Fusing CMAQ, RLINE and Observations to develop 250m resolution daily pollutant exposure fields as part of a fertility study

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Background

- Lower fertility is an increasing issue. 15-25% of couples are affected by infertility.
- Some studies suggested high exposure to **traffic-related** air pollution can have adverse effects on reproductive systems.

Question: Is traffic-related exposure to air pollution associated with lower fertility?

We use data from **vitrified oocyte donation assisted reproductive technology(ART)** to evaluate the impact of air pollution on human reproduction.

Cohort study: 2400 cycles from 500 donors and 1400 recipients attending a fertility clinic in **Atlanta** from **2005 to 2019 (This is why we need fine-scale spatial-temporal concentration fields).**

Objective

We aim to create concentration fields that capture:

- Non-linear chemical reactions (Chemical Transport Models).
- Effects of a specific source of emission in fine resolution, like roadway emission (Dispersion Models).

Objective:
Concentration fields of CO, NOx and PM2.5 from 2005 to 2019 (Atlanta, 250m resolution).

Method

Fused daily chemical transport model fields and annual dispersion model fields.

Chemical Transport Model (CMAQ at 12km)

- **Step1**: Fused original CMAQ fields and observed data[1].
- **Step2**: Spatially adjusted fused CMAQ and observed fields by Random Forest[1].

Dispersion Model (RLINE at 250m)

- **Step1**: Created the 2010 RLINE field[2].
- **Step2**: Scaled the 2010 RLINE field to rest years (2005 to 2019) using annual emissions estimates.

Fused CMAQ and RLINE

❖Additive method: $PM_{2.5}$[3]
❖Multiplicative Method: CO and NOx[3]

Additive method:

- **Step 1**: For each CMAQ grid (12km x 12km), we calculated the average concentration of all RLINE girds (250m x 250m) that are in this CMAQ grid.

$$\overline{RLINE}_{coarse}(l,y) = \frac{\sum_{i=1}^{n} RLINE(x_n,y)}{n}$$

- **Step 2**: For each CMAQ grid, we adjusted the concentration by subtracting the averaged RLINE value from CMAQ value.

$$CMAQ(l,d) - \overline{RLINE}_{coarse}(l,y)$$

- **Step 3**: Interpolated the CMAQ field to increase the resolution from 12km to 250m.

$$(CMAQ(l,d) - \overline{RLINE}_{coarse}(l,y))_{interpolated}$$

- **Step 4**: Fused the downscaled CMAQ field (250m x 250m) with the RLINE field (250m x 250m).

$$PM_{2.5}(x,d) = (CMAQ(l,d) - \overline{RLINE}_{coarse}(l,y))_{interpolated} + RLINE(x,y)$$

Multiplicative method:

- **Step 1**: The same as the additive method. We calculated the averaged RLINE concentration for each CMAQ grid.
- **Step 2**: For each CMAQ grid, we calculated the background concentration by dividing CMAQ value by RLINE value.

$$\frac{CMAQ(l,d)}{\overline{RLINE}_{coarse}(l,y)}$$

- **Step 3**: The same as the additive method, we calculated the background field by kriging interpolation.

$$\left(\frac{CMAQ(l,d)}{\overline{RLINE}_{coarse}(l,y)}\right)_{interpolated}$$

- **Step4**: Fused RLINE with CMAQ fields.

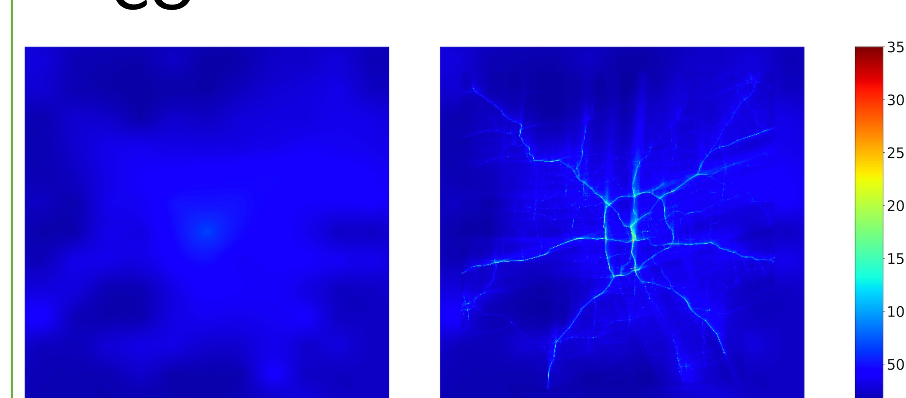
$$NOx \ or \ CO(x,d) = \left(\frac{CMAQ(l,d)}{\overline{RLINE}_{coarse}(l,y)}\right)_{interpolated} * RLINE(x,y)$$

l: CMAQ grid
d: day
y: year
x: RLINE grid

Results

Example Results: 2019 fields at 250m

- CO



(a) (b)

Fig1. Comparison of Jan 1st 2019 CMAQ (a) and Jan 1st 2019 CMAQ + RLINE (b)

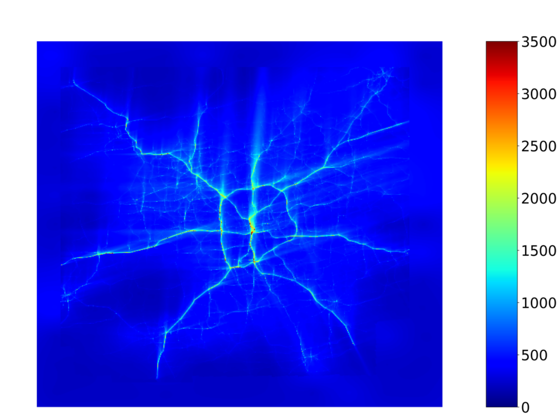
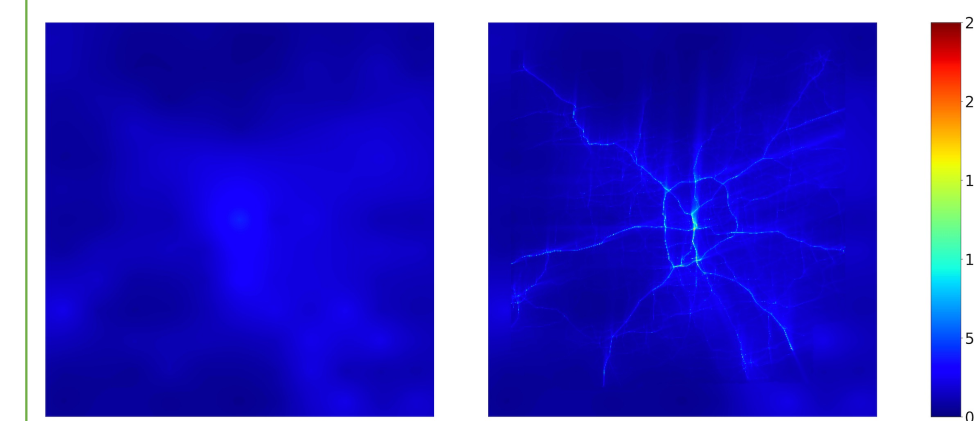


Fig2. Annual averaged CMAQ + RLINE

- NOx



(a) (b)

Fig3. Comparison of Jan 1st 2019 CMAQ (a) and Jan 1st 2019 CMAQ + RLINE (b)

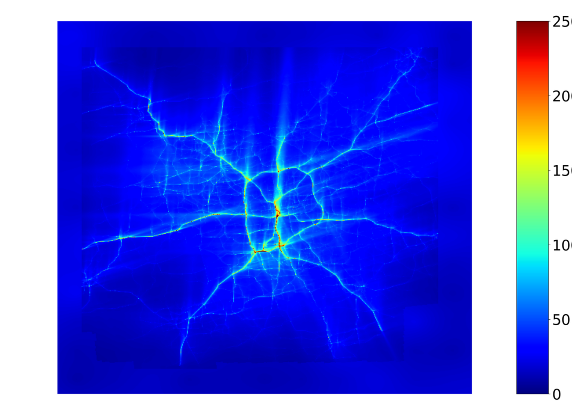
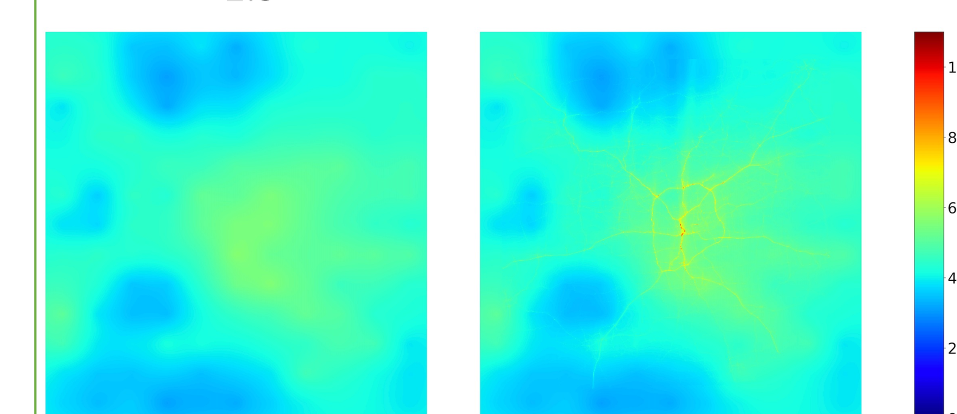


Fig4. Annual averaged CMAQ + RLINE

- $PM_{2.5}$



(a) (b)

Fig5. Comparison of Jan 1st 2019 CMAQ (a) and Jan 1st 2019 CMAQ + RLINE (b)

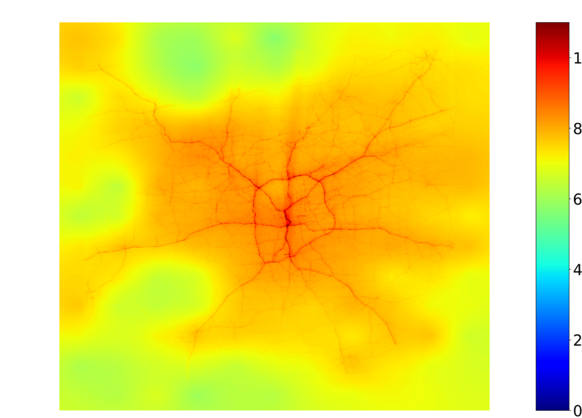


Fig6. Annual averaged CMAQ + RLINE

Conclusion

- Compared to CAMQ fields, fused fields can capture the impact of roadway emissions.
- High levels over freeways.

Future work

- We are looking for machine learning methods to reduce the bias between observed data and predictions at some near road monitoring sites.

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❖For more information contact Yifeng Wang (ywang3627@gatech.edu).

References

[1] Senthilkumar, N., Gilfether, M., Metcalf, F., Russell, A. G., Mulholland, J. A., & Chang, H. H. (2019). Application of a fusion method for gas and particle air pollutants between observational data and chemical transport model simulations over the contiguous United States for 2005–2014. International Journal of Environmental Research and Public Health, 16(18), 3314. https://doi.org/10.3390/ijerph16183314
[2] Zhai, X., Russell, A. G., Sampath, P., Mulholland, J. A., Kim, B.-U., Kim, Y., & D'Onofrio, D. (2016). Calibrating R-line model results with observational data to develop annual mobile source air pollutant fields at fine spatial resolution: Application in Atlanta. *Atmospheric Environment*, *147*, 446–457. https://doi.org/10.1016/j.atmosenv.2016.10.015
[3]Bates, J. T., Pennington, A. F., Zhai, X., Friberg, M. D., Metcalf, F., Darrow, L., Strickland, M., Mulholland, J., & Russell, A. (2018). Application and evaluation of two model fusion approaches to obtain ambient air pollutant concentrations at a fine spatial resolution (250m) in Atlanta. *Environmental Modelling & Software*, *109*, 182–190. https://doi.org/10.1016/j.envsoft.2018.06.008