Exposures to ambient nitrogen oxides in the Tampa area considering spatiotemporal travel activity data
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Abstract
Accurate estimation of exposures to urban air pollution is important to understanding population health, social equity, and urban sustainability. Here, we studied population exposures to ambient levels of oxides of nitrogen (NOx), specifically investigating impacts of spatiotemporal travel activities on estimates of exposure, and on the social distribution of that exposure, in Hillsborough County, Florida. The 2009 National Household Travel Survey (NHTS) dataset was used to derive diurnal location activity and space for data records with residence locations in the county. To estimate exposure, the time-location activity data were combined with data on diurnal NOx concentrations at 1 km spatial resolution, obtained from CALPUFF dispersion modeling results. Group exposure results indicate higher than average exposures for African American/black residents, below poverty households, and those with residences located in higher density areas. On average, use of the travel activity data led to small differences in exposure estimates when compared to using residence location data only, though the range of differences was more substantial. The potential for exposure error was lower for population groups that had higher estimated exposures.

Motivation
On-road transportation vehicles contribute substantially to emissions of many urban air pollutants with known adverse health effects, including NOx, benzene, and 1,3-butadiene. Vehicle emissions also contribute to the formation of O3 and PM.

Multiple interactions between urban form, transportation infrastructure, air pollutant emissions, and population exposures exist but are not well understood. Previous work also suggests potential inequities in exposures by sociodemographic subgroup, which could be impacted by urban/transportation development. The 2009 NHTS database provides an opportunity to investigate human activity patterns and their impact on the estimated exposures and differences in exposures by subgroup.

Objectives and Scope
The objectives of the study are to
1. Estimate individuals exposures to ambient concentrations of oxides of nitrogen (NOx) in Hillsborough County, Florida.
2. Determine effects of the use of time-activity data on NOx exposure estimates.
3. Investigate socio-demographic disparities in exposure to NOx and impacts of urban form on those disparities.

Pollutant focus: NOx is considered a surrogate for complex mixture of traffic pollutants.

Study area: Hillsborough County, Florida has a diverse mix of emissions sources and population groups, an extensive highway network with few other transportation options, and concentrations of ozone that sometimes exceed the national standard.

Methods

Travel Behavior: Human Time-Activity Data
The National Household Travel Survey (NHTS) collects data to characterize the people’s transportation and travel patterns in the United States.

Records daily trips taken by individuals and households over a 24-hour period. Data include socio-demographic characteristics, trip lengths and times, trip and residential locations. Human activity patterns for Hillsborough County, Florida were characterized using the 2009 NHTS data.

Time-Locatio Activity Patterns
Trip start and end times and locations used to derive individual activity patterns.

Routes assumed as shortest time path between Origin-Destination.

Spatiotemporal location (x, y, t) with resolution of 100 meters along path and 1 hr.

Ambient NOx Concentration
2002 Hourly ambient NOx concentrations at spatial resolution of 1 km.

Results were aggregated to generate the average diurnal cycle.

Exposure Estimates
Activity-based exposure (AE):

\[ \text{AE} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m} C_{ij} t_{ij}}{T} \]

where \( C_{ij} \) is the concentration at spatial location \( ij \) and the hour of the day \( k \) \( t_{ij} \), is the time spent at location \( ij \) and the hour of the day \( k \) \( T \) is the total time (24 hr).

Residence-based exposure (RE):
Assumes the person stays at the home location for the whole 24 hr period.

Exposure Error:
Relative percent difference between activity and RE

Results

Discussion
Exposure estimates based on activity patterns were generally slightly higher than those based on residence location alone.

Regarding environmental equity, some differences between socio-demographic subgroups were observed. Mean/median exposures were highest for the black/African American subgroup and lowest for the Asian and white subgroup. Mean/median exposures for below poverty groups were also higher than above poverty groups. Urban region residents were subject to higher exposures compared to the residents from rural regions.

Population subgroups with higher exposures were subject to low exposure error.

Limitations include a) estimated routes b) concentrations estimated from highly aggregated AADT data and c) concentration and activity data represent different time periods.

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