vegetation cover is derived from the Center of Sustainability and the Global Environment's Global Potential Vegetation Dataset, which represents potential vegetation without human influence.

Natural land cover was determined mainly by recalibrating satellite information through the DISCover land cover data set.

Agriculture was modeled separately. Meteorological variables were used to drive IBIS. After the initial spin-up, the models were run by cycling through the same year four times using daily data from a RCM for the years 1995—RCM1995—and 2050—RCM2050 with meteorological variables. The resolution of the RCM data is 30 km x 30 km, aggregated to 0.333° latitude by 0.333° longitude.

The following simulations were performed:

1) control using RCM1995 daily average data (hereafter called CONTROL);
2) future using RCM2050 daily average data (hereafter called FUTURE);
3) control using RCM1995 daily average data with crops (hereafter called CONTROL_CROP); and
4) future using RCM2050 daily average data with crops (hereafter called FUTURE_CROP).

- In order to investigate the sensitivity of biogenic emissions on climate, results from CONTROL and CONTROL_CROP are compared with results from FUTURE and FUTURE_CROP.

- Dynamic vegetation allows the vegetation to respond to the future climate and compete based on climatological constraints.

- The model was run for three years so that the vegetation could respond with the RCM2050 climate without reflecting any anomalies that may be present in the climate data. This allowed the vegetation to change slightly and the final output is in quasi-equilibrium.

3. RESULTS AND DISCUSSION

Results obtained from simulations with the CT-REIMS are based on two separate projections of future EMI (Tao et al., 2007) developed in this work. In one case the EMI for each sector is held constant so the change in emissions is due solely to changes in economic output. The second case is for a time varying EMI projected for each sector according to an extension of the past observed behavior.

For each EMI scenario the effects of two different emission control strategies are investigated.

1. We assume an 80% use of biodiesel fuel by trucks starting in 2007. The biodiesel scenario is projected to lead to a 40% reduction in CO and an 8% increase in NOx in truck transportation (Sector 29).

2. We assume that the US EPA's heavy duty diesel rule (HDDR, http://www.ucsusa.org/clean_vehicles/big_rig_cleanup/epas-heavyduty-diesel-rule.html) is put in place from 2007 onwards. In this case the NOx emissions coefficient for truck transportation is reduced by 95%.

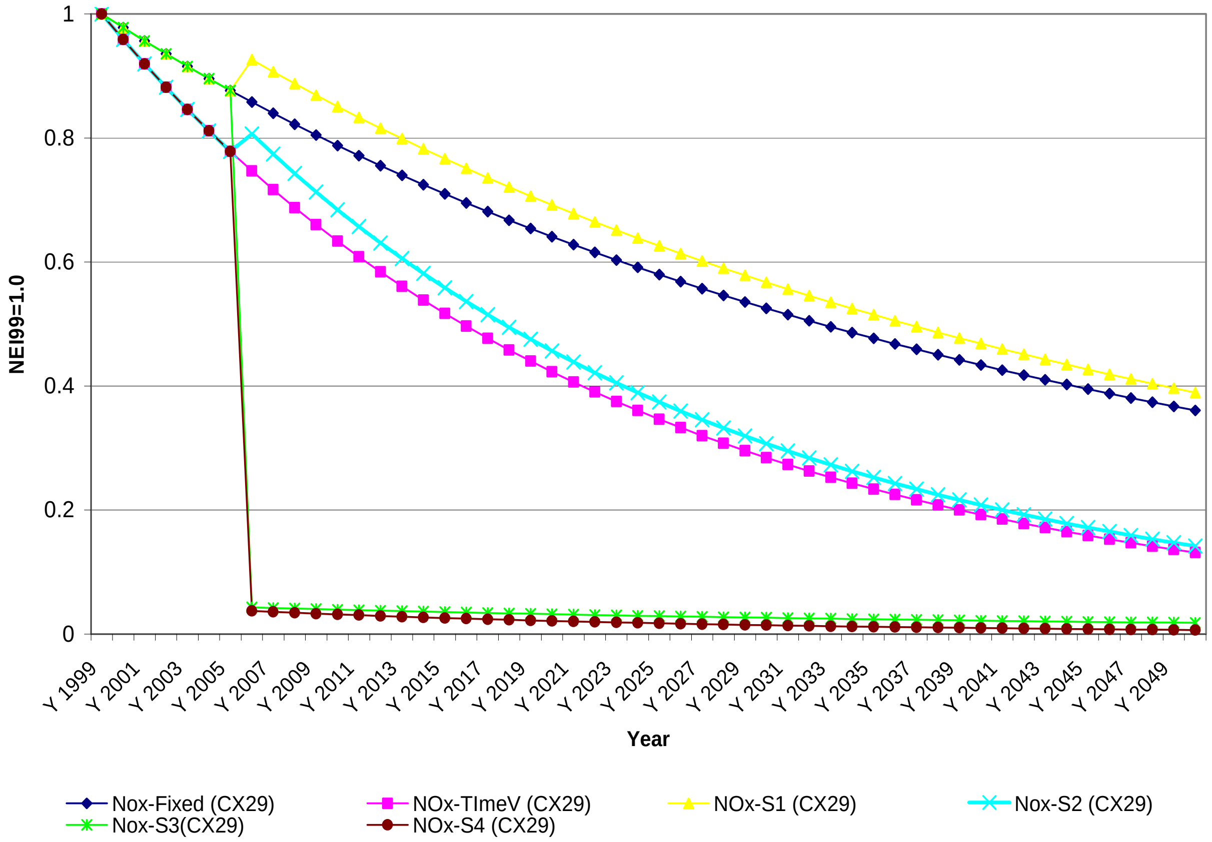
(These four scenarios—two strategies w/two assumptions about EMI—are only examples of the kinds of scenarios that could be studies with the EIMS)

3.1. Chicago Case

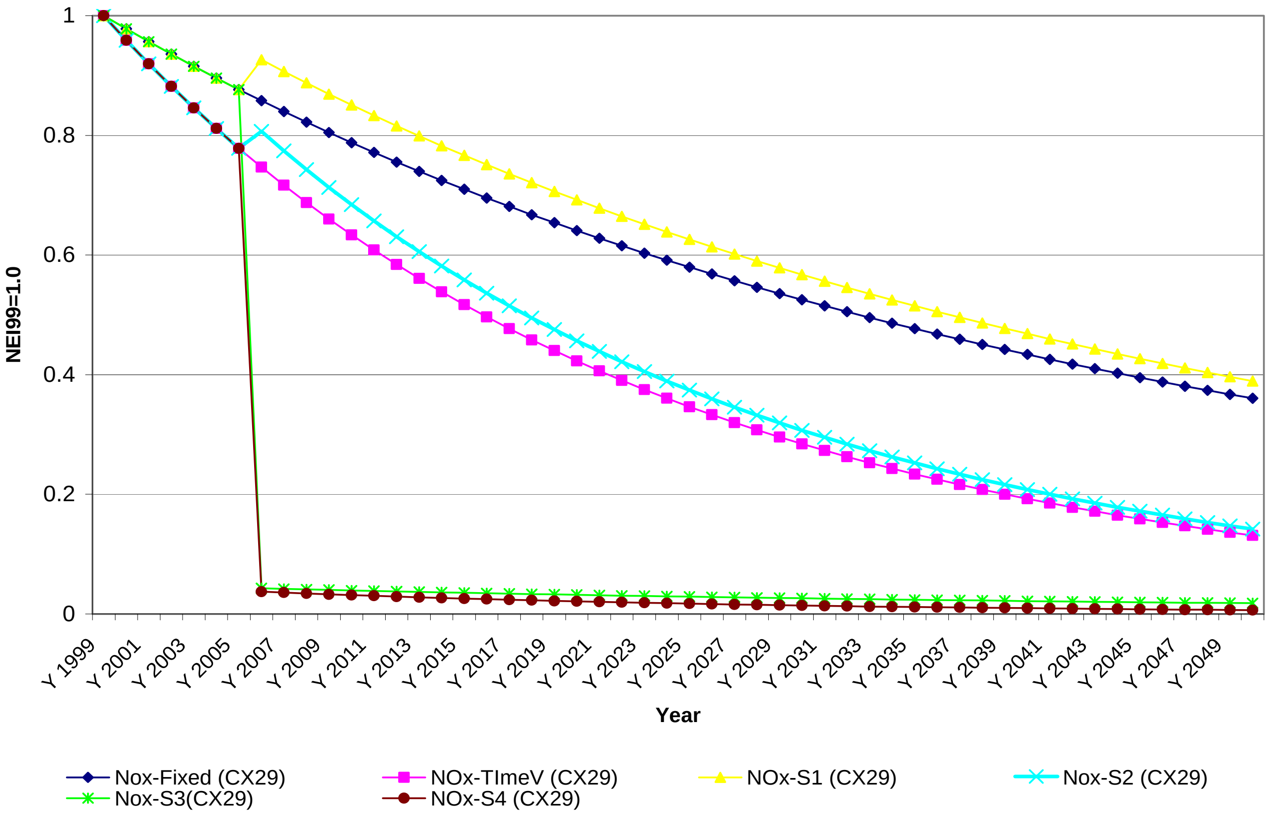
The developed emission inventory model was first applied to Chicago metropolitan area that covers Cook, DuPage, Kane, Lake, McHenry, and Will counties. The pollutants considered are the criteria pollutants carbon monoxide (CO), nitrogen oxide (NOx), sulfur dioxide (SO2), and particular matter (PM10 and PM2.5 with diameter less than 10 and 2.5 µm, respectively). In addition, volatile organic compound (VOC) and ammonia (NH3) are also included.

1970-2002 Average Annual EMI Change Rate (%/year), Chicago MA

Sector	CO	NH3	NOx	PM10	PM25	SO2	VOC
1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	-0.0968	0.0000	0.0000	0.0000	0.0000	-1.0340	-2.7306
5	0.0000	-5.6438	0.0000	-1.6798	0.0000	0.0000	-1.1730
Manufacture (sectors 6-23)	-3.5641	-14.1154	-1.4860	-5.4551	-3.8971	-3.6795	-2.9989
Services (sectors 24-45)	-1.0656	-11.9354	-1.9604	-1.3065	-2.8810	-4.9153	-2.9665
CXFGE + CXSLGE	-1.0656	-11.9354	-1.9604	-1.3065	-2.8810	-4.9153	-2.9665
Household	-0.5424	-6.6199	-0.2426	-0.0751	-2.8790	-2.8788	-1.2384
LDV	-5.2013	0.0000	-3.9352	-4.8770	-8.2240	-2.1633	-6.2223
Truck	-5.2013	0.0000	-3.9352	-4.8770	-8.2240	-2.1633	-6.2223



CO Emissions from Sector 29 Relative (to 1999), under the Scenarios for Chicago
(Sector 29: Truck Transportation, Warehousing, Waste and Remediation Services)



NOx Emissions from Sector 29 Relative (to 1999), under the Scenarios for Chicago

3.2 Midwest Case

Sector Mnemonic of Midwest CT-REIM

Sector	Sector description	NAICS
1	Agriculture, Forestry and Fisheries	111,112,113,114,115
2	Mining	21
3	Construction	23
4	Food and Kindred Products	311
5	Chemicals and Allied Products	325
6	Primary Metals Industries	331
7	Fabricated Metal Products	332
8	Industrial Machinery and Equipment	333
9	Electronic and other Electric Equipment	334,335
10	Transportation Equipment	336
11	Other Non-durable Manufacturing	312, 313, 314, 315, 322, 323, 511, 516, 324, 326, 316
12	Other Durable Manufacturing	321,337,327,339
13	TCU, Service and Government Enterprises	the rest of all sectors except above ones
XOFGC	Output, Other Federal Government, Civilian	

Example: Present EMI for Each Emission Activity[1] for Illinois

Sector	CO	NH3	NOx	PM10	PM25	SO2	VOC
EMI							
1	54.9331	11.2910	4.7382	42.4935	8.9608	0.5166	4.3247
2	1.8047	0.0010	1.0691	10.0137	2.3904	0.2590	0.2317
3	1.2250	0.0009	0.7984	1.8105	0.4202	0.1060	0.1510
4	0.7668	0.0070	0.6907	0.3053	0.1652	1.2111	0.4782
5	1.3782	0.0070	0.7527	0.2563	0.1870	1.5423	1.1746
6	5.7059	0.0083	1.2078	1.0644	0.9398	1.3817	0.7708
7	0.5079	0.0074	0.2301	0.0732	0.0580	0.1625	1.7290
8	0.4630	0.0071	0.2011	0.0376	0.0293	0.1641	0.3585
9	0.4455	0.0070	0.1412	0.0370	0.0311	0.0858	0.7309
10	0.4660	0.0070	0.2425	0.0443	0.0369	0.2278	0.6031
11	0.5493	0.0249	0.8769	0.1696	0.1206	2.7562	0.9443
12	0.5531	0.0243	0.8093	0.3228	0.1832	1.2425	1.2157
13	1.0807	0.0460	1.2146	0.1474	0.1228	2.2217	0.4712
XOFGC	0.4238	0.0005	0.4116	0.2831	0.1595	0.3528	0.4243
Household[2]	0.0106	0.0000	0.0021	0.0270	0.0059	0.0004	0.0091
LDV[3]	27.3122	0.1076	1.6403	0.0366	0.0210	0.0840	2.1254
Truck[3]	16.9250	0.0339	15.2099	0.5084	0.4444	0.3966	1.8357

1 unit is tons/million $ output unless otherwise indicated
2 unit is tons/person
3 unit is tons/million miles traveled

Example: Average Annual EMI Change Rate for Illinois

Average annual EMI change rate (%/year)

1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	0.0000	-2.2411	0.0000	0.0000	0.0000	-0.1549	0.0000
3	0.0000	-2.3976	0.0000	-1.6026	0.0000	0.0000	0.0000
4	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
5	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
6	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
7	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
8	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
9	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
10	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
11	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
12	-3.5288	-4.7946	-2.0249	-5.7496	-1.9225	-4.3160	-3.4497
13	-0.3258	-1.4404	-2.2146	-3.9075	0.0000	-3.8584	-3.2301
XOFGC	-0.3258	-1.4404	-2.2146	-3.9075	0.0000	-3.8584	-3.2301
Household	-2.2079	0.0000	-0.3422	0.0000	-0.5199	-3.1076	-1.4950
LDV	-5.7078	0.0000	-4.4496	-5.3876	-8.3927	-2.6872	-6.7236
Truck	-6.4950	0.0000	-5.2496	-6.1760	-9.1275	-3.5013	-7.5065

The Midwest Model coves the five states of Illinois, Indiana, Michigan, Ohio, and Wisconsin and the rest of the U.S. The regional differences in EMI are large, reflecting the structural inhomogeneity in the state economies and the imbalance of technology penetration.

Holding EMI constant, emission inventories produced for Michigan show the most decreasing trend for the Midwest region, except in the case of SO2, where Illinois has the most decreasing pattern. Generally, Wisconsin is the most unchanged state in producing its emission into future.

State Emissions as a Fraction of 1999 Inventory for Fixed EMI Coefficients

	Rest of U.S.			Illinois			Indiana			Michigan			Ohio			Wisconsin		
	2010	2035	2060	2010	2035	2060	2010	2035	2060	2010	2035	2060	2010	2035	2060	2010	2035	2060
CO	0.790	0.517	0.379	0.934	0.847	0.800	0.828	0.598	0.481	0.750	0.408	0.235	0.904	0.737	0.618	0.990	0.977	0.970
NH3	0.799	0.457	0.275	0.975	0.936	0.908	0.785	0.446	0.280	0.766	0.397	0.220	0.923	0.759	0.641	0.998	0.993	0.989
NOx	0.856	0.705	0.644	0.833	0.618	0.513	0.923	0.816	0.755	0.788	0.539	0.416	0.848	0.622	0.486	0.972	0.940	0.924
PM10	0.859	0.669	0.571	0.893	0757	0.687	0.873	0.698	0.604	0.737	0.395	0.228	0.883	0.698	0.576	0.936	0.888	0.874
PM25	0.840	0.641	0.545	0.874	0.715	0.636	0.889	0.737	0.656	0.748	0.421	0.260	0.876	0.682	0.556	0.940	0.893	0.878
SO2	0.843	0.684	0.621	0.816	0.574	0.453	0.960	0.895	0.848	0.915	0.785	0.692	0.882	0.700	0.585	0.967	0.915	0.880
VOC	0.811	0.610	0.529	0.815	0.577	0.460	0.931	0.832	0.774	0.785	0.518	0.384	0.862	0.644	0.505	0.968	0.924	0.898

Comparative emission inventory participation of each state in total inventory:

- Other states’shares of CO continue to increase. By 2035, the CO share of Ohio becomes bigger than Michigan’s share.
- In the case of NH3 for 2010, Michigan is ranked as 1st, Wisconsin as 2nd, and Ohio as 3rd, but in 2060, the ranking is changed with Wisconsin, Ohio, and Illinois's share of NH3 are increased.
- Even though NOx emission shares for Michigan, Ohio, and Illinois decrease with time, Michigan is still the biggest contributor to NOx emission inventories.
- While Michigan drops to only 3% of total PM10 and PM25 emission, the SO2 share of Michigan stays around 10%.
- While Michigan, Ohio, and Illinois contribute smaller shares of VOC emission, the corresponding shares grow in Indiana and Wisconsin.

Comparative State Emissions as a Fraction of Total State Emissions for Fixed EMI Coefficients

	Rest of U.S.			**Illinois**			**Indiana**			**Michigan**			**Ohio**			**Wisconsin**		
	2010	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**
CO	0.575	0.550	0.530	0.038	0.051	0.063	0.036	0.038	0.041	0.167	0.133	0.101	0.137	0.163	0.180	0.043	0.063	0.082
NH3	0.671	0.608	0.520	0.031	0.046	0.065	0.033	0.030	0.027	0.101	0.084	0.067	0.074	0.096	0.117	0.087	0.134	0.193
NOx	0.780	0.790	0.803	0.035	0.032	0.029	0.040	0.044	0.045	0.070	0.059	0.050	0.049	0.044	0.038	0.024	0.028	0.031
PM10	0.674	0.676	0.678	0.061	0.067	0.072	0.065	0.067	0.068	0.070	0.048	0.032	0.079	0.080	0.078	0.049	0.060	0.069
PM25	0.695	0.691	0.692	0.057	0.061	0.064	0.067	0.072	0.076	0.065	0.047	0.034	0.071	0.072	0.069	0.043	0.053	0.062
SO2	0.693	0.688	0.695	0.068	0.058	0.051	0.057	0.065	0.069	0.102	0.107	0.105	0.057	0.055	0.051	0.020	0.024	0.026
VOC	0.698	0.698	0.709	0.044	0.041	0.038	0.046	0.055	0.060	0.107	0.094	0.082	0.071	0.071	0.065	0.031	0.039	0.044

For time-varying EMI:

- Michigan is the state with the most reduced emissions of all kinds by 2060, which is a similar pattern to the fixed EMI results.

But emission inventories with time-varying EMI in the states with less reductions show different characteristics in comparison with the fixed EMI’s case.

- The amount of CO produced in Wisconsin decreases slowly compared with other Midwest regions.
- Ohio shows the smallest decreasing rate of NH3 and Rest of U.S. is very slow to reduce its NOx emission.

State Emissions as a Fraction of 1999 Inventory for Changing EMI Coefficients

	Rest of U.S.			Illinois			Indiana			Michigan			Ohio			Wisconsin		
	2010	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**
CO	0.633	0.295	0.176	0.646	0.255	0.108	0.541	0.203	0.124	0.604	0.207	0.080	0.601	0.289	0.224	0.853	0.604	0.435
NH3	0.557	0.187	0.082	0.570	0.162	0.047	0.487	0.167	0.107	0.459	0.095	0.030	0.575	0.279	0.230	0.483	0.133	0.076
NOx	0.778	0.551	0.445	0.681	0.315	0.160	0.735	0.416	0.276	0.658	0.285	0.137	0.688	0.330	0.191	0.715	0.347	0.179
PM10	0.674	0.360	0.227	0.555	0.167	0.062	0.667	0.475	0.436	0.427	0.081	0.027	0.556	0.259	0.206	0.515	0.149	0.075
PM25	0.794	0.570	0.483	0.744	0.406	0.234	0.770	0.526	0.431	0.618	0.226	0.094	0.724	0.401	0.274	0.731	0.390	0.225
SO2	0.599	0.269	0.146	0.511	0.126	0.036	0.498	0.130	0.050	0.551	0.148	0.041	0.537	0.155	0.058	0.587	0.182	0.060
VOC	0.607	0.250	0.121	0.560	0.169	0.057	0.600	0.213	0.093	0.542	0.152	0.050	0.610	0.253	0.156	0.639	0.246	0.107

In comparative terms:

- The share of CO produced from Michigan is decreased and Ohio becomes the biggest producer of CO by 2060.
- Ohio’s share of NH3 increases quickly, making it the highest producer of NH3.
- Indiana increases up to 13.5% of total PM10 inventory in 2060 and all states except Indiana show the decreasing trend of their PM25 share.
- In general, all states are decreasing their share of NOx and SO2, which indicates the shares of NOx and SO2 emissions from Rest of U.S. are growing.

Comparative State Emissions as a Fraction of Total State Emissions for Changing EMI Coefficients

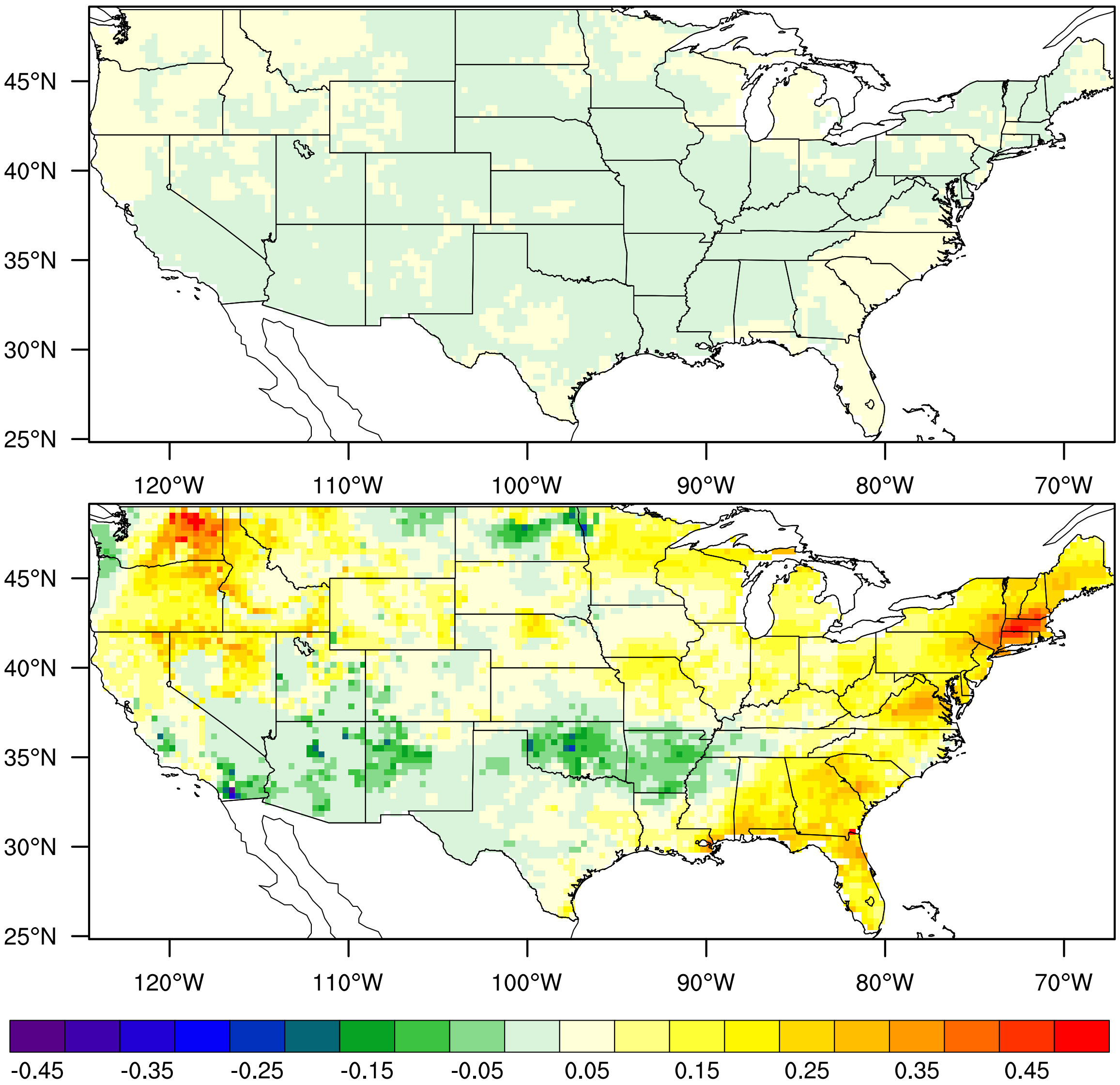
	Rest of U.S.			**Illinois**			**Indiana**			**Michigan**			**Ohio**			**Wisconsin**		
	2010	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**	**2010**	**2035**	**2060**
CO	0.594	0.611	0.612	0.034	0.030	0.021	0.031	0.025	0.026	0.173	0.131	0.085	0.117	0.124	0.162	0.048	0.075	0.091
NH3	0.714	0.728	0.664	0.027	0.023	0.014	0.031	0.032	0.043	0.093	0.058	0.039	0.070	0.103	0.175	0.062	0.053	0.062
NOx	0.799	0.855	0.896	0.032	0.022	0.015	0.036	0.031	0.026	0.066	0.043	0.027	0.044	0.032	0.024	0.019	0.014	0.009
PM10	0.719	0.766	0.742	0.052	0.031	0.017	0.068	0.096	0.135	0.055	0.021	0.010	0.067	0.062	0.076	0.036	0.021	0.016
PM25	0.721	0.775	0.818	0.053	0.043	0.031	0.063	0.065	0.066	0.059	0.032	0.016	0.065	0.053	0.045	0.037	0.029	0.021
SO2	0.730	0.081	0.884	0.063	0.039	0.022	0.044	0.028	0.022	0.091	0.061	0.034	0.051	0.037	0.027	0.018	0.014	0.009
VOC	0.717	0.755	0.770	0.041	0.032	0.023	0.041	0.037	0.034	0.102	0.073	0.050	0.069	0.073	0.095	0.028	0.027	0.025

3.3 Biogenic Emissions

Biogenic emissions are sensitive to a variety of factors including climate variables and vegetation characteristics. Increases in all biogenic emissions were predicted for the year 2050, however actual changes in emissions depend on regional and local environments. The 2050 climate scenario causes changes in vegetation structure and growth. Including both changes in climate and changes in vegetation structure, BVOC emissions increase by 17% over the entire U.S., while NOx emissions increases by 24%. The largest increase in emissions during the summer months is located in the eastern and northwest regions of the U.S. The largest decreases are mainly within the south-central U.S. areas.

The following figure shows the difference in isoprene emissions between the FUTURE and FUTURE_CROP scenarios and the CONTROL and CONTROL_CROP simulations for January and July.

Emissions show little change in January, but July shows regional differences regarding changes in isoprene emissions. For example, the eastern U.S. shows moderate to high increases in isoprene fluxes due to an increase in temperature for this region.



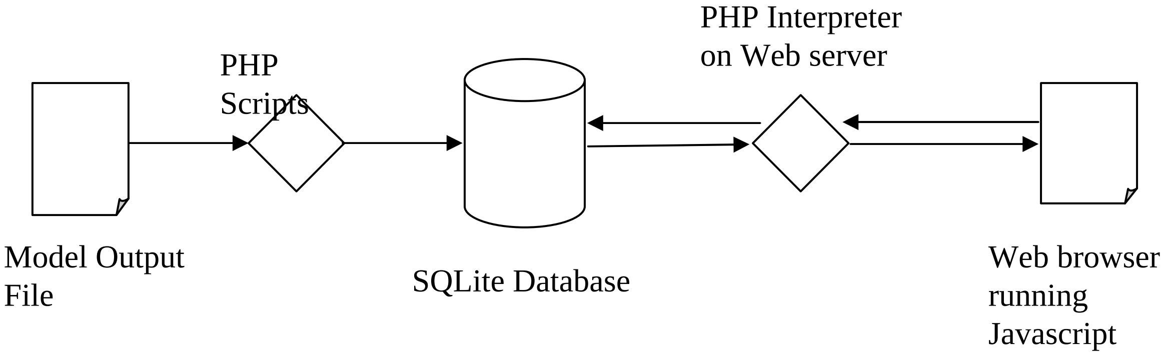
Difference (FUTURE-CONTROL*) between 2050 and 1995 simulated isoprene emission rates (g C m-2 month-1) during January (top) and July (bottom). * FUTURE refers to FUTURE and FUTURE_CROP and CONTROL refers to CONTROL and CONTROL_CROP simulations.

4. Decision Support System (DSS)

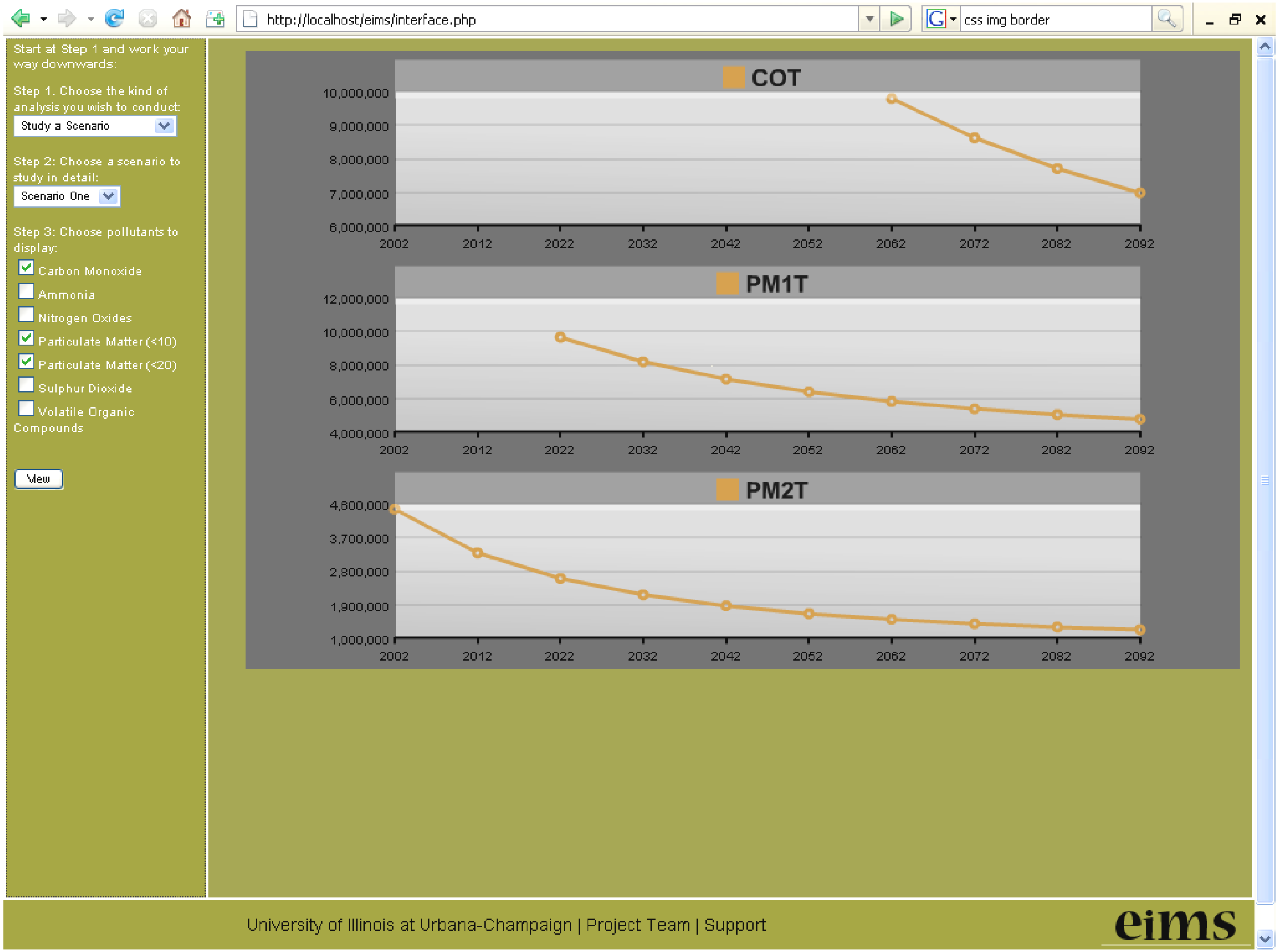
In developing the decision-support system for the project we have sought to make accessible the large amounts of data about future emissions under multiple scenarios that are produced through the coupling of the different sub-models. The resulting decision support system is intended to provide access to these data in a way that is both intuitive and does not result in cognitive overload.

This objective is realized through a Web-based decision support system that is loosely coupled with the underlying models. A Web-based system allows broad-based access to the system yet at the same time the system can more easily be kept current over time when compared to a standalone system that is run by end users.

The modular structure of the resulting system allows development of the various components to occur in parallel and development of one component is not hampered by setbacks in others.



Modeling framework of DSS



http://localhost/eims/interface.php

css img border

Start at Step 1 and work your way downwards:

Step 1. Choose the kind of analysis you wish to conduct: Study a Scenario

Step 2: Choose a scenario to study in detail: Scenario One

Step 3: Choose pollutants to display:

☑ Carbon Monoxide
☐ Ammonia
☐ Nitrogen Oxides
☑ Particulate Matter (<10)
☑ Particulate Matter (<20)
☐ Sulphur Dioxide
☐ Volatile Organic Compounds

University of Illinois at Urbana-Champaign | Project Team | Support

Sample Screen of Decision Support System

5. Future Improvements

The prototype of the EIMS developed in this study shows promise and flexibility for formulating future emissions scenarios based on regional social-econometric-technological advances. There is room for improvement:

Regional CT-REIM models, such as we have developed for the Midwest states, might be developed for other regions and then linked together for use in emissions inventory projections or simulations. Improvements in the specification of CT-REIMS can certainly be achieved to clarify structural relationships and to better frame policy choices and reactions to the same.

EMI can be better modeled. A new approach for estimation of future emission intensity would be to formulate the emission intensity of a particular pollutant from a given economic sector based on its past correspondence with the output of all sectors.

The EIMS DSS can be improved as well. While a textual description of the underlying model has been made available to users, a graphic representation of model structure would allow users to more easily identify how estimates of emissions have been produced.