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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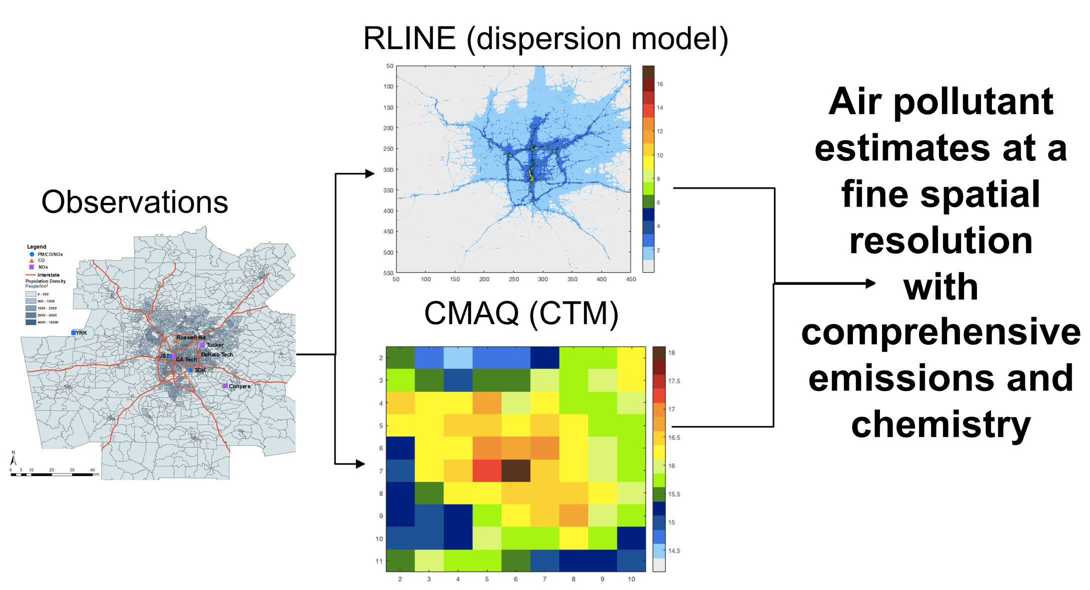
Introduction

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 intraurban 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



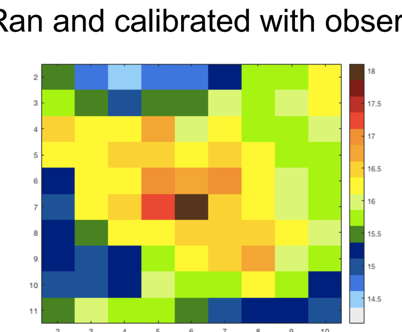
Model Inputs

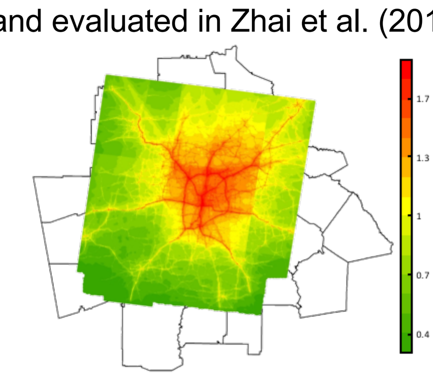
Chemical Transport Model: Data-Fused CMAQ (OBS-CMAQ)

- Daily values for 2003-2008
- Fused with observations and evaluated in Friberg et al. (2016)

Dispersion Model: Observation-Calibrated RLINE (OBS-RLINE)

- RLINE is a line-source model for near-surface releases of primary inert pollutants chosen to model concentrations near roadways
- Annual averages for 2003-2008
- Ran and calibrated with observations and evaluated in Zhai et al. (2016)



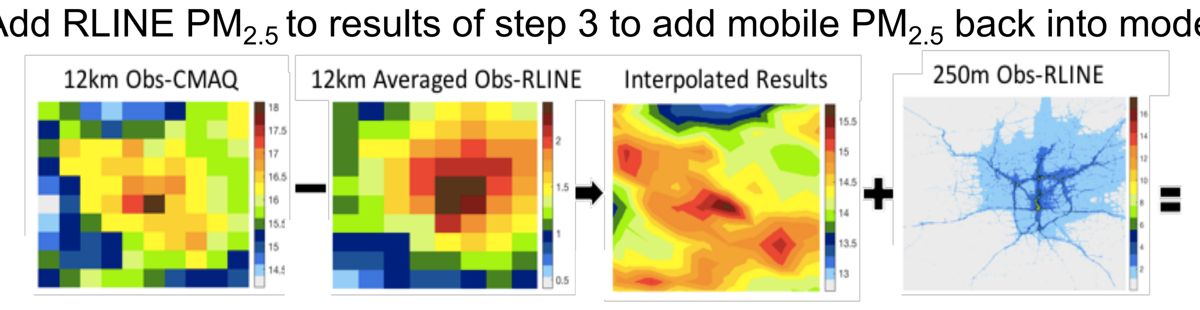


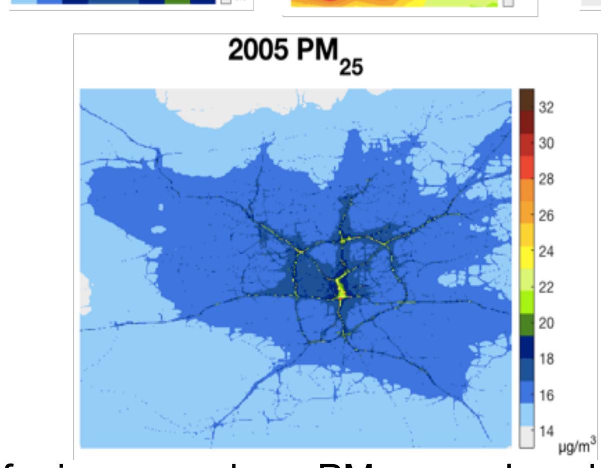
2005 Annual Averages for 12km CMAQ (left) and 250m RLINE (right)

Additive Approach ($PM_{2.5}$)

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

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



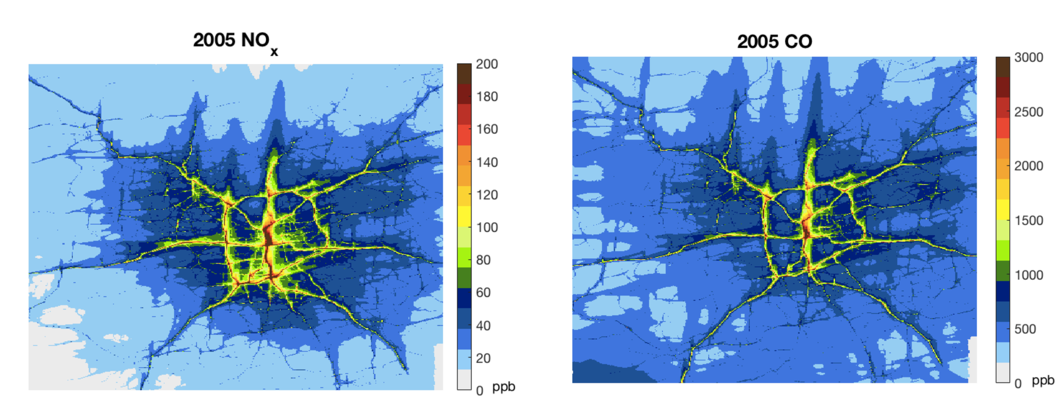


Overall, concentrations of primary roadway $PM_{2.5}$ are placed in their respective locations inside CMAQ grids after removing average roadway primary $PM_{2.5}$ from the CMAQ estimates to avoid double counting.

Multiplicative Approach (NOx & CO)

The additive approach can lead to unphysical negative results if $RLINE_{12km}$ is higher than $CMAQ_{12km}$. To avoid this phenomenon, a multiplicative approach that scales RLINE by CMAQ using a linear adjustment factor was developed.

$$Gas_{250m} = \left[\left(\frac{CMAQ_{12km}}{\overline{RLINE}_{12km}}\right)_{interpolated}\right] * RLINE_{250m}$$



Performance & Evaluation

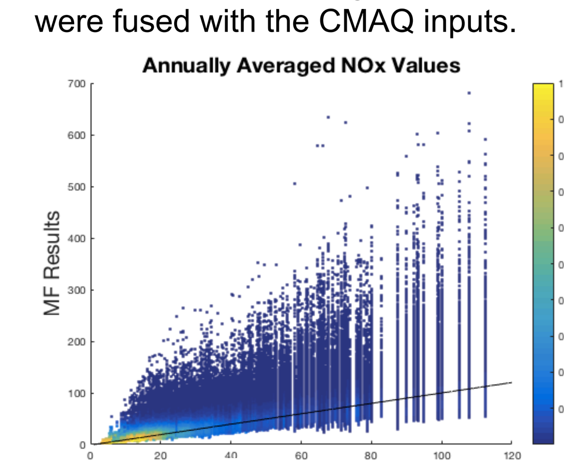
Spatial R values; reported is median over years 2003-2008 with minimum and maximum

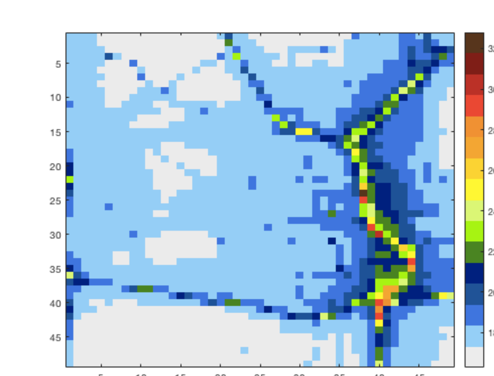
SPECIES	MODEL FUSION	OBS-CMAQ	OBS-RLINE
$PM_{2.5}$	0.60 (0.34—0.77)	0.61 (0.37—0.80)	0.38 (0.16—0.62)
CO	0.98 (0.97—1.00)	0.84 (0.78—0.91)	0.96 (0.93—1.00)
NO_X	0.84 (0.76—0.89)	0.78 (0.72—0.83)	0.74 (0.68—0.77)

Evaluation statistics; median over years 2003-2008 with minimum and maximum

	24-hr $PM_{2.5}$	1-hr max CO	1-hr max NOx
Normalized Mean Error (%)			
Model Fusion	9.9 (9.0—12.1)	23.8 (15.6—25.7)	39.6 (35.3—55.3)
Model Fusion Withholding	27.3 (26.5—29.1)	40.4 (36.4—45.0)	61.0 (59.5—74.7)
Normalized Mean Bias (%)			
Model Fusion	6.9 (1.5—8.0)	0.2 (-1.7—8.4)	4.3 (0.9—22.2)
Model Fusion Withholding	7.8 (4.4—11.1)	1.1 (-2.2—10.1)	8.3 (4.4—26.5)
Temporal R			
Model Fusion	0.99 (0.92—0.99)	0.93 (0.92—0.95)	0.98 (0.89—1.0)
Model Fusion Withholding	0.77 (0.73—0.79)	0.54 (0.52—0.59)	0.60 (0.58—0.62)

Model fusion witholding represents a 100% witholding test, i.e. no observations were fused with the CMAQ inputs.





Model Fusion versus CMAQ (left) and model fusion results within one 12-km grid (right) showing the distribution of results within one 12km grid that these approaches capture

Conclusions

1. Model fusion approaches simulate steep spatial gradients within one 12km gird 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:

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