Modeling distribution of urban population for improved estimation of energy demand and greenhouse gas emissions

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When planning for sustainable cities and the reduction of greenhouse gas emissions (GHGs) it is important to consider green building technology as well as the reduction potential due to urban density and land use mix. The density and form of the built infrastructure, including the number of dwelling inhabitants, influence energy demand and transportation emissions. This project aims to improve GHG emission estimates by combining Statistics Canada census data with novel geospatial data rather than using Canada-wide archetypes (Natural Resources Canada) with standard inhabitant assignments.

Statistics Canada provides population and housing data as fine as a census dissemination area (approximately 150 homes), which does not allow for population to be assessed at the dwelling level. In order to more accurately distribute population data, land use information was combined with census data in a Geographic Information System (ArcGIS). This was then merged statistically to building volumes derived from Light Detection and Ranging (LiDAR) data. LiDAR, a remotely sensed surface characterization product has recently been applied to the urban surface (Tooke et al., 2009). This LiDAR-based method made it possible to assign the number of nighttime inhabitants to individual buildings in an automated process, thus improving on NRCan estimates. There is potential for using this method for a wide range of urban areas resulting in a variety of applications that require a detailed population distribution.

Example Application: The Building Energy Model (BEM)

The Building Energy Model (BEM) is used to accurately estimate the energy consumption of various types of buildings. Shown are the three common types of single family dwellings (SFD) found in Vancouver-Sunset. The number of people living in a dwelling increases overall energy consumption, but decreases per capita consumption.

Natural Resources Canada (NRCan) uses “urbane archetypes” with generic dwelling populations (either 3 or 4/SFD) to estimate energy demand. Assigning populations to individual buildings improves the accuracy of the BEM.

The use of higher resolution population densities shows the influence of population density on per capita building sector CO2. Previous studies on anthropogenic CO2 such as Matese et al. 2009 used natural gas pumping stations in order to estimate building emissions, which does not allow for such a resolution. Although the sample size is small, there is an apparent pattern of decreasing per capita emissions with increasing density. The LiDAR transect continues NW towards Downtown Vancouver where density increases with the introduction of residential high rise buildings. This data should reveal a continuation of this trend.

Flow chart of process of assigning populations to individual buildings in the study area. Shown above is a subset of the 4km2 study area selected to show a range of building types. Analysis was only carried out for DAs that (i) lie completely within the study area (i.e. LiDAR data available) and (ii) contain at least one apartment building according to BC Assessment data. Incomplete DAs were populated by using parameters defined by the results of the complete DAs.

Study area – Vancouver-Sunset. The 4km2 study area lies in the southeast Vancouver neighbourhood of Sunset which contains approximately 6000 buildings and has a population density of 64 inh./ha.

The (i) DA shapes are irregular and thus make analysis of emissions difficult. The (ii) 50 x 50m raster improves the resolution by downsampling and allows for emissions to be allocated to a smaller, regular area. This improved resolution is needed in meteorological dispersion or source area models, for example. It can also be seen that (ii) has much wider range of population densities, whereas in (i) highly populated areas are not seen due to the lower resolution. Finally, parks are shown to have zero population in (ii).

Population density vs. per capita CO2 building emissions in the Vancouver-Sunset neighbourhood based on a 200 x 200m raster cell size.

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Conclusion

This advanced method for modelling population distributions allows for a much improved resolution by taking advantage of LiDAR data. Despite the complexity of the process, if LiDAR data is present, the method can easily be replicated in urban areas where census and assessment data are available. A study which extends the ground truthing of assigned values would be needed to evaluate the accuracy of this method. This technique could also be applied to other aspects of urban meteorology such as air pollution exposure analysis, emergency response models, or the estimation of anthropogenic heat flux for urban weather forecasting.

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