DEVELOPMENT AND EVALUATION OF ALTERNATIVE METRICS OF AMBIENT AIR POLLUTION EXPOSURE FOR USE IN EPIDEMIOLOGIC STUDIES

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1. INTRODUCTION

Recent studies (Sarnat et al. 2010) have shown that more narrowly defining the geographic domain of the study populations and the improvements in the corresponding ambient PM concentrations, lead to stronger associations between ambient concentrations and hospital admissions and mortality records. To meet these needs, rsearchers are now beginning to use air quality dispersion models to support air pollution exposure and health studies (Isakov et. al., 2009; Özkaynak, et. al., 2008; Georgopolis, et. al., 2005). There are many advantages to using air quality models over traditional approaches used by epidemiologist such using ambient measurement. The direct use of monitoring data inherently assumes that they are representative of the air quality over a broad area. However, there is increasing evidence that the monitoring network is not capturing the sharp gradients in exposure due to high concentrations near, for example, major roadways (Zhou & Levi 2007). Monitoring networks are sparse in both space and time, are costly to maintain, and are often designed purposely to avoid detecting highly localized sources. Air quality models, on the other hand, have a long history of use in air pollution regulations and thus are widely available and supported by regulatory agencies and a large user community. Here, the hybrid modeling approach (Isakov et al., 2009) was used to estimate air quality model concentrations.

Here we explore the associations between traffic-related (NO_x) and regional ($PM_{2.5}$) pollutants and two acute adverse health Emergency Department (ED) and Implanted Cardio Defibrillator (ICD) studies collected in Atlanta, Georgia during 1999-2002. We also compare the resulting hybrid model concentration estimates with available ambient monitoring data. Evaluation is critical for any air quality model application. However, evaluating spatially- and temporally-resolved model concentrations in a large urban area is a challenge because observations are usually not available at this level.

2. ATLANTA MODELING STUDY

The Atlanta study area is centered on downtown and extends to a 100 km in all directions in order to include the impacts from a majority of emission sources. For this paper, we have focused on two air pollutants: particulate matter at 2.5 microns or less ($PM_{2.5}$) and nitrogen oxides (NO_x). These pollutants were selected because of health

outcomes based on previous known associations: respiratory disease hospitalization and mortality ($PM_{2.5}$ and NO_x) and cardiovascular disease hospitalization and mortality ($PM_{2.5}$). Also, these pollutants represent different pattern of spatial and temporal structure (e.g. $PM_{2.5}$ is mostly regional, while NO_x has both local and regional components).

Pollutant specific local-scale air concentrations were first estimated using the EPA's AERMOD dispersion model which uses information on local emission sources and local meteorological conditions to provide hourly and annual average concentrations at multiple receptors. To estimate the total air concentrations, an estimate of the regional background concentrations is needed. Here we used a statistical approach based on ambient monitoring data to obtain these estimates (Wade et al., 2006). Daily and annual average air quality model simulations during four years (1999 – 2002) were made to coincide with available health outcomes.

3. RESULTS

Figure 1 shows the relative contribution of local and regional average daily modeled concentrations at all 225 receptors. For PM2.5 (Figure 1a) the contribution of the AERMOD dispersion model to the total concentrations is small. As seen in the monitoring data, this pollutant is driven primarily by regional sources. The hybrid concentration reflects the influence of the estimated regional background concentration.

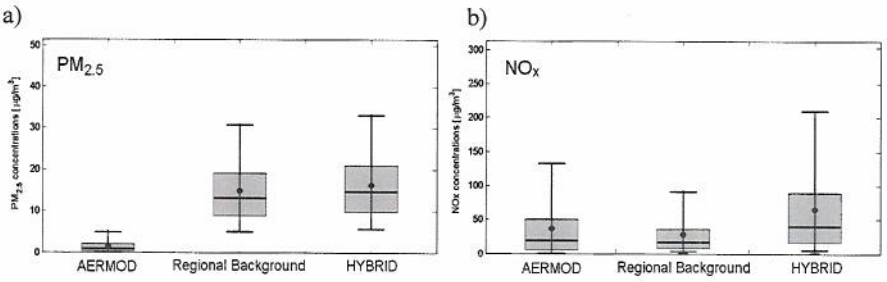

Figure 1. Relative contributions of local and regional signals in a) $PM_{2.5}$ and b) NO_x concentrations in Atlanta based on daily average estimates at 225 zip code receptors

We examined the relationship between daily modeled air pollution concentrations and ED visits for respiratory and cardiovascular disease using Poisson generalized linear models (Sarnat, et al., 2010). In our analysis, we assumed that greater levels of refinement in air quality model concentrations used as metrics of exposure would result in reduced exposure measurement error. Thus, differences in estimated relative risks when different air pollution exposure metrics are used may serve to illustrate the relative degree of exposure error. According to this assumption, if the health outcome is caused by the exposure, using a more accurate measure of exposure should typically result in less bias towards the null. Comparing observed relative risks may, therefore,

provide a means of evaluating this error. In Figure 2, we compare the relative risks using different measures of exposure using different air quality concentration estimates (central monitoring site, AERMOD and hybrid model). We anticipated that the hybrid model, which accounts for greater levels of spatio-temporal heterogeneity throughout our large modeling domain compared to that from a central monitoring site, will have the strongest associations with the health outcomes.

Preliminary results suggest that the effect of improved spatiotemporal heterogeneity on the observed relative risk estimates depend on the pollutant by outcome of interest, as expected. For spatially homogeneous pollutants (i.e., $PM_{2.5}$), relative risk estimates, in particular, for respiratory ED visits, were generally higher using model based metrics. For spatially heterogeneous pollutants (i.e., CO and NO_2), estimated associations also varied but to a lesser extent.

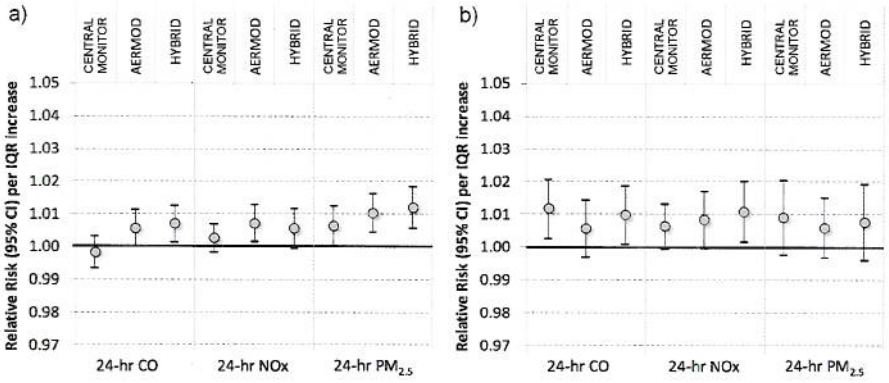

Figure 2. Mean Results of the epidemiologic analysis for a) respiratory and b) cardiovascular disease.

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