Development of Two Model Fusion Techniques Utilizing CMAQ and RLINE to Obtain PM$_{2.5}$, CO, and NOx Concentrations at 250m Resolution over Atlanta, GA
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Introduction
Birth cohort study with individual-level residence data needs air pollutant concentration fields at a fine spatial resolution with minimal temporal and spatial bias. Inaccurately capturing intratumvarial variability in air pollutant concentrations can affect risk ratio estimates.

- Air quality measurements may not capture full spatial variability due to lack of monitoring stations
- Dispersion models simulate small-scale variations but do not simulate chemistry or regional emissions
- Chemical transport models (CTM) can simulate chemistry and local and regional emissions but usually at a coarse resolution

Objective: Develop and apply model fusion approaches that combine observation-fused CTM and dispersion model outputs to obtain fine particulate matter (PM$_{2.5}$), carbon monoxide (CO) and nitrogen oxides (NO+NO$_2$=NOx) estimates at a 250m resolution that retain chemistry and comprehensive emissions

Additive Approach (PM$_{2.5}$)

$PM_{250m} = \left[ CMAQ_{12km} - RLINE_{12km} \right]_{interpolated} + RLINE_{250m}$

1. Spatially average RLINE values to match grid of CMAQ (12 km)
2. Subtract 12km averaged RLINE concentrations from 12km CMAQ values to remove mobile impacts on PM$_{2.5}$, resulting in urban background estimates (i.e. particulate matter resulting from all secondary formation and primary sources except mobile emissions)
3. Spatially interpolate urban background using triangulation-based linear interpolation algorithm to obtain spatially smooth estimates at 250m grids
4. Add RLINE PM$_{2.5}$ to results of step 3 to add mobile PM$_{2.5}$ back into model

Overall, concentrations of primary roadway PM$_{2.5}$ are placed in their respective locations inside CMAQ grids after removing average roadway primary PM$_{2.5}$ from the CMAQ estimates to avoid double counting.

Multiplicative Approach (NOx & CO)
The additive approach can lead to unphysical negative results if RLINE is higher than CMAQ. To avoid this phenomenon, a multiplicative approach that scales RLINE by CMAQ using a linear adjustment factor was developed.

$GAS_{250m} = \left[ CMAQ_{12km} / RLINE_{12km} \right]_{interpolated} \times RLINE_{250m}$

Performance & Evaluation

Spatial R$_2$ values: reported median over years 2003-2008 with minimum and maximum

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>MODEL FUSION</th>
<th>OBS-CMAQ</th>
<th>OBS-RLINE</th>
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<tbody>
<tr>
<td>PM$_{2.5}$</td>
<td>0.97</td>
<td>0.81</td>
<td>0.38</td>
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<tr>
<td>CO</td>
<td>0.98</td>
<td>0.96</td>
<td>0.96</td>
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<tr>
<td>NOx</td>
<td>0.94</td>
<td>0.78</td>
<td>0.74</td>
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Evaluation statistics, median over years 2003-2008 with minimum and maximum

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<tr>
<td>Normalized Mean Error (%)</td>
<td>24.9</td>
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<tr>
<td>Normalized Mean Bias (%)</td>
<td>8.9</td>
<td>22.2</td>
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Temporal R$_2$

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<tbody>
<tr>
<td>Normalized Mean Error (%)</td>
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<td>Normalized Mean Bias (%)</td>
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Overall, model fusion results with observational data to develop annual mobile source air pollutant fields at fine spatial resolution

Conclusions
1. Model fusion approaches simulate steep spatial gradients within one 12km grid while retaining comprehensive emissions and chemistry, which minimizes spatial and temporal biases
2. Model input biases affect model fusion performance; calibrations with observations should be made to inputs a priori
3. Additive method should be used unless background is very small
4. Methods could be applied to other models, locations, and pollutants

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References:
2. Bates, J., et al., "Developing a Model Fusion Technique Utilizing CMAQ and RLINE to Obtain PM$_{2.5}$, CO, and NOx Concentrations at 250m Resolution over Atlanta, GA," 2016.