Validation of carbon dioxide emission inventories in the Portland metropolitan area

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Introduction

Carbon dioxide (CO_2) is responsible for about two-thirds of the total radiative forcing caused by greenhouse gases. While nations work on protocols for Greenhouse Gas (GHG) management, smaller regions like the Pacific Northwest have developed ambitious climate mitigation plans. For example, the City of Portland and Multnomah County aim to reduce carbon emissions by 80% by the year 2050. The effectiveness of such plans requires rigorous methods to validate and verify emission decreases. Tools for estimating urban GHG emissions under different scenarios are being solicited to aid planners. Here we show preliminary steps towards a new framework to validate emissions at the urban scale.

Motivation

Transportation is responsible for 32% of the nationwide CO_2 emissions. Figure 1 shows that transportation is the obvious target for mitigating GHG emissions in the city, and must be included if Portland is to meet the stated goal of reducing emissions to 80% of the year 1990 levels by the year 2050 [1]. The main goal is to verify and validate bottom-up emission inventories using observational constraints of measured atmospheric CO_2. Without verifiable emissions we will not know if policies are effective and whether planners are meeting their targets. Other models for this region exist, such as Oregon Department of Transportation (ODOT) GreenSTEP [2], however no regional model exists which spatially assigns emissions. Only a model which localizes emissions can produce a result that will correlate with actual concentrations (top-down modeling).

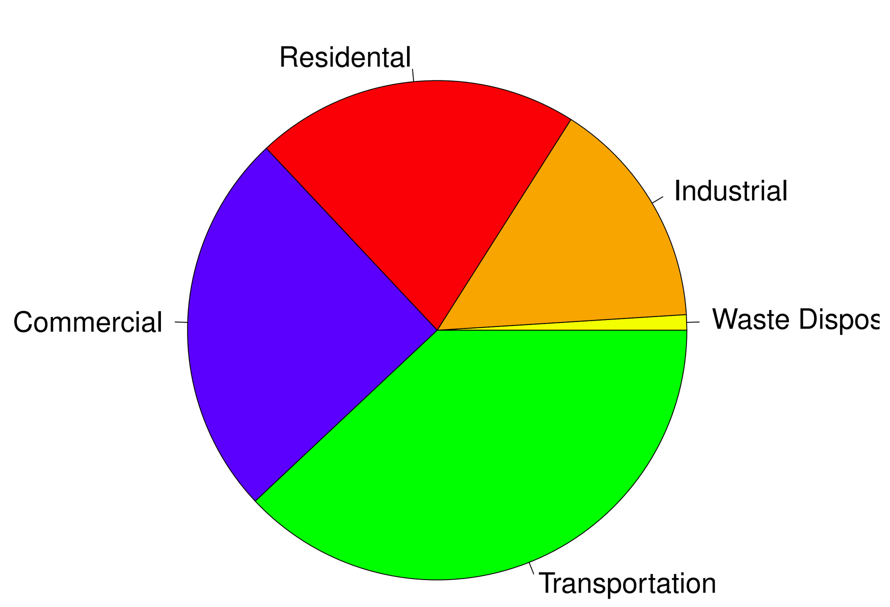

Figure 1: Transport is the largest contributor of GHG in Multnomah County, Oregon, USA [1, p.21].

Methods

Figure 2: Conceptual diagram of verification framework. Factors determining urban CO_2 concentrations.

Emissions validation

Our objective is to use measurements of atmospheric CO_2 to constrain emissions from key sectors. The atmospheric burden of CO_2 at any one location depends on:

- Anthropogenic emissions (transportation, residential, commercial and industrial)
- Biogenic fluxes (net ecosystem exchange)
- Background levels of CO_2
- Meteorology (transport fields)

The mesoscale meteorology model Weather Research and Forecasting (WRF) will be used to connect measured CO_2 with emission sources. High resolution models of emissions will be constructed for each sector and used as inputs to WRF. A top-down inverse approach will be used to optimize fluxes.

In this poster we discuss the construction of a traffic regression model to produce high-resolution gridded inventories of transportation emissions.

Figure 3: Conceptual model of the modeling of urban CO_2 concentrations.

Results

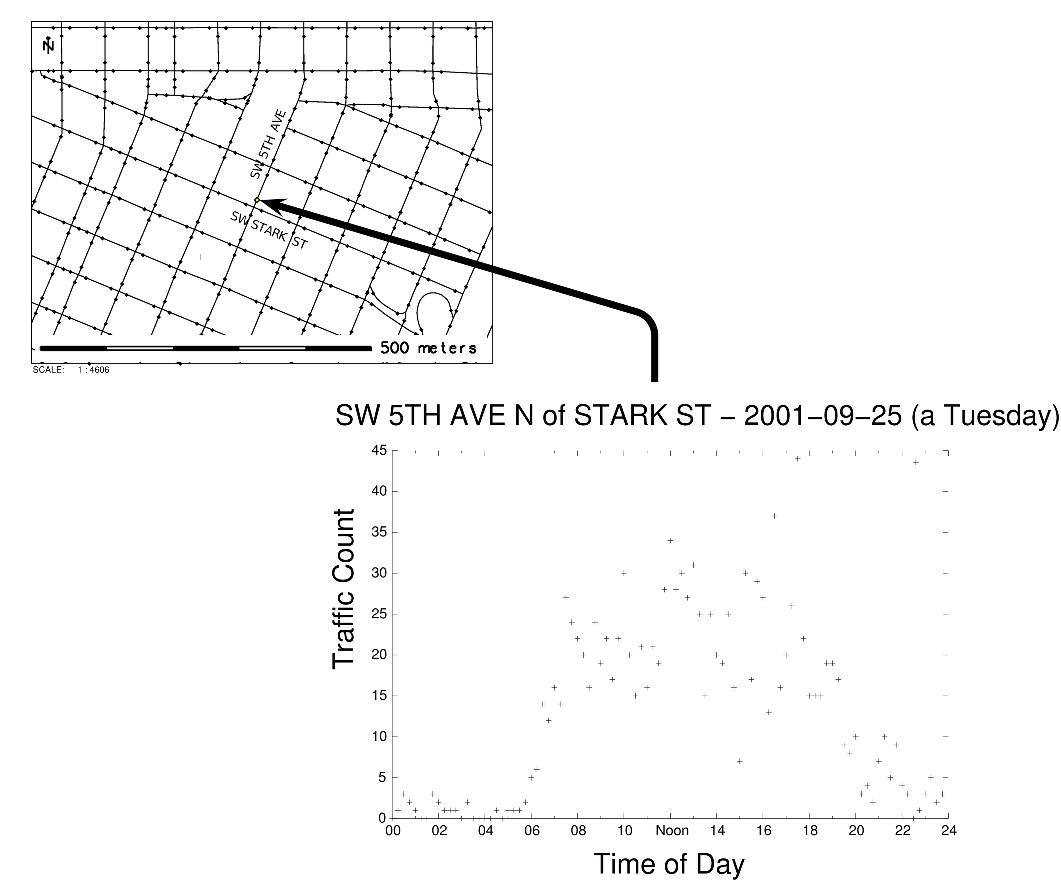

Figure 4: Traffic recorded at one counter among many that have been distributed in downtown Portland.

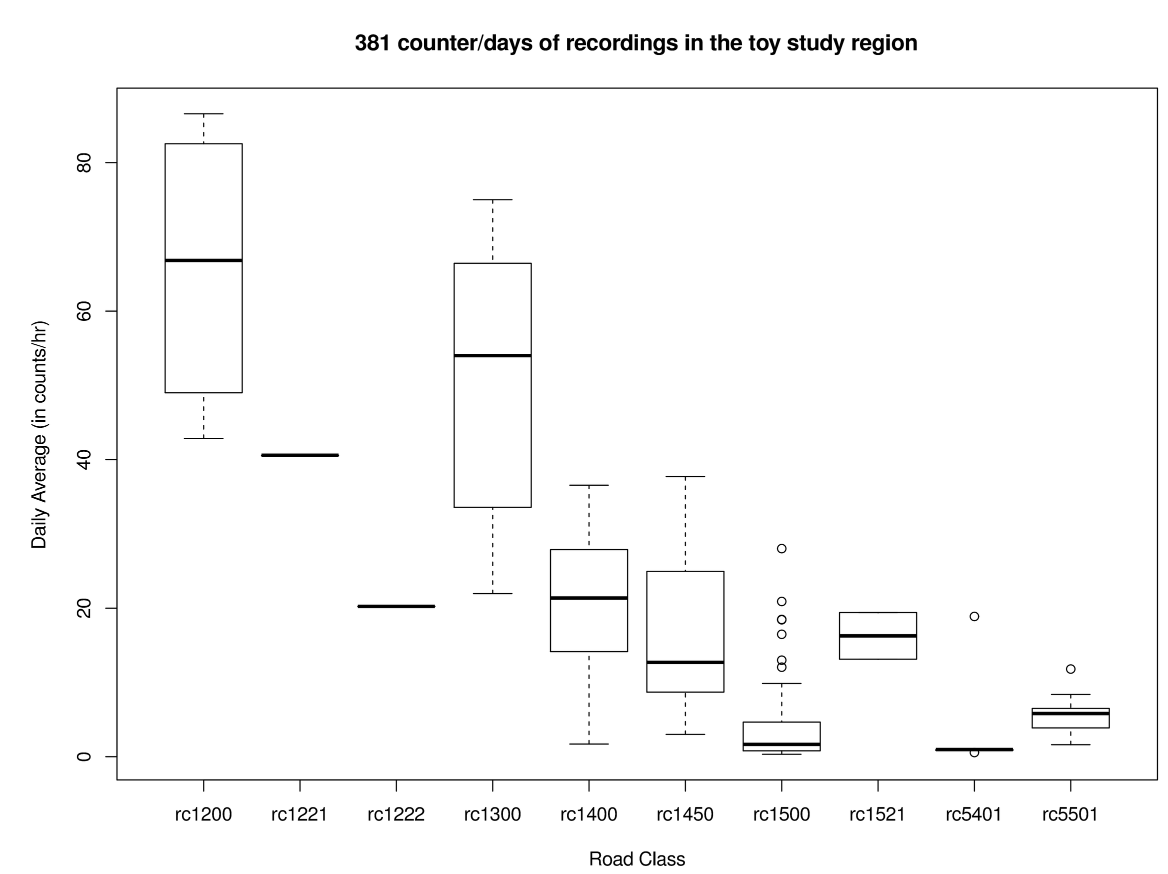

Figure 5: Road class traffic summarized. rc1200=highway, rc1221 and 1222 are on and off ramps respectively, rc1300=primary arterial, 1400=secondary, 1450=other, 1500=minor streets.

The regression model has been developed as far as estimating traffic density based on road class. The model is $Avg\_daily\_traffic\_counts = highway \times 1205.94 + off\_ramps \times 425.69 + primary\_arterial \times 427.90 + secondary \times 267.71 + other \times 130.50 + minor\_streets \times -49.24 + primary\_arterial\_with\_rapid\_transit \times 135.12$. The interquartile range is shown by the box (values between the 25th and 75th percentile), and the median is shown by the line. The "whiskers" show adjacent values, and outliers far outside of the range for normally distributed data are shown by the plotted points.

Results, cont.

Road Class	Coefficient (counts/day)	F value	Pr(>F)	
highway	1205.94	74.1995	5.618×10^{-15}	***
off-ramp	425.69	5.5659	0.01949	*
primary arterial	427.90	166.2315	$< 2.2 \times 10^{-16}$	***
secondary arterial	267.71	70.7289	1.902×10^{-14}	***
other	130.50	33.6820	3.267×10^{-08}	***
minor streets	-49.24	18.9355	2.370×10^{-5}	***
primary arterial w/rapid transit	135.12	5.7084	0.01802	*

Table 1: ANOVA results for the linear model Avg_daily_traffic_counts. Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1. Units are traffic counts per day.

Analysis of Variance (ANOVA) shows significant predictive ($P < 0.001$) power for five road classes.

Conclusion

We have completed the first steps towards building a high resolution inventory of CO_2 emissions. We have a linear model that allows for the prediction of traffic. The next step is to add other variables such as population density and mileage of area highway on-ramp to the linear regression model. The model will then be combined with engine efficiency and fleet information supplied by the Environmental Protection Agency (EPA) in its MOtor Vehicle Emission Simulator (MOVES) system to produce a high resolution CO_2 emission map for Portland. We will use the Weather Research and Forecasting (WRF) meteorological model to transport these and other CO_2 emissions throughout the Portland metropolitan region and compare simulated CO_2 concentrations at select Portland locations to observed data.

References

[1] Adams, S. and Cogen, J. (eds.) (2009) *Climate Action Plan 2009*. City of Portland.

[2] Gregor, B. (2010) *GreenSTEP: Greenhouse Gas Statewide Transportation Emissions Planning Model*. Oregon Dept. of Trans. Planning Analysis Unit.