Estimating Regional Background Air Quality using Space/Time Ordinary Kriging to Support Exposure Studies

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BACKGROUND

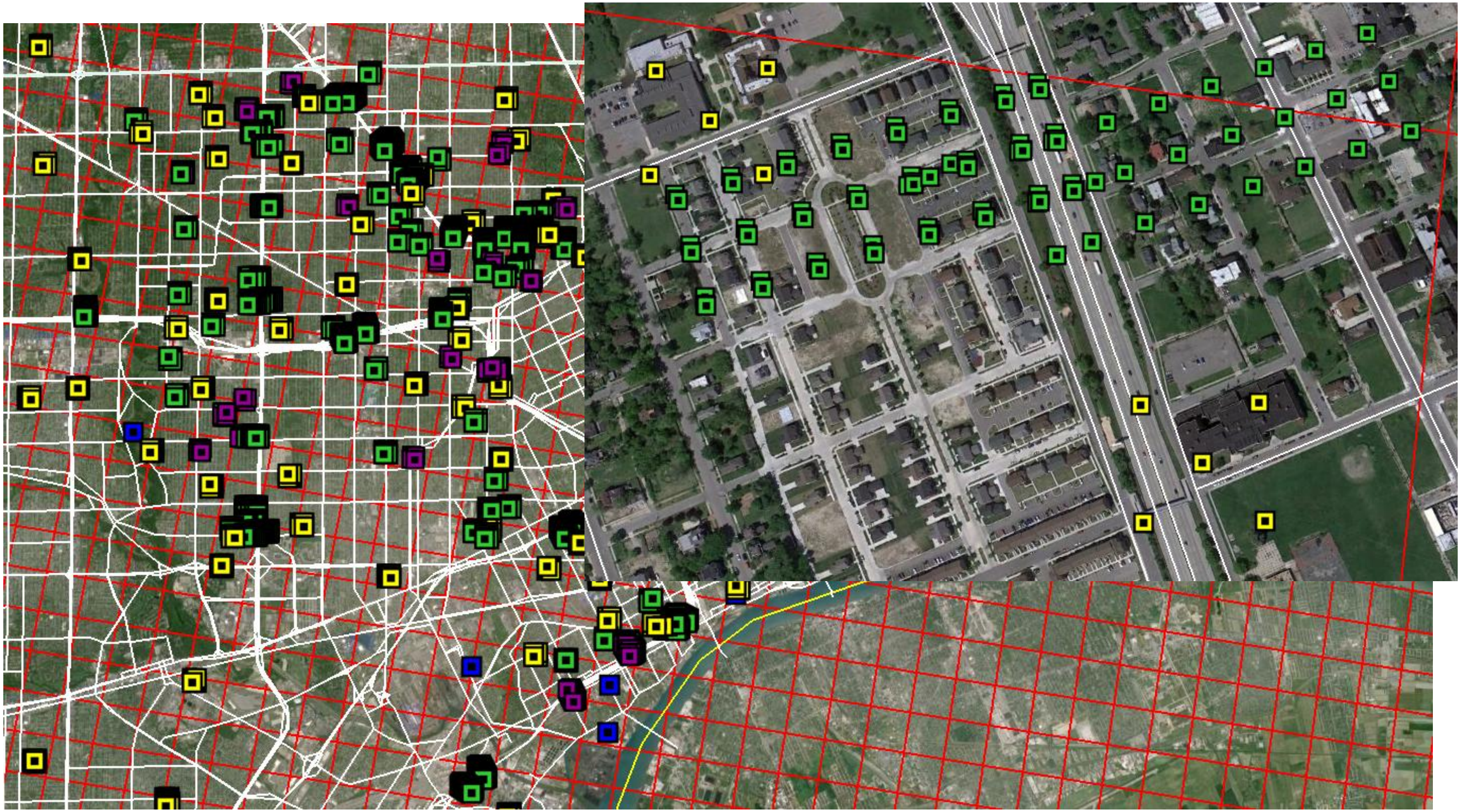
- Motivation
  - Exposure studies rely on detailed spatio-temporal characterization of air quality fields
  - While this is potentially easily done for targeted emissions sources, characterization of regional background is a challenging task at the scales of the study
- Previous Work
  - Ambient-based method
    - Percentile of monitoring site concentrations
  - Emissions-based method
  - Chemistry transport model based method
    - Run models such as CMAQ, but without the local sources
      - Spatially coarse, and potentially resource-intensive

OBJECTIVE

- To develop a method to estimate background concentration for the Near-Roadways Exposure to Urban Air Pollutants (NEXUS) Study in Detroit
    - At very fine spatial scales at numerous cohort locations, as well as near-road receptors near roadways
    - 29-month period from January 2010 – May 2012

METHODOLOGY

Detroit Study Domain



- 4122 Receptors

Space/Time Variability Modeling

- The space/time dependency was characterized by the means of its covariance function
- Assumptions:
  - Constant **global mean trend** is given by the average of all the observations
  - The **residuals concentrations** obtained by subtracting this constant global mean from the observations were isotropic and homogeneous-stationary
  - This implies that the **space/time covariance function** of the residuals is dependent on the spatial and temporal distance between two space/time points

Space/Time Ordinary Kriging (STOK)

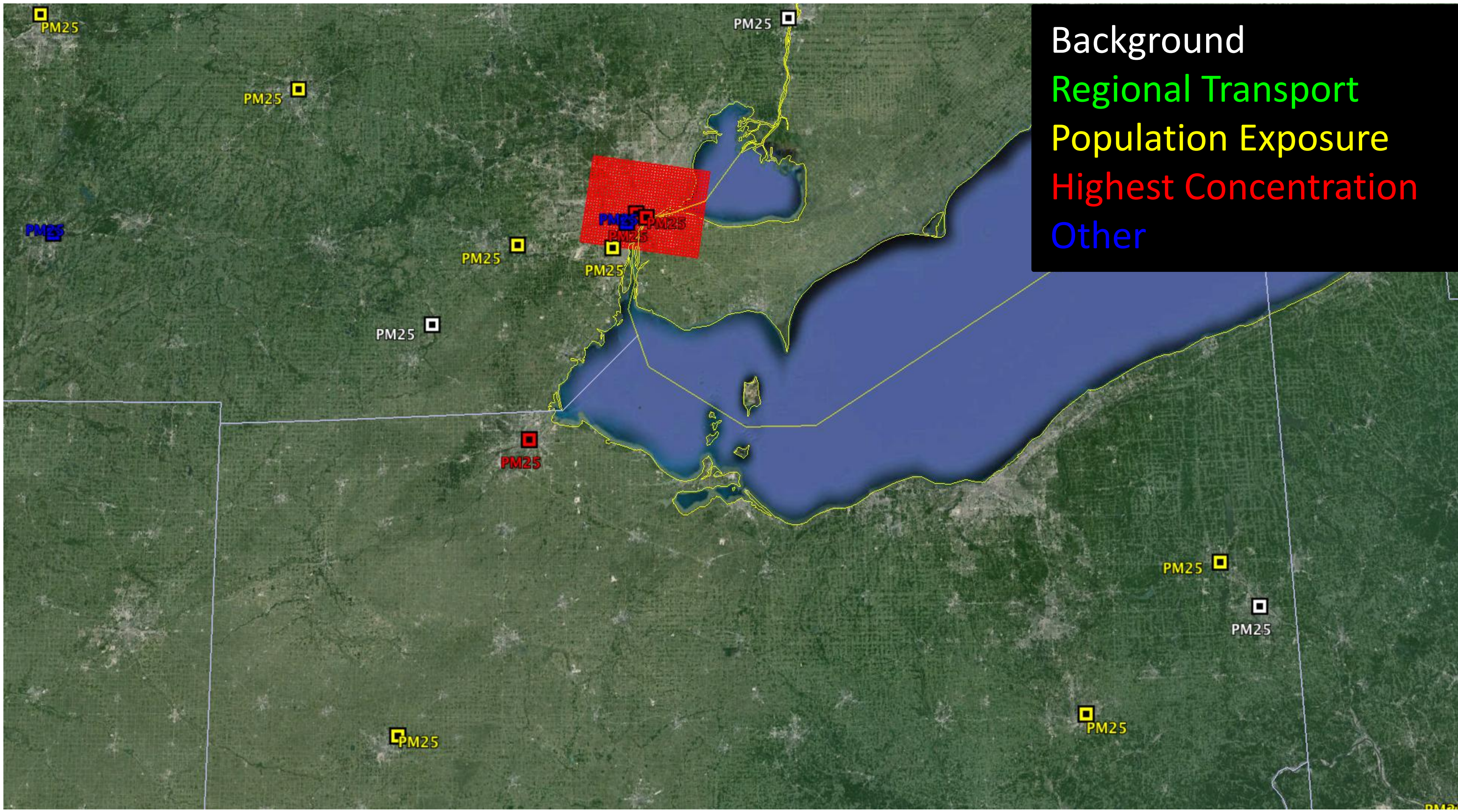
- STOK estimate is given by the linear combination of nearby samples
- The kriging weights are obtained by minimizing the estimation mean square error subject to the unbiasedness constraint
- In this study, we used 50 nearby samples which were observed within five temporal units (days or hours) from the estimation time
- Nearby samples were selected based on the space/time distance defined below where (space/time metric) is the ratio of the spatial covariance range and temporal covariance range

$$\left({}^{space}\!/_{time}\ distance\right) = \left(spatial\ distance\right) + \left({}^{space}\!/_{time}\ metric\right) \times \left(temporal\ distance\right)$$

Input Data for STOK

- Data from AQS sites with "Monitoring Objective = Background" used as **Hard Data**
- Uses all other AQS Obs. as **Soft Data**
  - $R_{2005} = CMAQ_{Background}/CMAQ_{Total}$
  - Z_{2010} = AQS Obs. (Not Background)
  - Soft data mean = mean (Z * R) = Z*mean(R)
  - Soft data variance = var(Z * R) = Z^2 * var(R)
  - Removed Soft data mean and variance below 1% and above 99%

AQS Sites by Monitor Objective



Only 2 – 6 “Background” AQS sites in the region for the various pollutants

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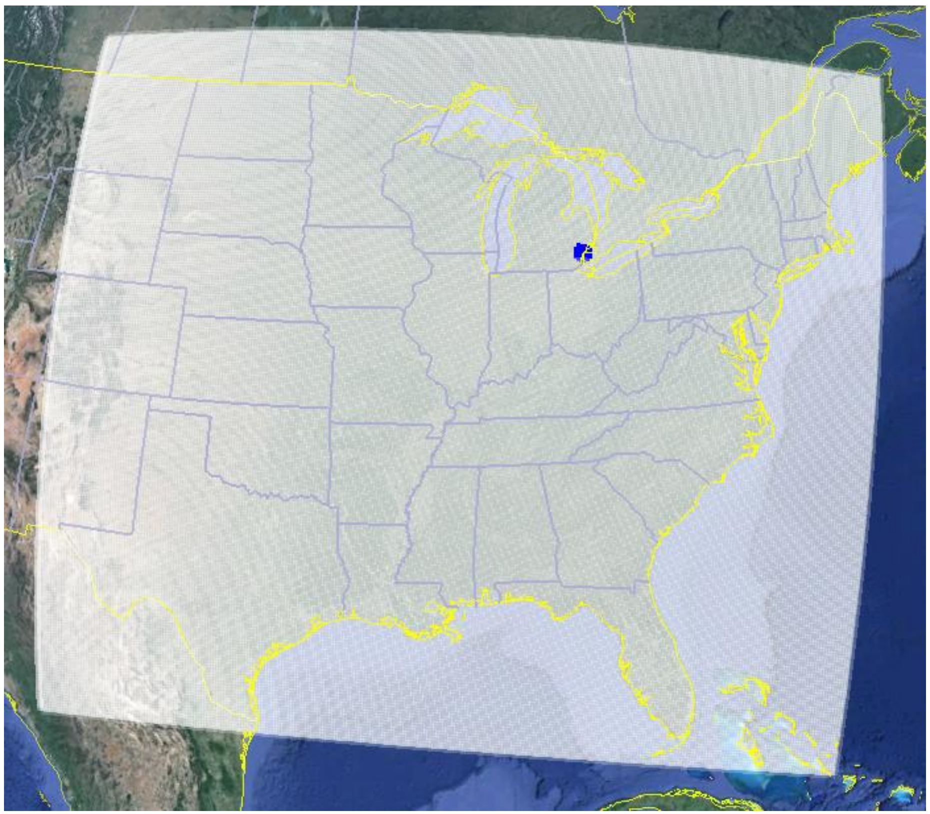
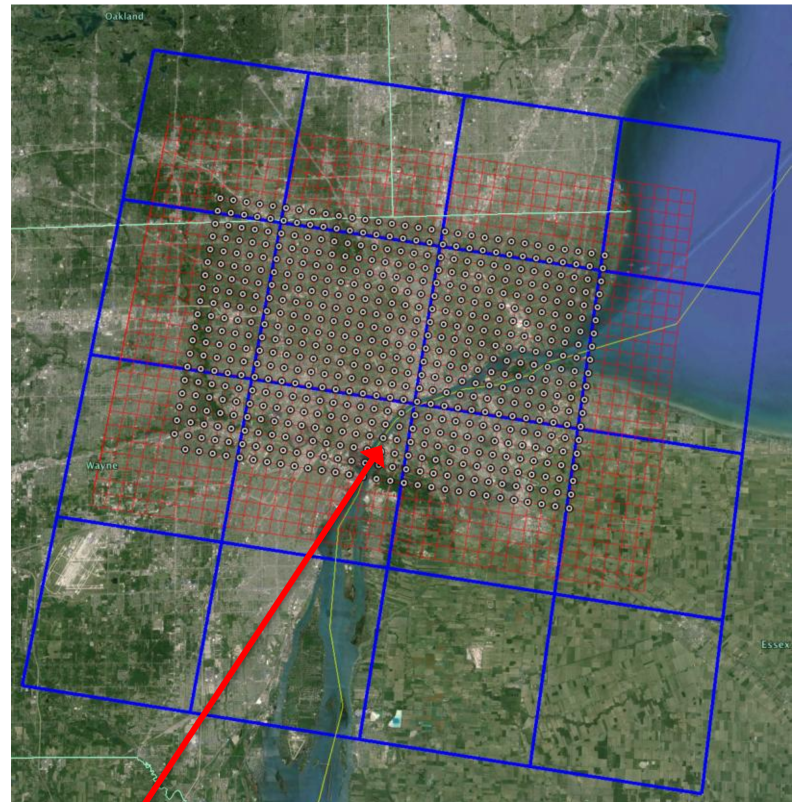
CMAQ Model Application

- CMAQ Simulations for annual 2005
  - Using CMAQ v4.7.1
  - 12km x 12 km
  - $PM_{2.5}$, CO, NOx, Benzene, EC and OC
  - 2 CMAQ Simulations
    - $CMAQ_{Total}$
      - Base Case
    - $CMAQ_{Background}$
      - Local Sources in Detroit have been zeroed out

CMAQ Modeling Domain

Study location for NEXUS

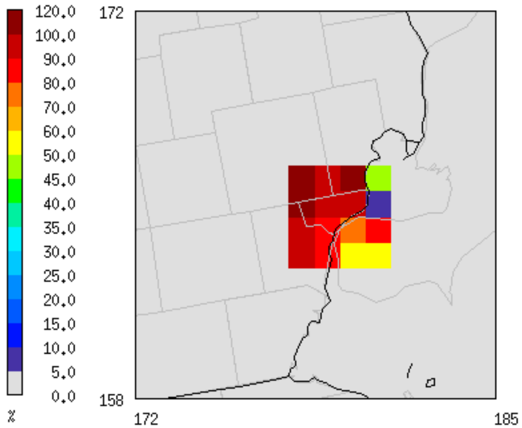




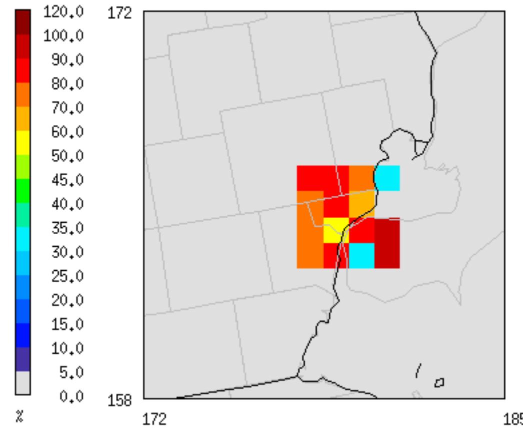
Estimation locations

RESULTS

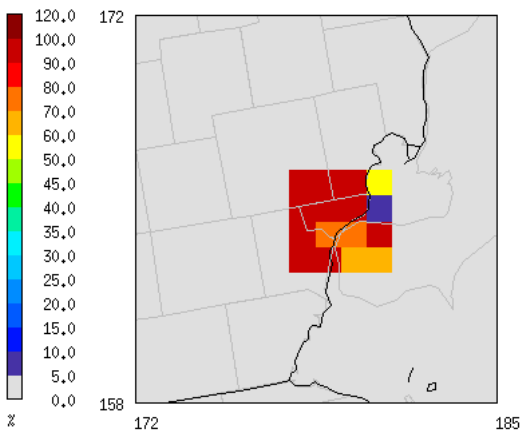
Monthly Average Emissions
Local Sources/Total



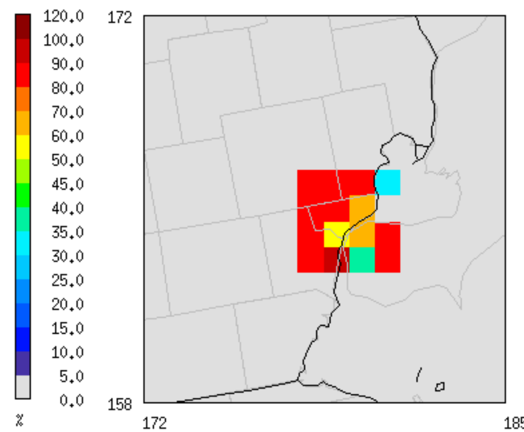
Summer NOX



Summer $PM_{2.5}$



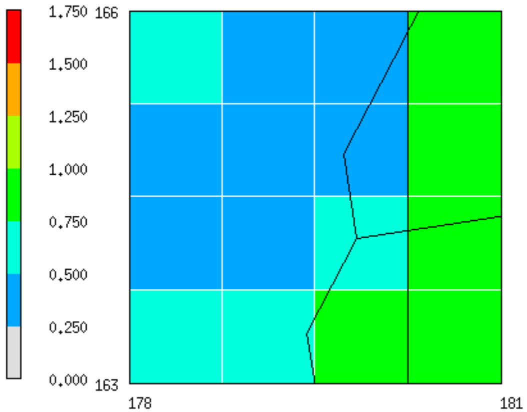
Winter NOX



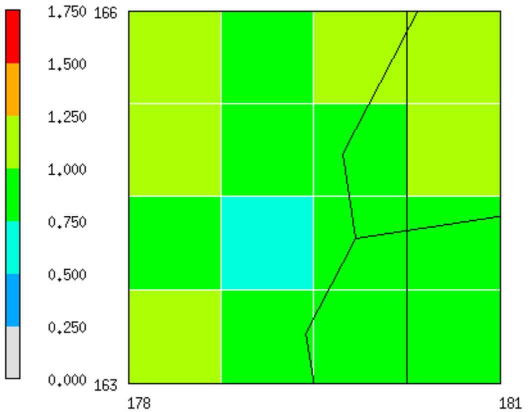
Winter $PM_{2.5}$

- These do not match next slide and are just a place holder for now

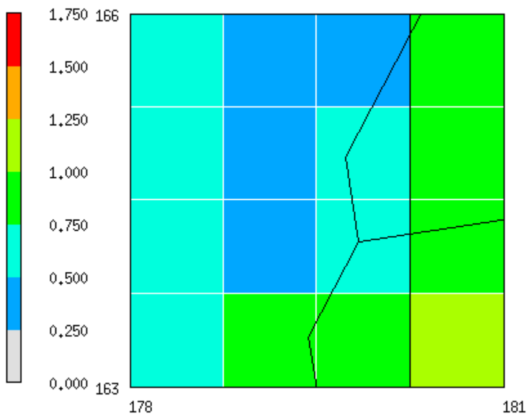
Monthly Average Concentrations
Zero Out/Total



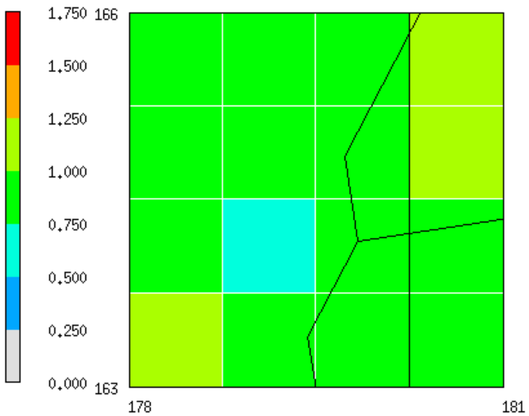
Summer NOX



Summer $PM_{2.5}$



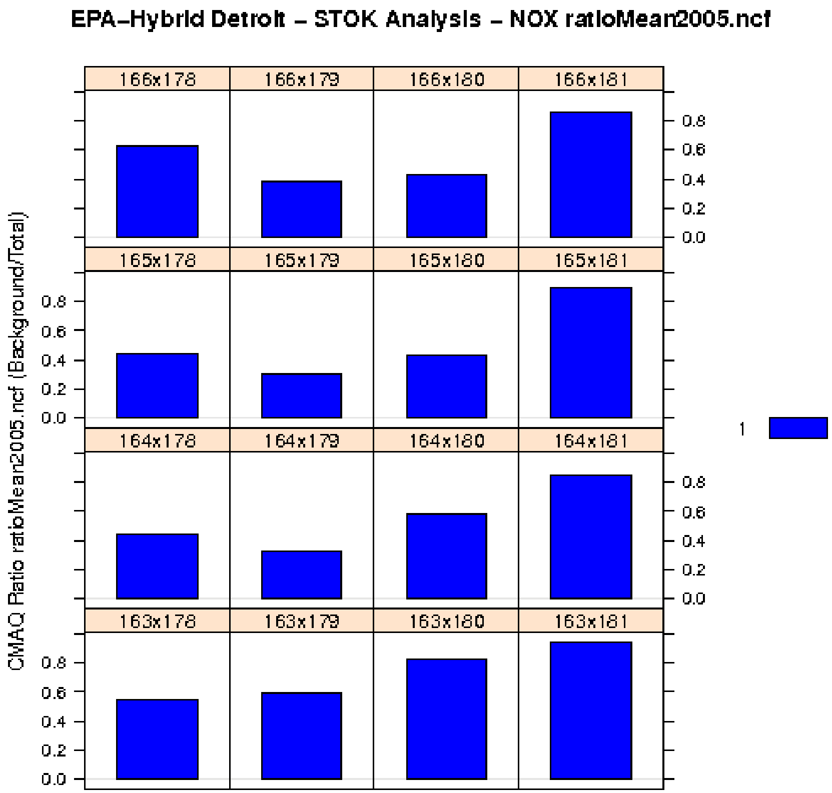
Winter NOX



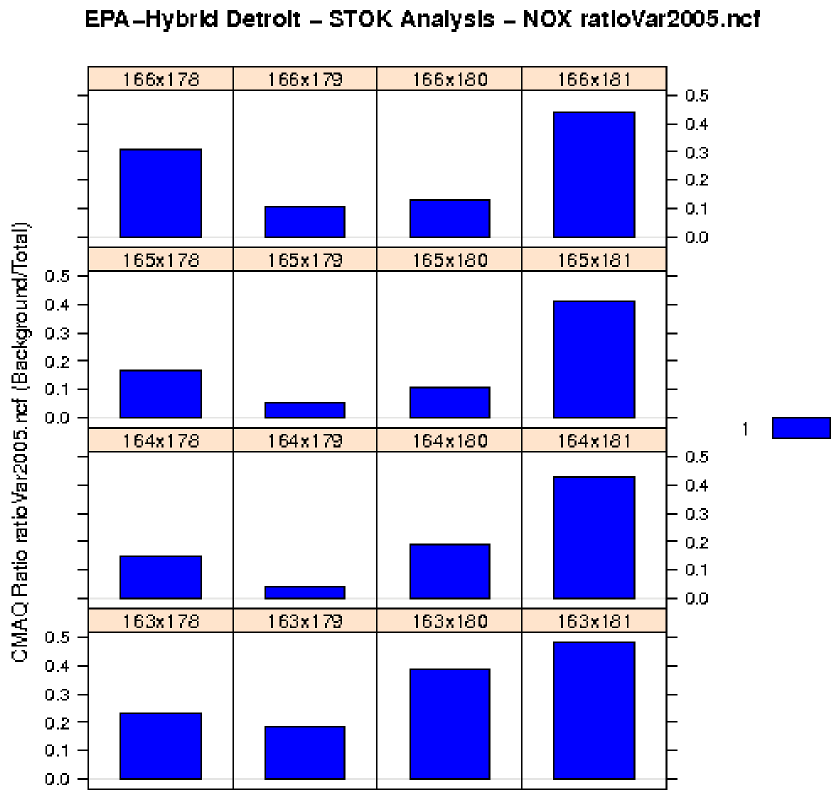
Winter $PM_{2.5}$

- Zero Out/Total ratio shows decrease due to zero out of emission

Annual NOx Ratio



R Mean



R Variance

- Zero Out/Total Ratio Mean shows most reduction at Detroit metro area
- Zero Out/Total Ratio shows least variance at Detroit metro area

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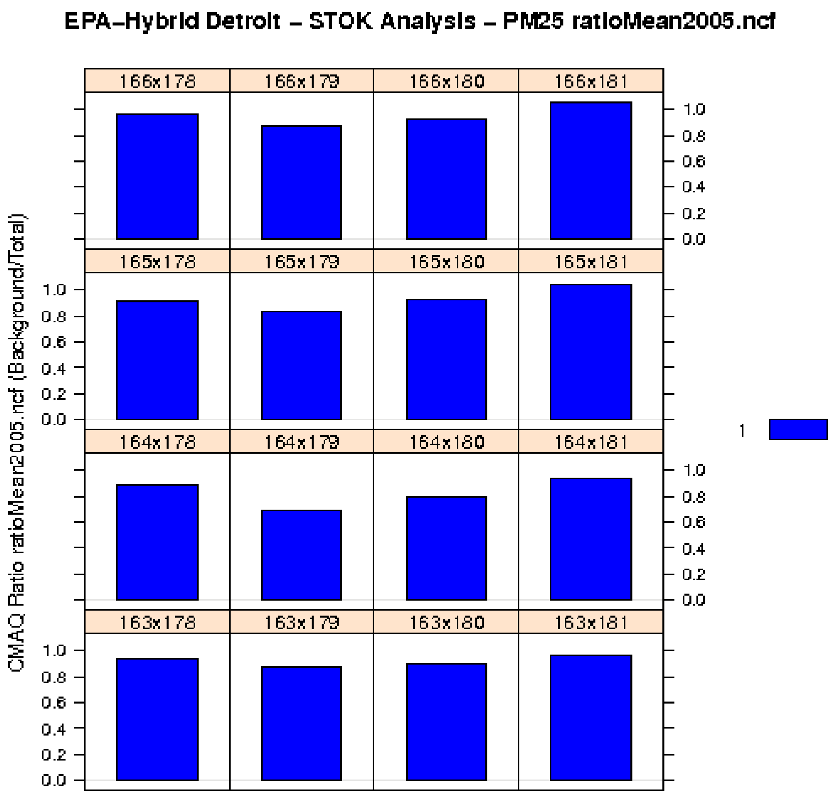
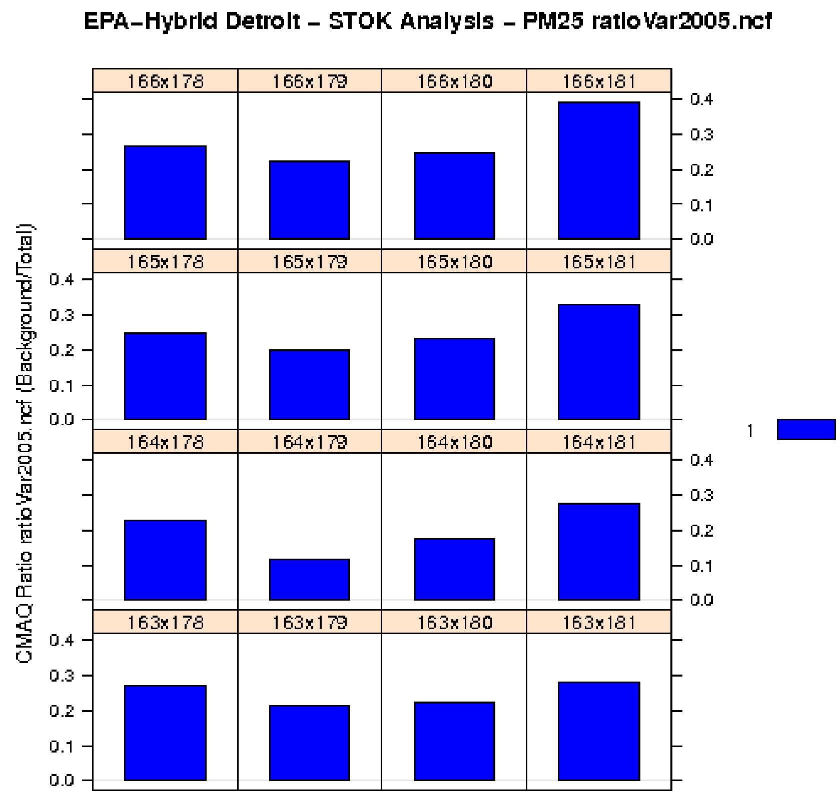
Annual $PM_{2.5}$ Ratio



R Mean



R Variance

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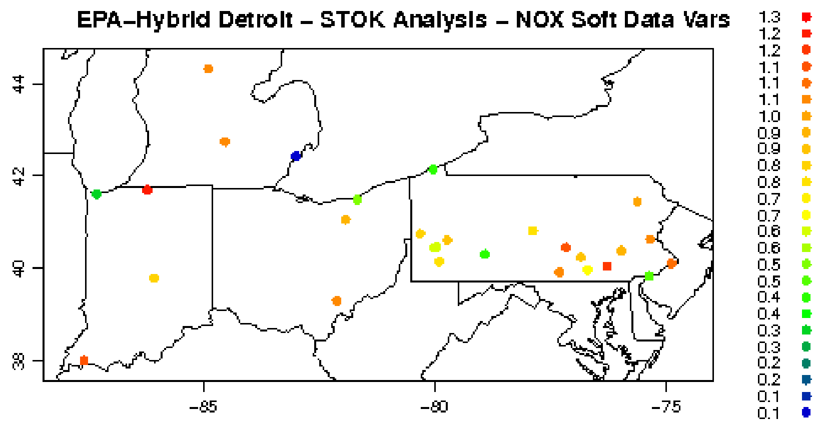
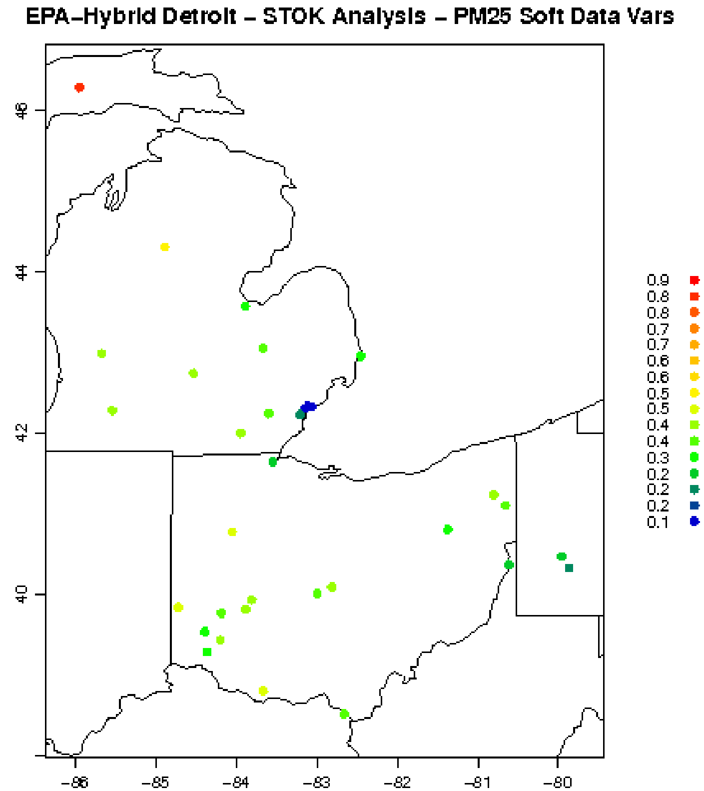
Spatial Variability of Soft Data



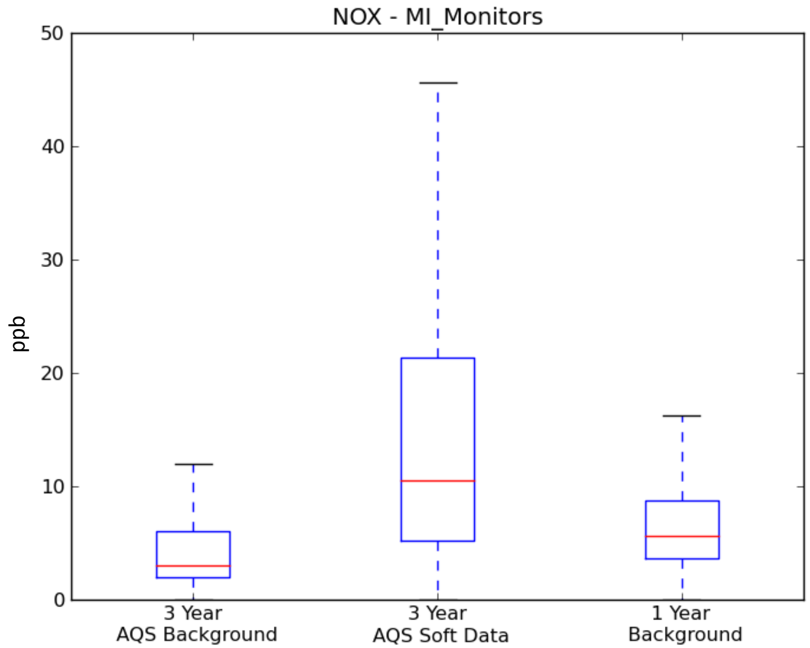


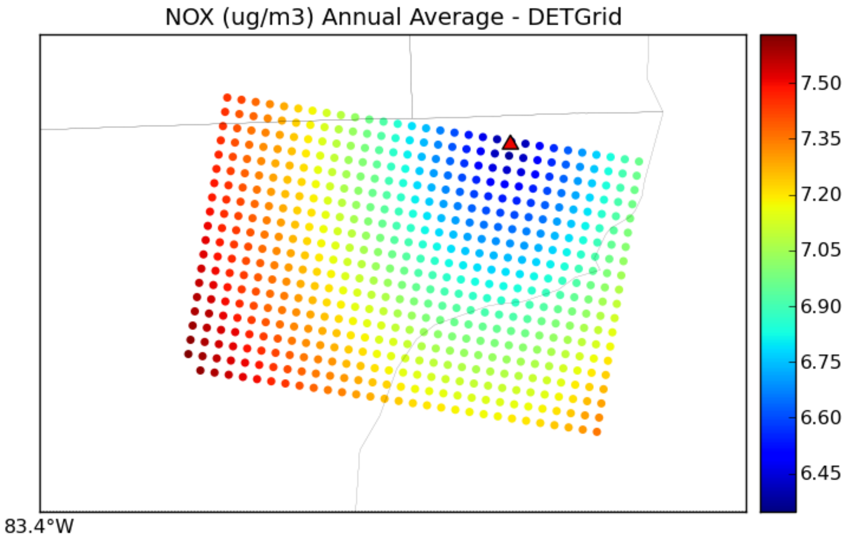
NOx

PM2.5

- Both NOx and PM2.5 have high variance as you move away from Detroit area

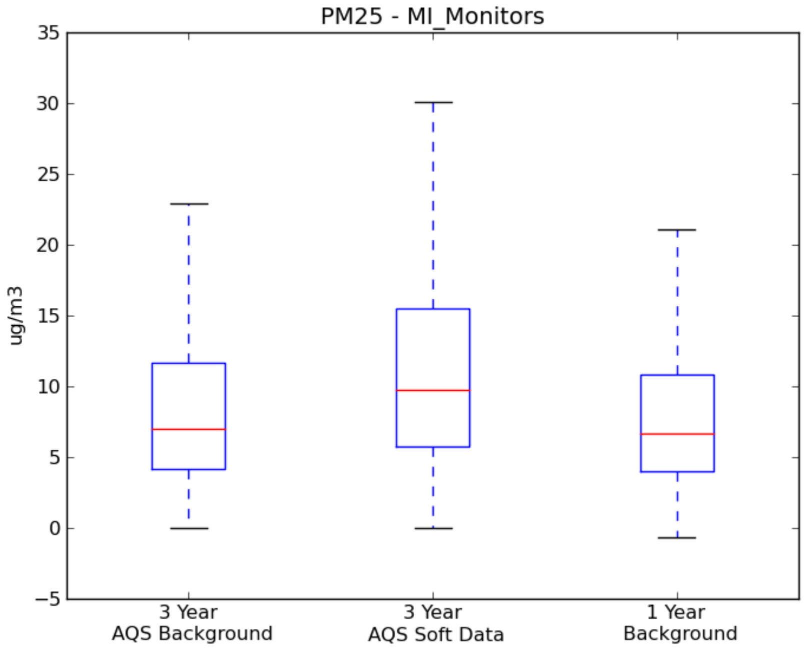
STOK Background – NOx

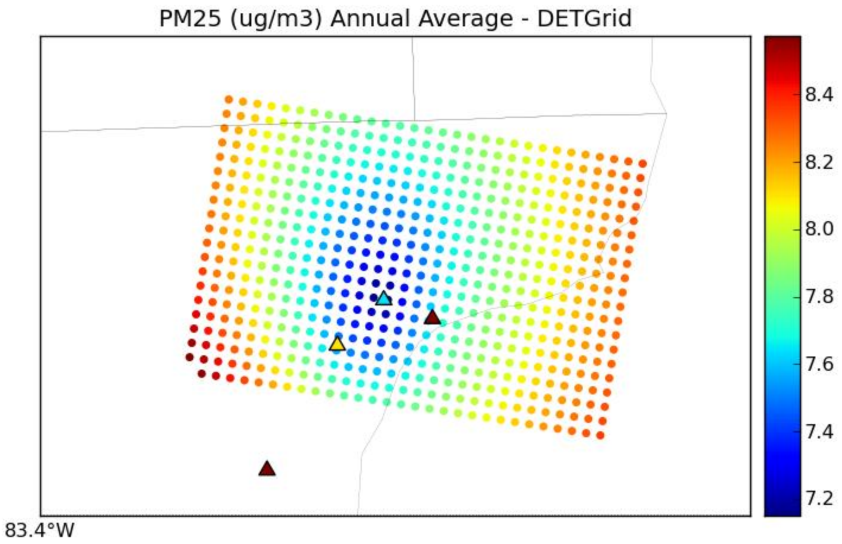




- STOK Background distribution is comparable to Monitors classified as background
- Spatial concentration gradient influenced by non-background monitors

STOK Background – $PM_{2.5}$





- STOK Background distribution is comparable to Monitors classified as background
- Spatial concentration gradient influenced by non-background monitors

CONCLUSIONS

- Developed a new approach that relies on both observations and model to estimate fine-scale background concentrations
- Successfully applied for ongoing exposure study in Detroit for a 29-month period for multiple pollutants
- Background concentrations clearly influenced by both soft and hard data
- Soft Data variance greatly affect background concentration
- STOK Background concentrations at estimation points comparable to AQS Sites classified as background

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