Improving Spatial Resolution of EDGAR Emissions for Mexico

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Introduction / Motivation

- High-resolution emissions are generally lacking within Mexico (Figure 1), which poses challenges to communities on the U.S.-Mexico border as they try to determine the sources of emissions impacting their air quality
- The two cities of El Paso, Texas (844,000 people) and Ciudad Juárez, Mexico (2.54 million people) sit on either side of the U.S.-Mexico border near the westernmost Texas border.
- EDGAR emissions have global coverage at a resolution of 0.1˚x0.1˚, but air quality simulations require a finer resolution (~ 0.01˚x0.01˚or ~ 1 km x 1km)
- In this work we:
  - **Determined the major sectors contributing to major air quality-relevant species within Ciudad Juárez**
  - **Redistributed these emissions at a higher spatial resolution**

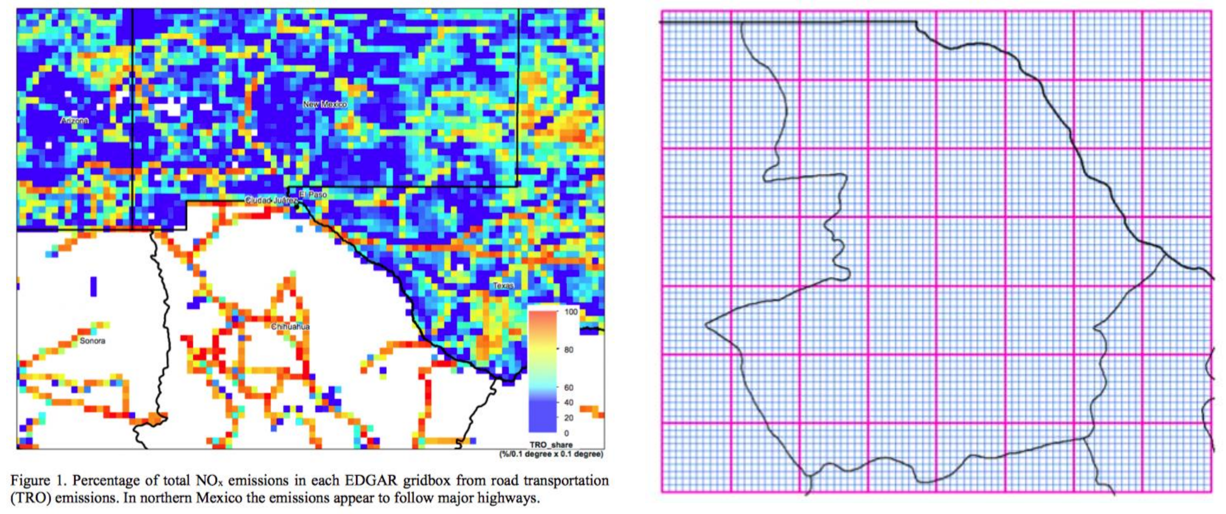

Figure 1. Percentage of total NO_x emissions in each EDGAR gridbox from road transportation (TRO) emissions. In northern Mexico the emissions appear to follow major highways.

Satellite Imagery and Census Data Analysis and Emission Redistribution

Table 9. List of Sectors and Pollutants by Reallocation Method.

Sector	Name	Pollutants	Reallocation Method
RCO	Residential Combustion	NO_x, NMVOC, CO, SO_2, BC, OC, $PM_{2.5}$, PM_{10}	Urban/Rural NALCMS
IND	Combustion for Manufacturing Industry	NO_x, SO_2, BC, OC, $PM_{2.5}$	Urban/Rural NALCMS
TRO	Road Transportation	NO_x, NMVOC, CO, BC, $PM_{2.5}$	Major Roads
REF TRF	Oil Refineries	NMVOC, SO_2, BC, $PM_{2.5}$, PM_{10}	Urban/Rural NALCMS
ENE	Power Industry	NO_x, SO_2, $PM_{2.5}$, PM_{10}	Point Source
FOO PAP	Food and Paper Production	NMVOC, SO_2, PM_{10}	Urban/Rural NALCMS
TNR	Non-Road Transportation	CO	Railways
CHE	Production of Chemicals	NMVOC	Urban/Rural NALCMS

- Table 9 lists the major pollutant sectors for Ciudad Juárez
- On-Road and Off-Road transportation emissions (TRO, TNR) were reallocated using high-resolution road datasets and railway datasets
- Power emissions (ENE) were reallocated based on the identification of major point-source power plants
- All other emissions were reallocated via a population proxy (based on census data) split among urban and rural populations
- Figure 13 shows a satellite image and grid-level image with the urban areas in green
- Our procedure was to move sector-by-sector and perform spatial reallocations of the emissions.

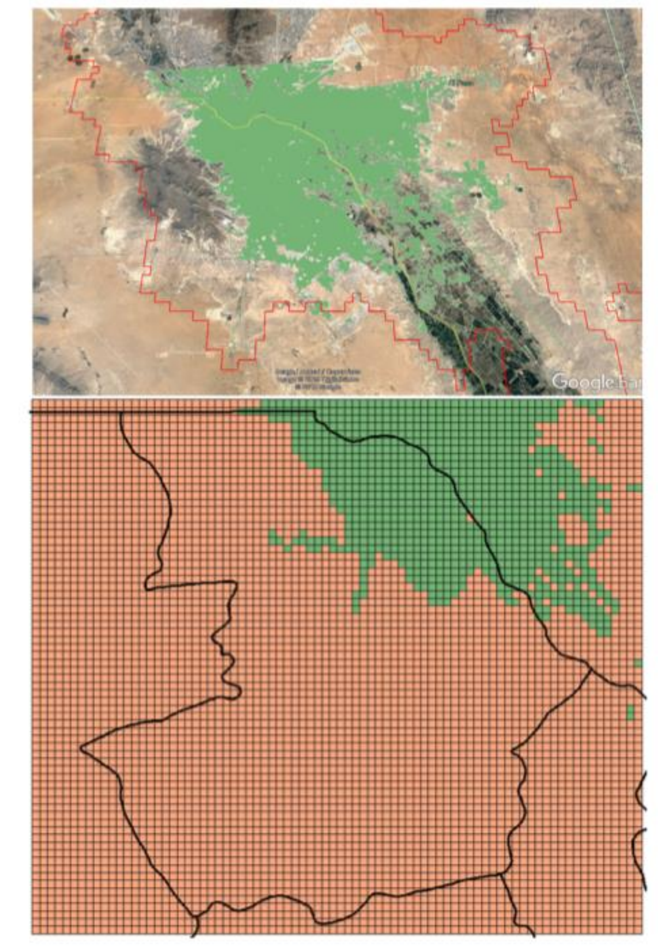

Figure 13. (Top) GRUMP Urban Extent (red outline) and NALCMS Urban land (green shading) over the El Paso/ Juárez area. (Bottom) Fine Grid: Urban (green) and Rural (orange) land use.

- For RCO (residential combustion), the EDGAR emissions show higher NO_x emissions in the rural regions and lower emissions in the urban regions. Thus a redistribution based on a scaling of emissions by a population proxy results in three cases:
  - *High emissions x low population*: low overall emissions
  - *Low emissions x high population*: moderate overall emissions
  - *Moderate emissions x moderate population*: high emissions
- This results in an overall NO_x emissions reallocation that follows population with a slight "ring-effect" where higher EDGAR emissions are redistributed over a sub-urban population

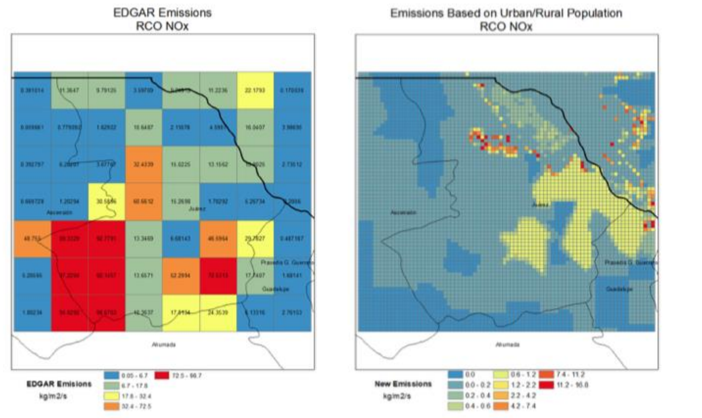

Figure 15. Sector RCO Pollutant NO_x (Left) EDGAR Emissions and (Right) Reallocated Emissions by Urban-Rural Population.

- For TRO (on-road transportation), the EDGAR emissions show high NO_x emissions over urban and suburban regions as well as regions with major transportation corridors, and little emissions over rural regions
- We reallocated TRO emissions based on the location of major transportation corridors within cities and between cities. If there were no transportation corridors in a grid cell with EDGAR emissions, we distributed emissions over the EDGAR grid cell
- The resulting reallocation is well-represented in regions with major transportation corridors, while rural regions without major transportation corridors lack any TRO emissions reallocation

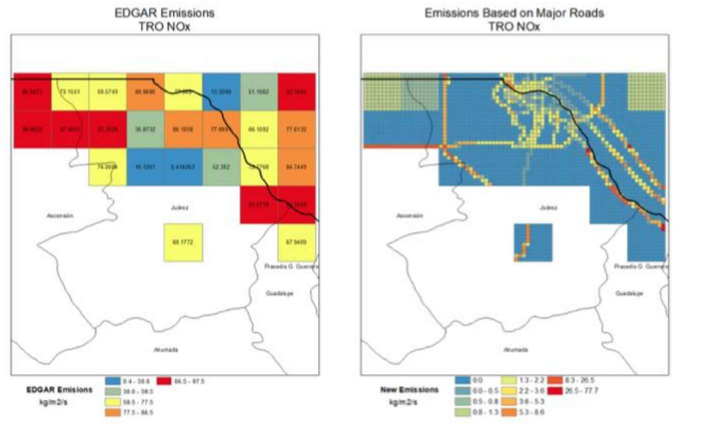

Figure 17. Sector TRO Pollutant NO_x (Left) EDGAR Emissions (Right) Reallocated Emissions by Major Roads.

EDGAR Emissions

- The Emissions Database for Global Atmospheric Research (EDGAR) v4.3.2 emission inventory (Crippa et al., 2018) is created using country-level data on factors to create country-specific time series (1970- 2012)
- Figure 3 shows Mexican NO_x emissions are continuing to increase (due largely to the transportation sector) while NMVOC emissions have leveled off

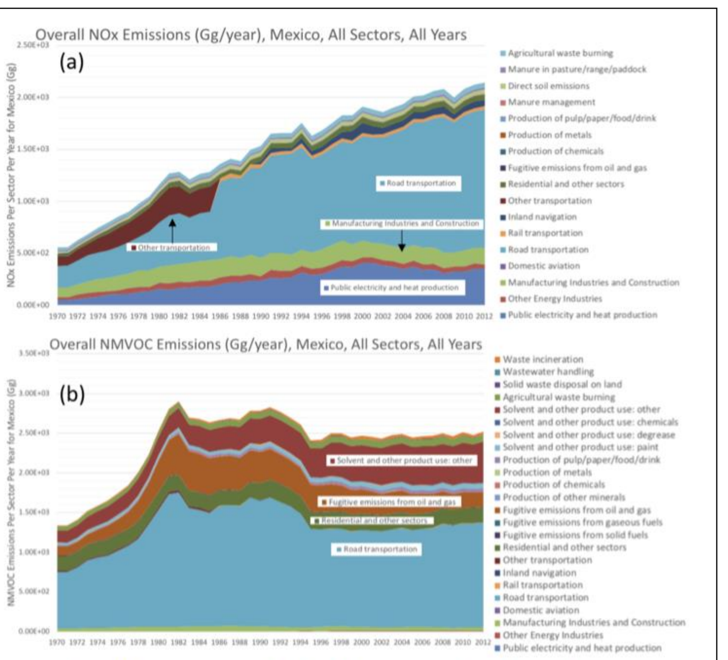

Figure 3. (a) Stacked time series plot of EDGAR v4.3.2 emissions of NO_x (Gg/year) from emission sectors in Mexico (b) Similar plot for NMVOC emissions.

Table 2. Emissions for Each Sector and Major Chemical Species in Ciudad Juárez

Sector	Code	NO_x	NMVOC	CO	SO_2	BC	OC	PM10	PM2.5
Agricultural Soils	AGS	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Agricultural Waste Burning	AWB	0.02%	0.04%	0.01%	0.01%	0.08%	0.62%	0.38%	0.61%
Production of Chemicals	CHE	0.01%	4.49%	0.00%	2.97%	0.02%	0.00%	0.11%	0.13%
Power Industry	ENE	14.98%	0.49%	0.22%	9.73%	0.33%	0.36%	1.19%	1.46%
Fossil Fuel Fires	FFF	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Production of Foods	FOO	0.25%	5.12%	0.00%	5.32%	0.09%	0.00%	5.20%	1.30%
Indirect Emissions	IDE	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Manufacturing Industry	IND	14.59%	4.35%	1.78%	46.85%	19.87%	15.28%	21.73%	27.40%
Production of Iron and Steel	IRO	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.11%	0.16%
Manure Management	MNM	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Production of Non-Ferrous Metals	NFE	0.00%	0.00%	0.00%	0.00%	0.13%	0.00%	0.97%	0.82%
Production of Non-Metalic Minerals	NMM	0.00%	0.02%	0.00%	0.00%	0.91%	0.00%	4.48%	4.56%
Production of Paper and Pulp	PAP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fuel Production/Transportation	PRO	0.00%	0.84%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Residential	RCO	8.58%	10.95%	34.14%	16.31%	43.43%	75.61%	58.28%	50.78%
Oil Refineries	REF	5.03%	11.22%	0.07%	16.87%	18.77%	1.78%	4.33%	7.29%
Solid Waste Disposal	SWD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Non-Road Transport	TNR	1.65%	0.11%	16.32%	0.29%	0.82%	0.21%	0.36%	0.62%
Transformation Industry	TRF	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Road Transportation	TRO	54.73%	62.33%	47.46%	1.65%	15.55%	6.13%	2.86%	4.87%
Waste Water	WWT	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 2 summarizes the EDGAR sectors and their percentage contribution to total emissions over Ciudad Juárez.

Table 3. Sectors that Make Up > 90% of Emissions for Each Species in Ciudad Juárez

Pollutant	NO_x	NMVOC	CO	SO_2	BC	OC	PM10	PM2.5
% Covered by Listed Sectors	92.88%	94.10%	97.92%	95.07%	97.63%	90.89%	90.72%	91.81%
Sectors	ENE TRO IND RCO	TRO REF RCO FOO CHE	TRO RCO TNR	IND ENE REF RCO FOO	RCO REF IND TRO	RCO IND	RCO IND FOO ENE REF	RCO IND REF ENE TRO

Table 3 lists the sectors which collectively total > 90% of the emissions for each species.

Acknowledgements

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Traffic Data via Google API

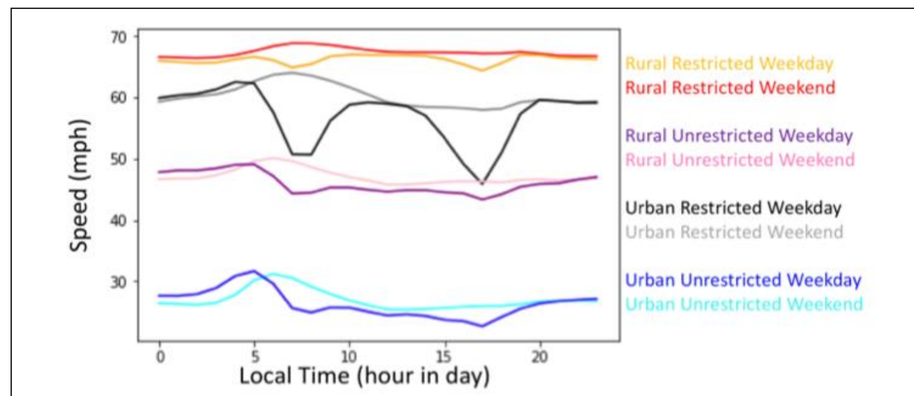


Figure 7. Default MOVES-Mexico Hourly Speeds on the Four Road Types for Both Weekday and Weekends

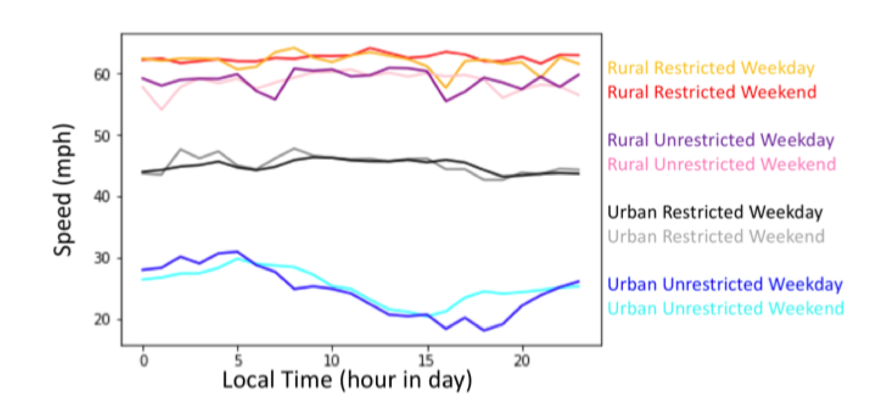
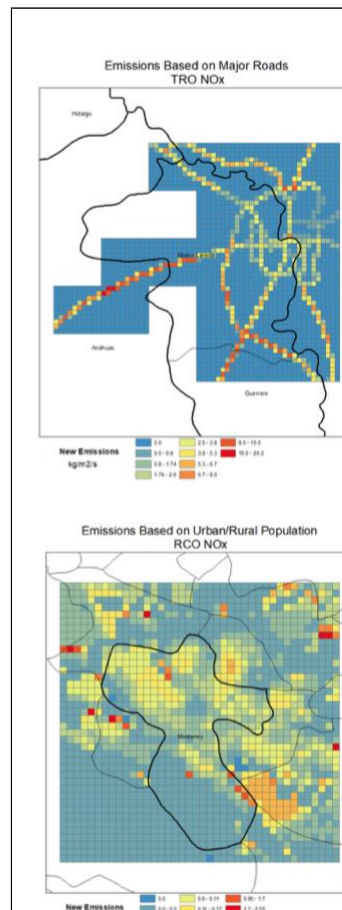


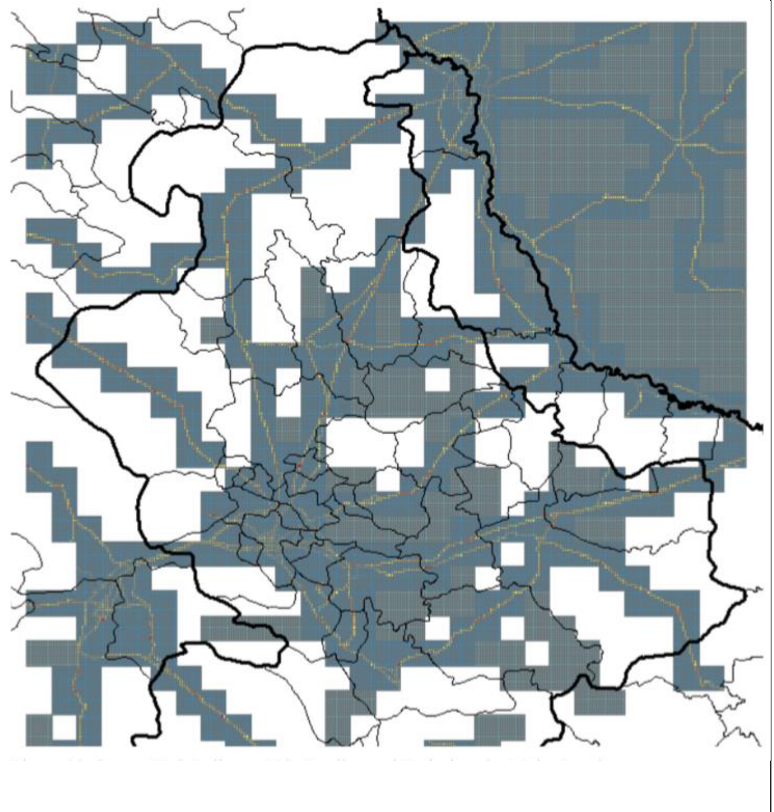
Figure 8. Updated Hourly Speeds on the Four Road Types for Both Weekday and Weekends Produced from Google Distance Matrix API Data

- In order to update the transportation emissions with real-world transportation patterns, we used the Google Maps Distance Matrix API to query (as you would with a Google Maps Application on your phone) the average and expected travel times over representative roadways within Ciudad Juárez
- These roadways are dived into four categories: Urban Restricted, Urban Unrestricted, Rural Restricted, and Rural Unrestricted
- These data were used to update MOVES-Mexico simulation baseline (uncertain) values to better represent real-world traffic patterns
- Figures 7 and 8 above plot the average speeds over these roadways (for both weekend and weekday traffic) for both the default (left) and updated (right) MOVES-Mexico traffic data
- The data queried in this work resulted in less than $10 of Google API charges, and thus may be a scalable means of getting local-scale traffic data

Extension to Other Regions



- The procedure and scripts we developed for the reallocation of Ciudad Juárez emissions were extended to two additional cities: Nuevo Laredo (left, top) and Monterrey (left, below)
- The TRO sector overall performed better than the other sectors, and so we additionally extended the TRO reallocation over the entire Mexican state of Nuevo León (right)
- The "checkerboard" pattern of TRO reallocation can still be seen over EDGAR grid cells with no major transportation corridors, but for those that have major highways, the reallocation method produces a high-resolution dataset that can be used in future work



Can you find the cities of Nuevo Laredo and Monterrey in the map above of Nuevo León?

Conclusions and Recommendations for Future Work

- We found the default MOVES-Mexico hourly road speed data to be largely consistent with the data collected using the Google Maps Distance Matrix approach, except for rural unrestricted roads.
- The MOVES-Mexico simulations require a large amount of detail which is largely unavailable for the Ciudad Juárez region, leading to high uncertainties for the magnitude of our emissions estimates. Future work would need to collect more data in order to reduce these uncertainties.
- A combination of urban/rural land use and population as a proxy worked better than either alone.
- The EDGAR emissions for the industry and power sectors did not line up with identified facilities (Figure 14).
- Our approach can provide high-resolution emissions data, but with high uncertainties due to lack of data within Mexico. Higher confidence lies in the spatial reallocation on on-road emissions.

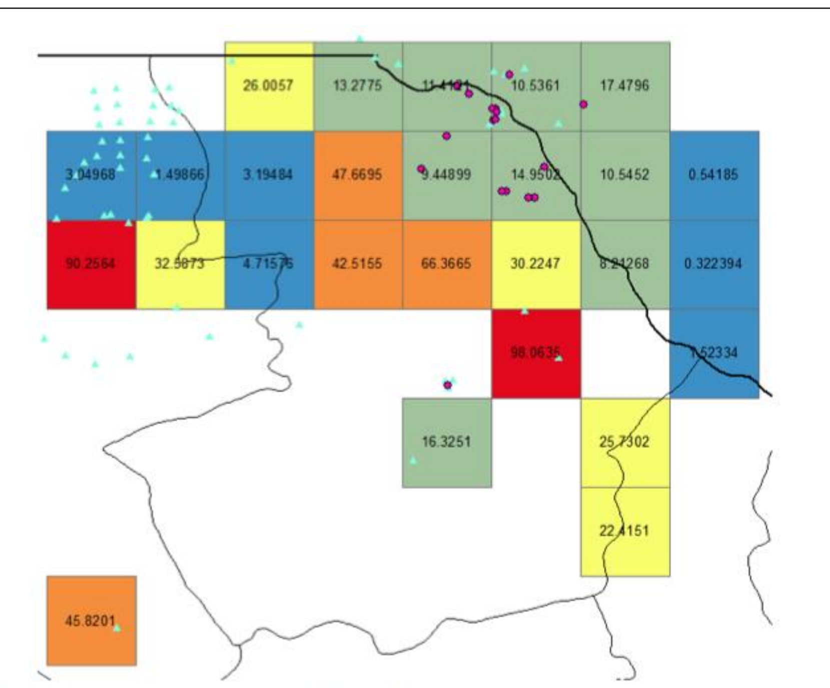


Figure 14. EDGAR emissions for sector IND - NO_x with referenced point sources (pink) and manually located industry points (light blue). Emissions are labeled for each grid box.

- Characterization, reallocation, and improvement of sector-based emissions is needed for air quality managers and policy-makers to develop strategies and policies to deal with air quality considerations under a changing climate
- For many sectors, emission trends and their spatial distribution depend on a complex, dynamic system that includes:
  - Population distribution and their changes over time
  - Economic indicators that control the location of industrial and manufacturing sources of emissions
  - Changing transportation systems that include: heavy-duty vehicles, light-duty vehicles, trains, ships, and airplanes, as well as the most efficient routes between centers of manufacture and sale
- Global datasets can provide a foundation for emissions estimates, but significant work is needed in order to scale these global datasets down to the high-resolutions needed for local-scale purposes.
- Future work would include additional considerations of:
  - The utility and limits of the urban/sub-urban/rural population proxy
  - How to deal with highly uncertain emissions (spatial and temporal)
  - How to obtain real-world data when existing inventories fail.