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Urban Scale Modeling of Atmospheric Carbon Dioxide and Validation of Emission Inventories

James E. Powell
Portland State University, powellj@centurylink.net

Christopher L. Butenhoff
Portland State University, cbuten@pdx.edu

Andrew L. Rice
Portland State University, arice@pdx.edu

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J. Powell (powellj@pdx.edu), C.L. Butenhoff, A.L. Rice, *Dept. of Physics, Portland State University, Portland, OR, 97207*

Introduction

There exists a pressing need for high resolution emissions inventories for cities. For greenhouse gases, cities and regions need a careful analysis of their carbon footprint to design effective policies to control and mitigate emissions. High resolution emissions inventories can be used in conjunction with meteorology models and atmospheric measurements to place top-down constraints on emissions. High resolution emissions inventories for criteria pollutants like NO_x, CO, and O_3 enable urban-scale air pollution modeling down to the neighborhood level. For example, the Vulcan project [1] estimates CO_2 using county-scale vehicle miles traveled (VMT) from the National Mobile Inventory Model (NMIM) County Database (NCD) [1]. The Hestia Project [2] similarly allocates CO_2 from Vulcan's county-level inventory down to the building scale using eQUEST and building footprints.

On-road transport is the most important sector for anthropogenic CO_2, 38% in Portland [3], 32% nationally. Here we show a technique to model CO_2 from transport at the urban scale. Urban-scale CO_2 emissions are relatively unknown compared to national and local emissions [4]. The general solution we show here is to combine VMT and emissions factors in order to estimate the flux of CO_2 and other species.

Methods

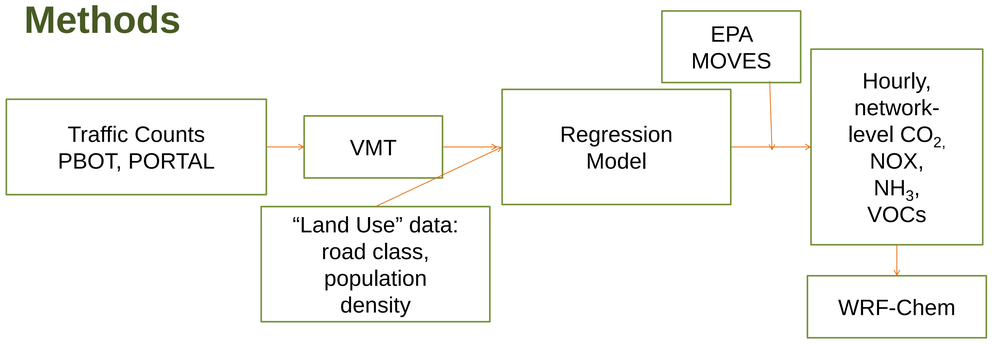


Figure 1: Conceptual Model

- Traffic count data from Portland Regional Transportation Archive Listing (PORTAL) [5] and Portland Bureau of Transportation (PBOT) were binned into 15 minute bins, and an hourly average over the entire stretch of the archive (e.g. 9 years for PORTAL) constructed.

Table 1: Summary of count archives used in this project.

Archive	Years	Street Types	# Counters	Time Step
PORTAL	2005-2014	Freeway, highway	308	15 min
PBOT	1986-2006	Arterial, local	7767	15 min

- To fill in gaps where traffic count data didn't exist we built a regression model using "land use" variables.

- At each count and node site (**N=105178**), GIS land use data were extracted from the Regional Land Information System (RLIS) and TIGER about population [6], road class, and extent of on-ramp road segments in circles extending out from 100m to 500m in 100m jumps were collected.

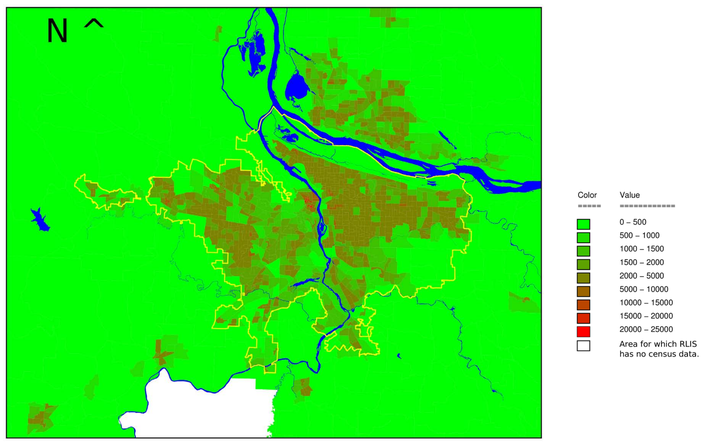
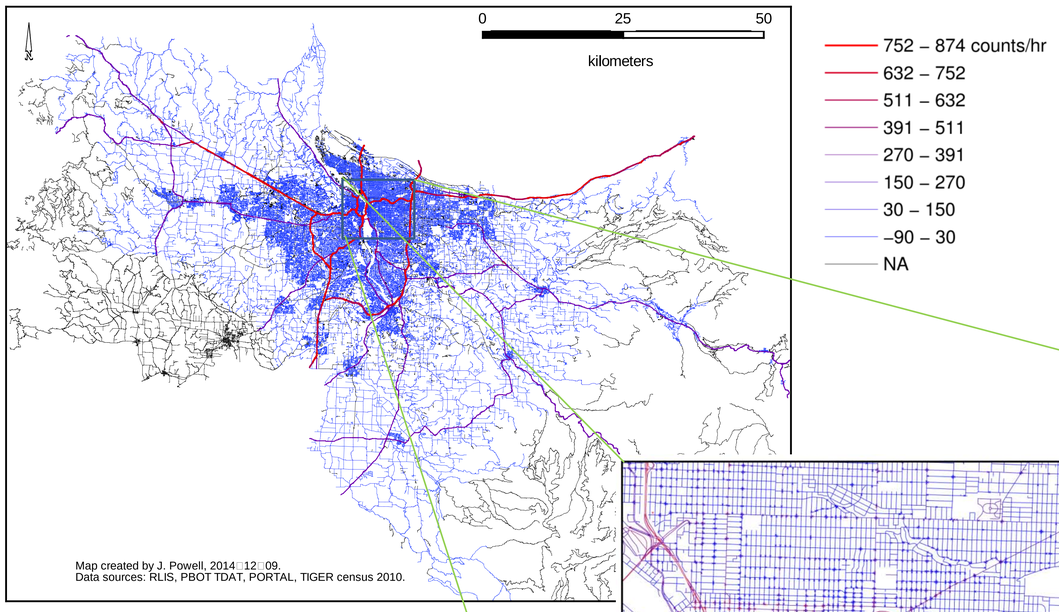


Figure 2: Population density in Portland, OR (2010 census, map by J. Powell.)



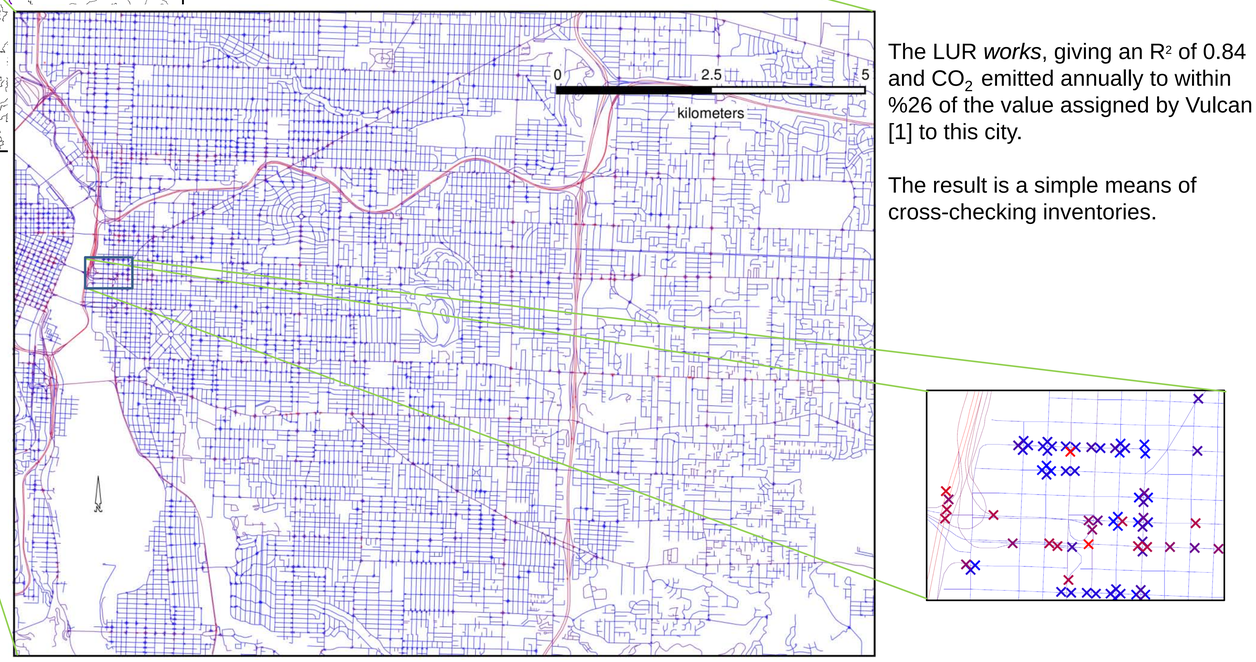


Figure 3: Map of interpolated and actual traffic counts.

Methods, cont.

The whole, N=6793, table was used to inform a linear regression. The table included errors (standard deviation) propagated out through the averaging, and these errors were used as weights in the linear regression. A stepwise process was used, which tested every possible combination and kept only the variables seen to improve the AIC statistic of the model [7]. The linear model was then used to calculate an hourly average traffic count for each internodal. VMT per hour was calculated by multiplying counts and road segment length.

- For illustrative purposes we used an EPA-provided CO_2 emissions factor to estimate CO_2 emissions.

Results

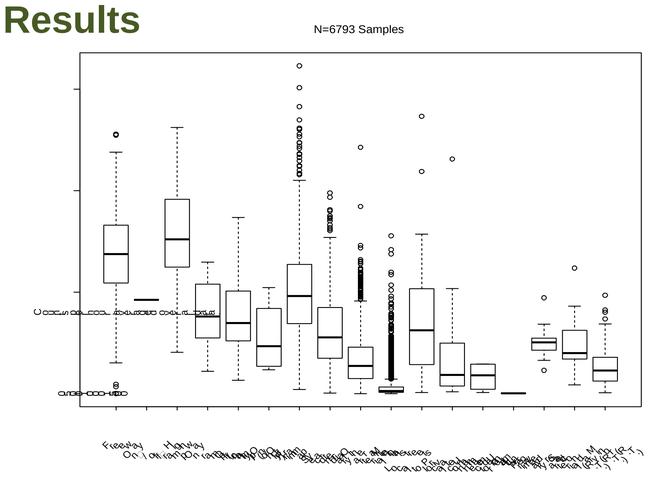


Figure 2: plot of counts/hour averaged over the totality of count data. R.T. labels road classes with rapid transit. The height of each box represents the 25th through to the 75th percentile of the data. Each box has inside it a line representing the median. The adjacent values display the range expected for a normal distribution. The outside values are drawn as circles.

Results, cont.

Table 2: Coefficients of the linear "land use" regression. Signif. code: '***' $p < 0.001$. R^2 is 0.84.

	Estimate (counts/hr)	Pr(>t)
(Intercept)	257	***
Freeway	339	***
Highway	221	***
Secondary arterial	-192	***
Other arterial	-226	***
Minor streets	-259	***
Local street to street connector	-213	***
Private named road	-244	***
Unnamed driveway	-247	***
Unimproved road	-262	***
Minor with rapid transit	-235	***
Population in 100m radius circle	0.085	***
Onramp length in 100m radius circle	0.0977	***

The LUR *works*, giving an R^2 of 0.84 and CO_2 emitted annually to within %26 of the value assigned by Vulcan [1] to this city.

The result is a simple means of cross-checking inventories.

Discussion and Next Steps

Here we show the result of using traffic counter records, census, and road density in a linear model which has been used to model urban-scale on-road transport at a high resolution. This model is necessary to complete the urban GHG emissions inventory and it will now be considered a necessary component of any urban scale GHG mitigation plan.

The completed model will separate out VMT by hour of day, day of week, and by season.

The LUR will be tested by holding back 1/3 of the data and checking the ability of the regression (based on the remaining 2/3rds) to predict the held-back part.

Apply MOVES to each road segment using Portland-specific vehicle fleet data and on-road data.

The traffic density regression will be used to construct high-resolution emission inventories for CO_2, NO_x, NH_3, and VOCs.

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