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Back-extrapolation of estimates of exposure from current land-use regression models

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ABSTRACT

Land use regression has been used in epidemiologic studies to estimate long-term exposure to air pollution within cities. The models are often developed toward the end of the study using recent air pollution data. Given that there may be spatially-dependent temporal trends in urban air pollution and that there is interest for epidemiologists in assessing period-specific exposures, especially early-life exposure, methods are required to extrapolate these models back in time. We present herein three new methods to back-extrapolate land use regression models. During three two-week periods in 2005–2006, we monitored nitrogen dioxide (NO_2) at about 130 locations in Montreal, Quebec, and then developed a land-use regression (LUR) model. Our three extrapolation methods entailed multiplying the predicted concentrations of NO_2 by the ratio of past estimates of concentrations from fixed-site monitors, such that they reflected the change in the spatial structure of NO_2 from measurements at fixed-site monitors. The specific methods depended on the availability of land use and traffic-related data, and we back-extrapolated the LUR model to 10 and 20 years into the past. We then applied these estimates to residential information from subjects enrolled in a case–control study of postmenopausal breast cancer that was conducted in 1996.

Observed and predicted concentrations of NO_2 in Montreal decreased and were correlated in time. The estimated concentrations using the three extrapolation methods had similar distributions, except that one method yielded slightly lower values. The spatial distributions varied slightly between methods. In the analysis of the breast cancer study, the odds ratios were insensitive to the method but varied with time: for a 5 ppb increase in NO_2 using the 2006 LUR the odds ratio (OR) was about 1.4 and the ORs in predicted past concentrations of NO_2 varied (OR ~ 1.2 for 1985 and OR ~ 1.3–1.5 for 1996). Thus, the ORs per unit exposure increased with time as the range and variance of the spatial distributions decreased, and this is due partly to the regression coefficient being approximately inversely proportional to the variance of exposure. Changing spatial variability complicates interpretation and this may have important implications for the management of risk. Further studies are needed to estimate the accuracy of the different methods.

1. Introduction

A particular challenge for epidemiologic studies is to accurately estimate historical exposure to traffic-related air pollution within cities. Land use regression (LUR) is a method to predict concentrations of pollutants at locations within cities for which measurements

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were not taken (Beelen et al., 2007; Brauer et al., 2003; Briggs et al., 1997; Crouse et al., 2009; Henderson et al., 2007; Hochadel et al., 2006; Jerrett et al., 2007; Madsen et al., 2007; Moore et al., 2007; Ross et al., 2007; Sahsuvaroglu et al., 2006; Wheeler et al., 2008). The method involves measuring ambient pollutants, usually using a dense environmental sampling campaign, and then developing a prediction model whereby the measured concentrations of air pollutants are regressed against proximate characteristics of land use and vehicular traffic. This method has been used in cohort studies to estimate the association between long-term exposure to air pollution and chronic health outcomes (Ballester et al., 2010; Beelen et al., 2008; Brauer et al., 2007, 2008; Brunekreef et al., 2009; Gehring et al., 2009; Jerrett et al., 2009; Suglia et al., 2008; von et al., 2009; Yorifuji et al., 2010), but can also be relevant to case–control studies. Often, the LUR is developed toward the end of the study (e.g., at end of follow-up) so it is important to understand whether these models can characterize exposure adequately during the relevant etiological periods. The validity of the methodology is especially critical for outcomes that have long latency (e.g., most cancers). Given that there may be non-homogeneous, spatially-dependent temporal trends in urban air pollution and that there is interest for epidemiologists in assessing period-specific exposures, especially early life exposure, methods are required to back-extrapolate these models into the past.

We present here three new methods to extrapolate a "current" LUR back in time by incorporating historical trends in spatially-dependent concentrations of pollutants as well as temporal changes in land use and vehicular traffic. For the purpose of illustration, we sought to back-extrapolate approximately 10 years (to 1996) and 20 years (to 1985) a current LUR that we developed using measurements of nitrogen dioxide (NO_2) in Montreal, Quebec, Canada, from a dense monitoring campaign that we conducted in 2005 and 2006 (Crouse et al., 2009). As a specific application of these new methods to an epidemiologic study, we applied the models to data from a case–control study of breast cancer that we conducted in the mid-1990s (Lenz et al., 2002; Labrèche et al., 2003, 2010).

2. Methods

2.1. Fixed-site monitoring data

Environment Canada, in collaboration with the City of Montreal, administers the Canadian National Air Pollution Surveillance (NAPS) network, a network of fixed-site monitors in the Montreal region (Fig. 1). The number of fixed-site monitors used to measure ambient concentrations of NO_2 varied from 8 to 13 during the period of 1985 and 2006. Measurements of NO_2 were made every hour and were analyzed using chemiluminescence (Thermo Environmental Instruments (TEI) Model 42C).

We obtained mean daily concentrations of NO_2 measured at the fixed-site monitors in 1985, 1996, and 2006 (from 10–12 monitors, depending on the year). For each year, we included all fixed-site monitors in the Montreal region. This allowed us to incorporate all sources of spatial variability that were represented in the monitoring network. The social geography of Montreal is quite complex, with some low and high income areas located close to expressways running through the city.

2.2. Development of the LUR model for 2005–2006

We conducted three separate monitoring campaigns measuring NO_2 between November 2005 and August 2006 (Crouse et al., 2009). Two-week integrated samples were measured using Ogawa passive samplers (Ogawa and Co., USA) that were deployed at 129 locations within the island of Montreal.

In a previous analysis of these data (Crouse et al., 2009), we made use of data from 2006 for land use, population density, and vehicular traffic to develop a LUR model to predict annual mean

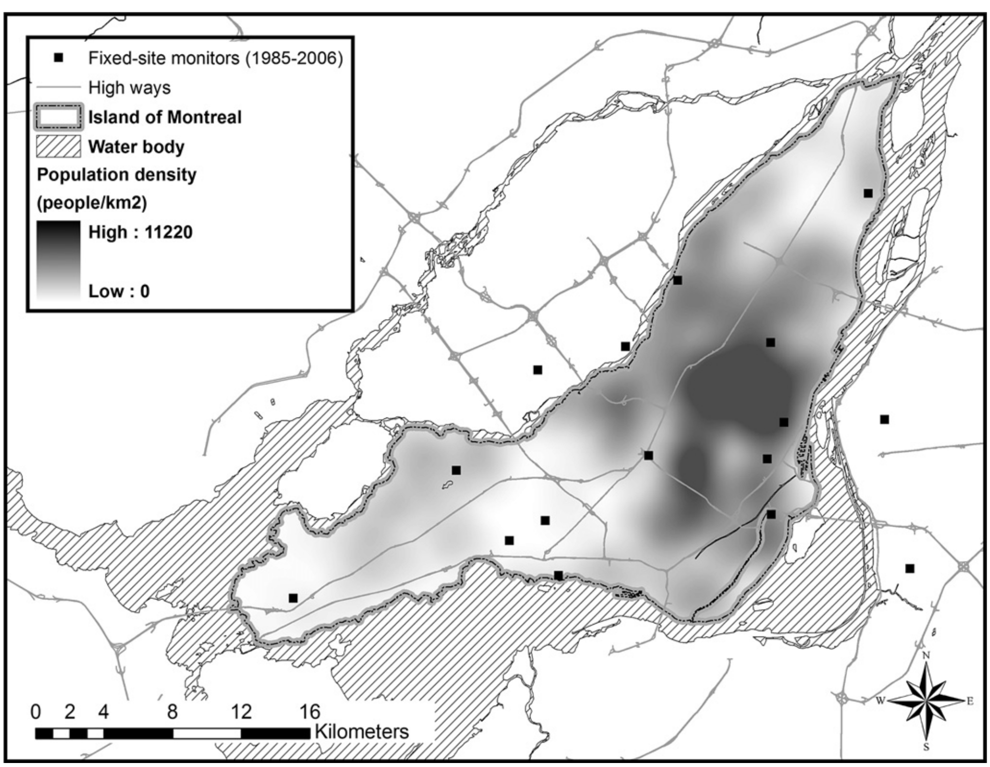

Fig. 1. Fixed-site monitors by the National Air Pollution Surveillance (NAPS) network in the Montreal region, 1985–2006. The number of fixed-site monitors varied between 8 and 13 depending on the year.