Non-parametric Trajectory Analysis of High Time Resolution $PM_{2.5}$ Data from EPA's Near-Road Monitoring Network Sites

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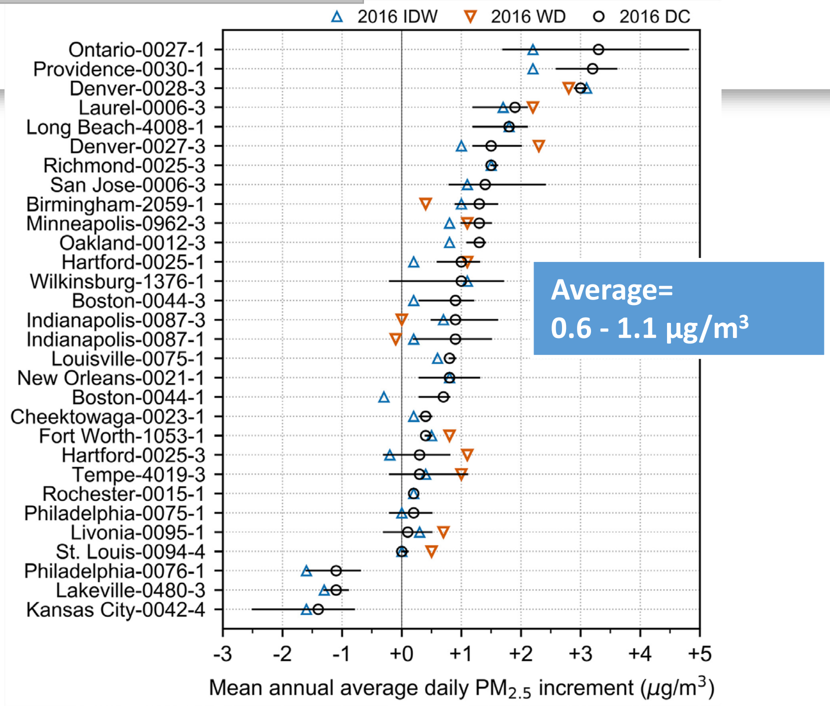
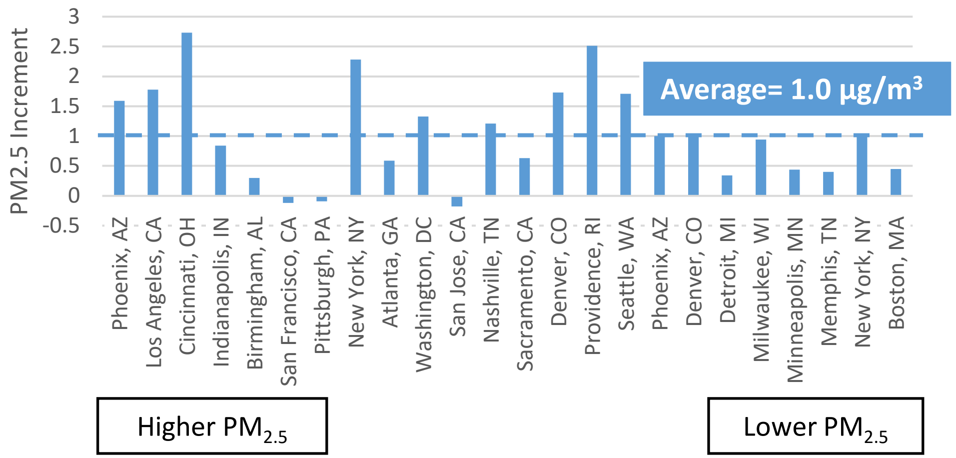
Background

- **EPA Near-road Monitoring Network**
  - Established to assess levels of NAAQS pollutants near major roadways
  - Provides continuous hourly measurements of air pollutants such as NO_2, CO and $PM_{2.5}$ at more than 50 sites across U.S.
- Recent analyses using Near Road Monitoring Network data estimated average “increment” from roadway
  - Methods calculated difference between near road site and other sites within urban area
  - “Increment” represents amount above background
  - Average $PM_{2.5}$ increment was ~1.0 µg/m^3 (~5 - 10%)
  - Differed between sites (up to 3 µg/m^3, a few negative)
  - Distance from roadway and traffic metrics not strong predictors of differences
  - Limitations of approach include using other sites to estimate urban background, and possible influence of other local sources

From Seagram et al 2019



Data from Gantt et al 2021



Background

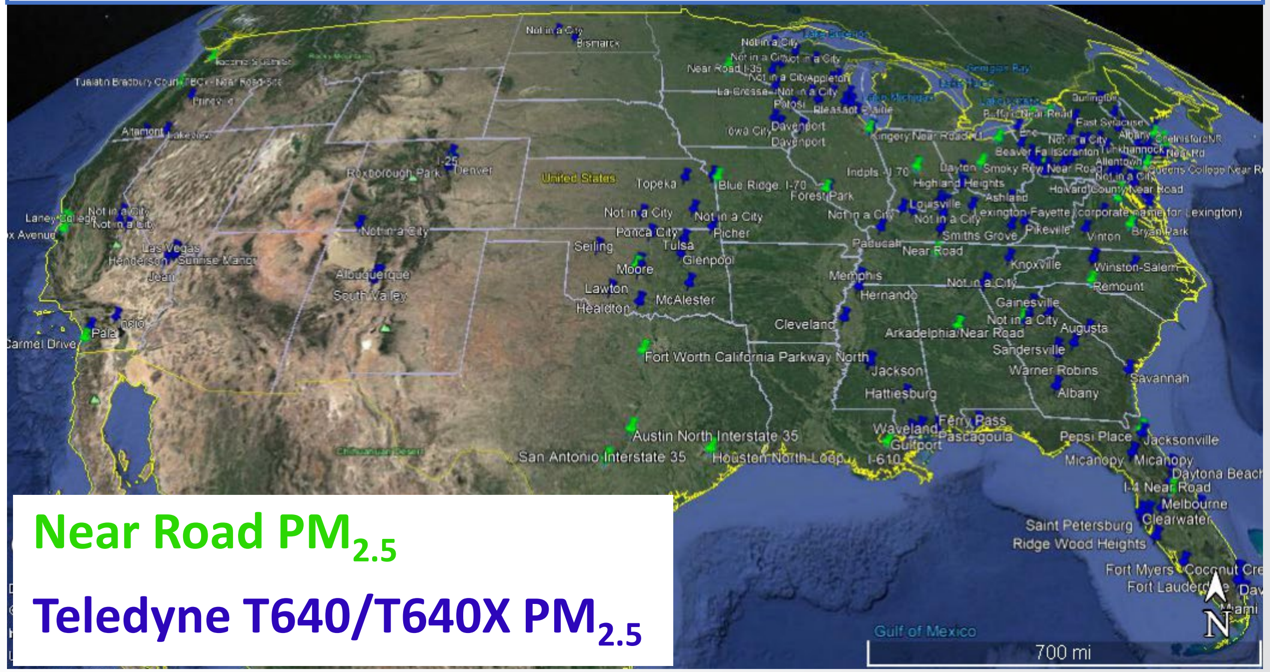
- **Non-parametric Trajectory Analysis (NTA)**
  - A potential data analysis approach for quantifying impact of a nearby source using data from a single site
  - NTA combines high time resolution wind speed/direction and air pollutant concentrations to identify, quantify, and visualize local-scale source impacts
  - NTA previously applied for EPA/ORD studies with high time resolution data (5 min, 1 min) for BC and NO_2 (not $PM_{2.5}$)
- EPA/ORD Detroit I-96 Near-Road Study
  - 5 min. $PM_{2.5}$ and wind speed/direction data available at multiple sites for evaluating approach for $PM_{2.5}$ at single near road site

Detroit I-96 Near-Road Study

Background

- **High time resolution $PM_{2.5}$ monitoring data for NTA**
  - Certain $PM_{2.5}$ monitors deployed in the Near-road Monitoring Network (FEMs) capable of reliably collecting 1 min. or 5 min. data
  - Working through EPA Regions, asked States to provide high time resolution data from their Near Road Monitoring Network sites
  - Several States store data at 1 min. or 5 min. resolution for these monitors
  - Three State/Local Agencies provided data for evaluation of NTA approach

Monitoring Sites in EPA's AQS



Near Road Monitoring Network Sites

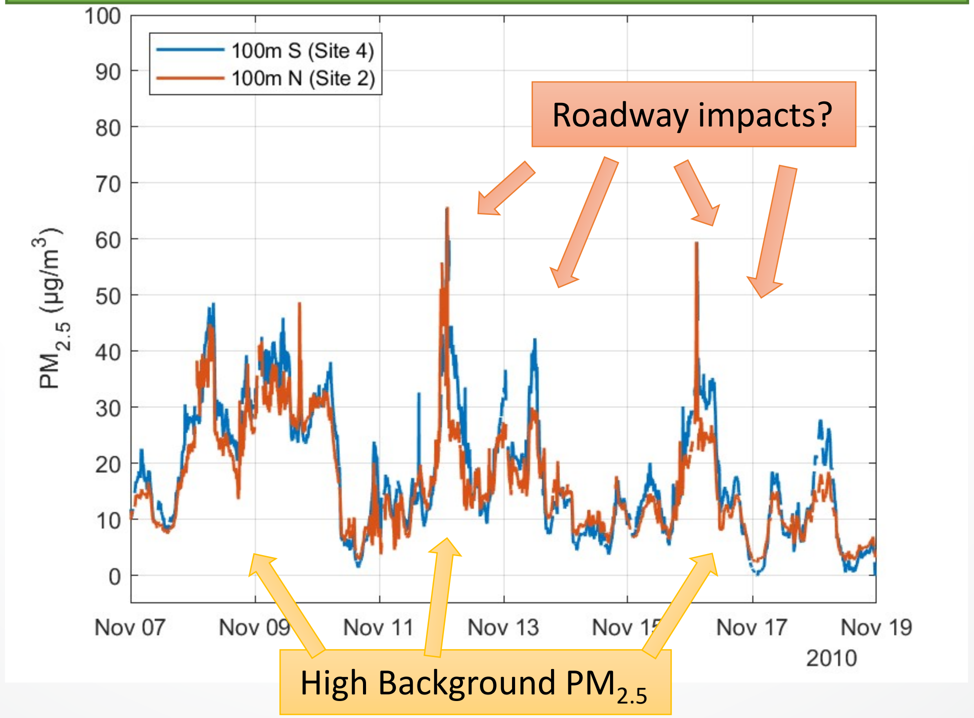
- **I-75 Cincinnati** (Cincinnati, OH)
  - **$PM_{2.5}$:** 5 min. (Thermo Scientific 5030 SHARP)
  - **WS WD:** 5 min. at nearby urban site (not near road)
- **I-25 Denver and I-25 Globeville** (Denver, CO)
  - 2 near road sites
  - **$PM_{2.5}$:** 1 min. (GRIMM EDM 180)
  - **WS WD:** 1 min. (vane)
- **I-64 Forest Park** (St. Louis, MO)
  - **$PM_{2.5}$:** 1 min. (Teledyne T640 *added July 2021*)
  - **WS WD:** 1 min. (sonic anemometer)
  - BC/UVC, $NO/NO_2/NO_X$: 1 min.

$PM_{2.5}$ Background Estimation

- **Detroit I-96 Near Road Study data used for evaluating $PM_{2.5}$ background algorithm**
  - 2 sites: 100m North and 100m South of I-96
  - 5 min. $PM_{2.5}$ Thermo Scientific 5030 SHARP and 5 min. wind speed/direction
  - Co-located instruments at Site 2 (100m North): Example Nov 7 – 18, 2010 with good agreement

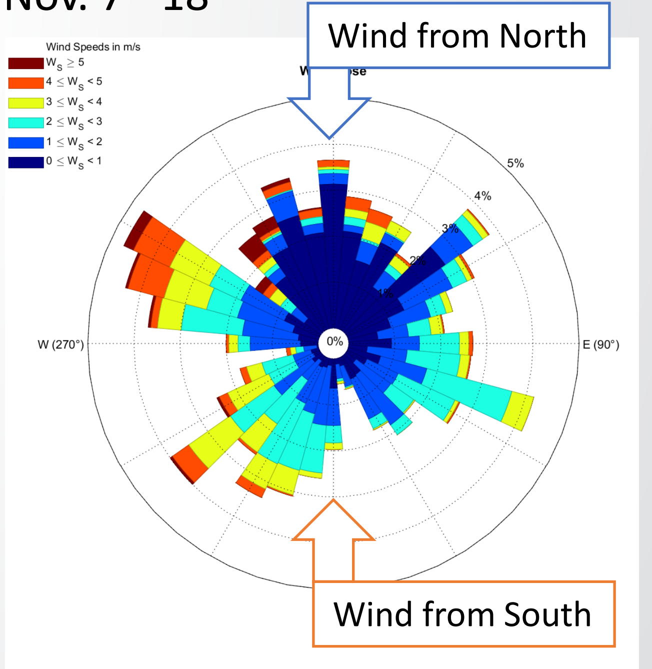
Site Locations

$PM_{2.5}$ Concentrations



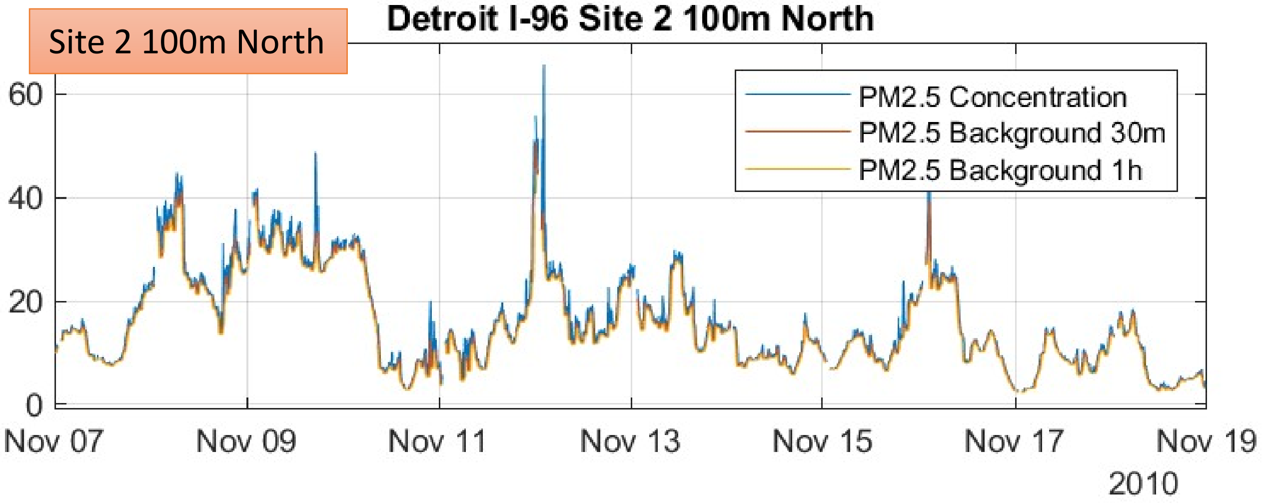
Wind Direction and Wind Speed

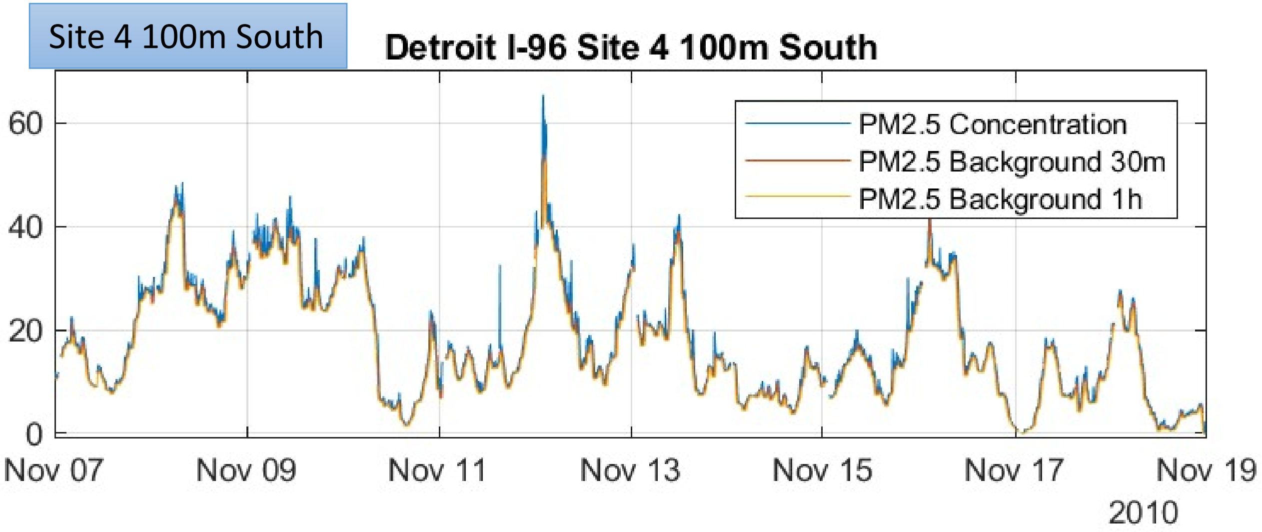
Nov. 7 - 18



$PM_{2.5}$ Background Estimation

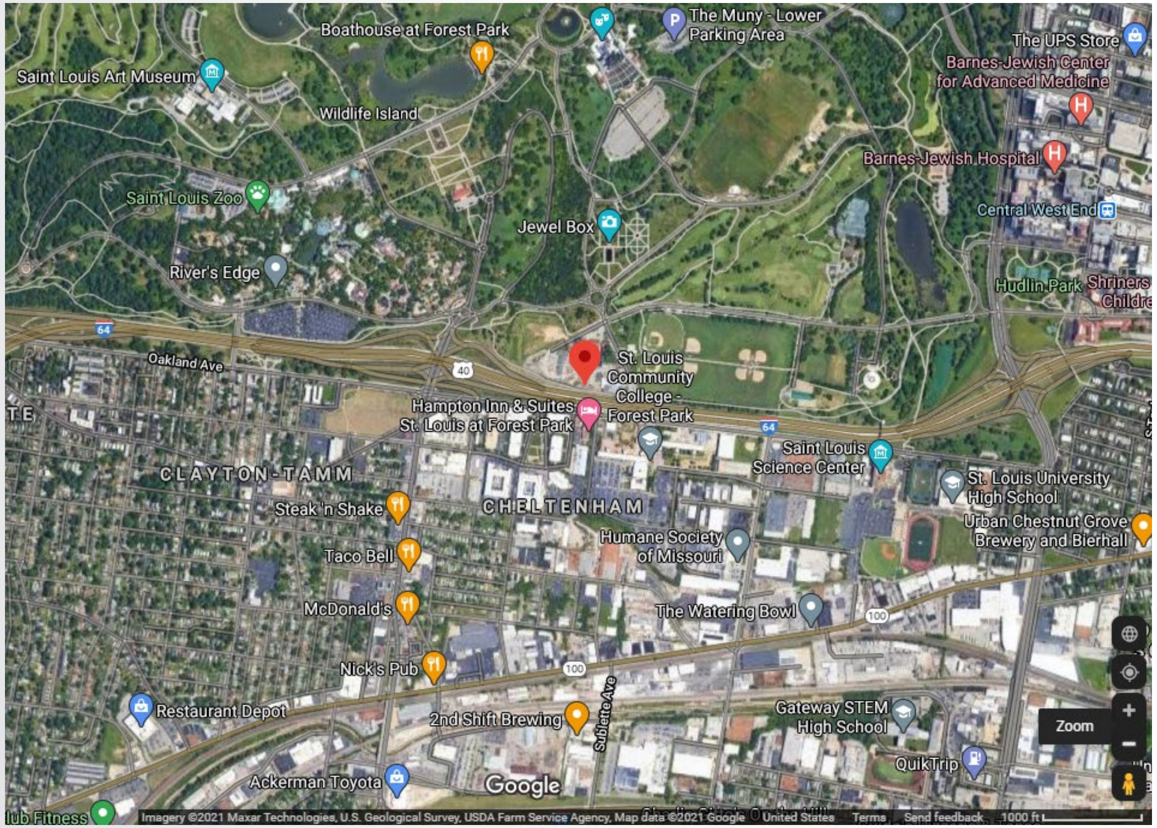
- **`Moving minimum' algorithm**
  - Goal: Quantify background as longer duration changes in $PM_{2.5}$, and subtract background so that short-term changes remain
  - Moving minimum calculates minimum over sliding window size centered about the current and previous elements
  - Compared window sizes up to 6 hours
  - Little change in estimated background with window size smaller than 30 min. for 5 min. SHARP data

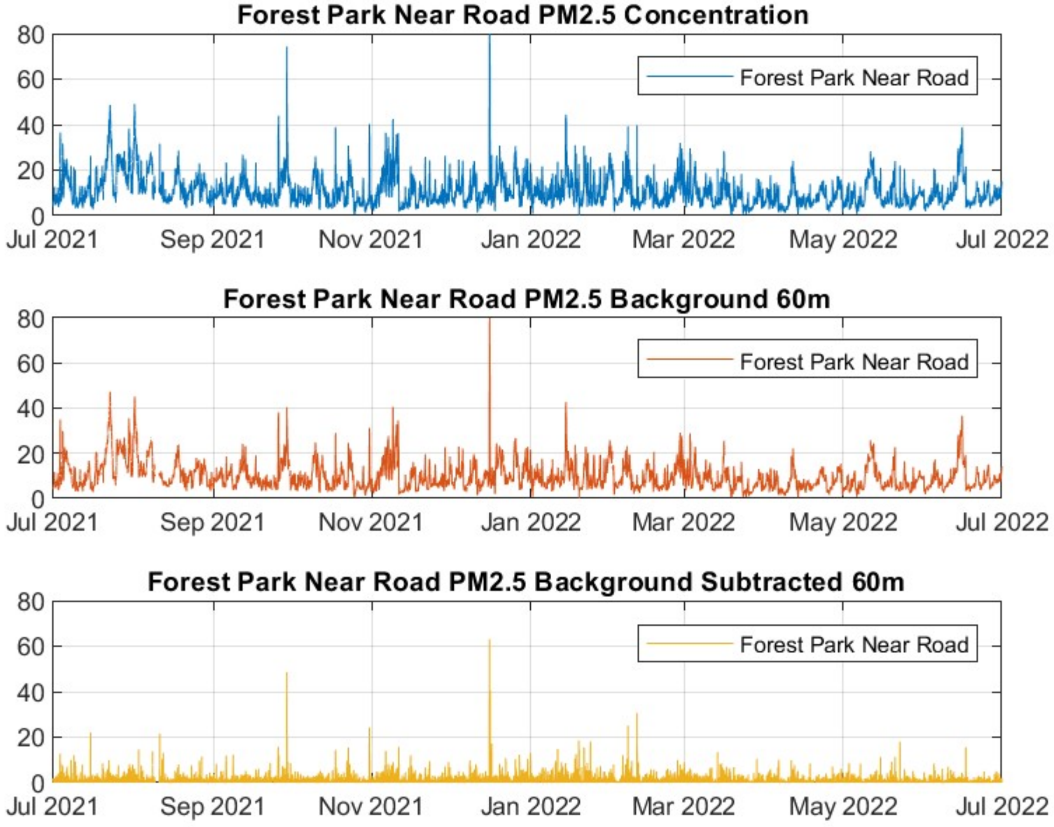




Background Subtracted $PM_{2.5}$ for NTA

- **Near Road Monitoring Network Site: I-64 Forest Park (St. Louis, MO)**
  - One year of 1 min. $PM_{2.5}$ (July 2021 – June 2022) Teledyne T640

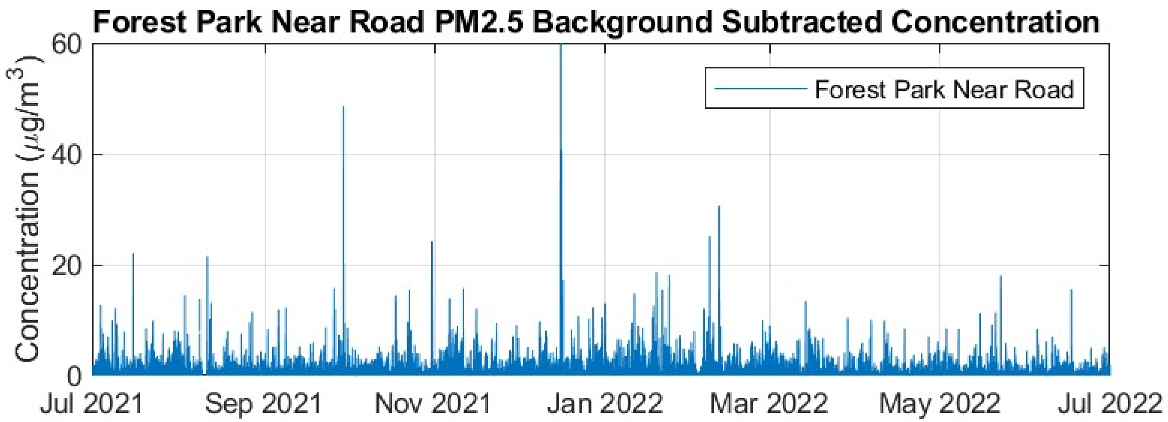




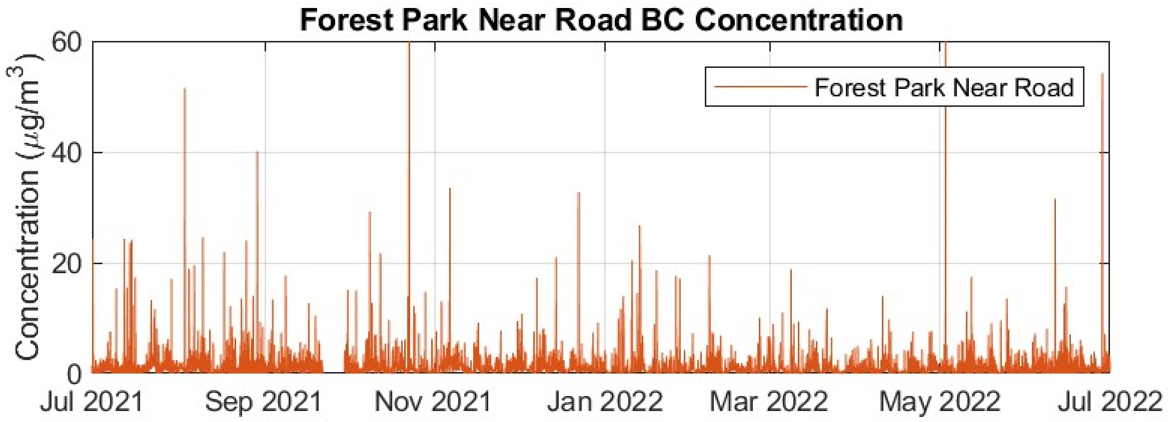
Background Subtracted $PM_{2.5}$ for NTA

- Comparison of $PM_{2.5}$ Background Subtracted with Black Carbon (BC)

$PM_{2.5}$ Bksbtr (µg/m³)

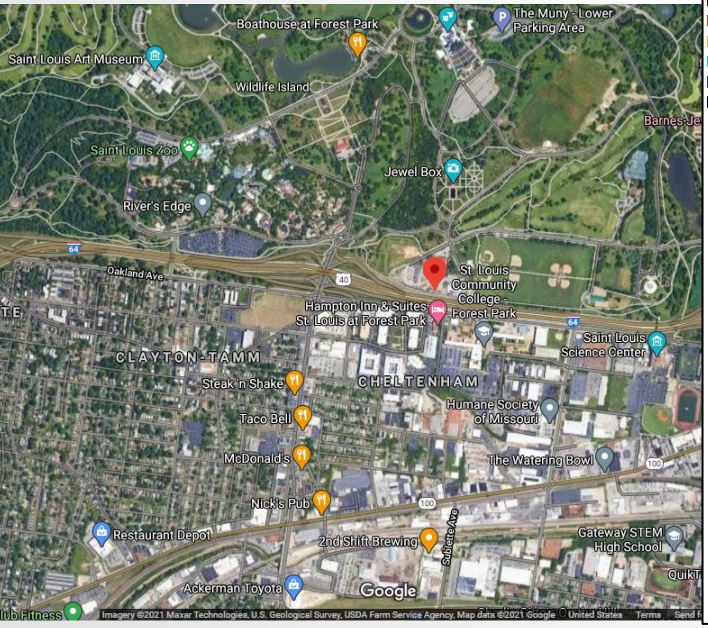


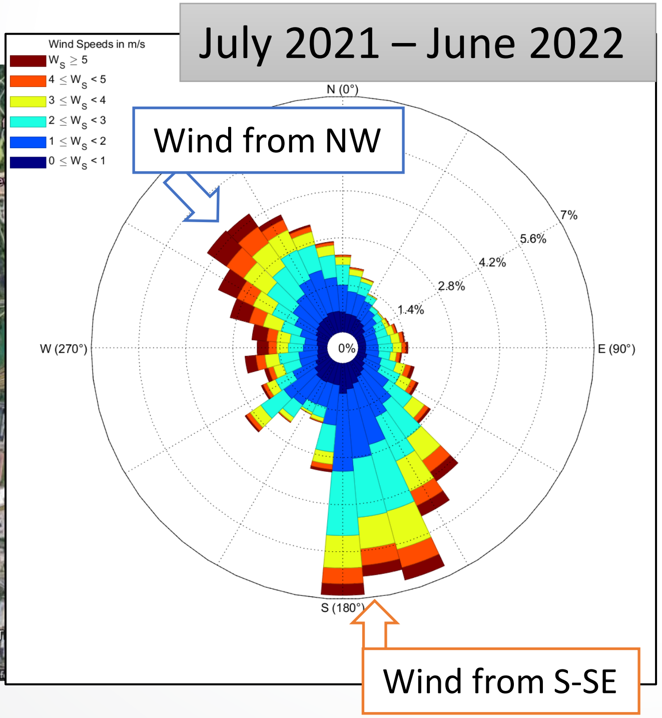
BC (µg/m³)

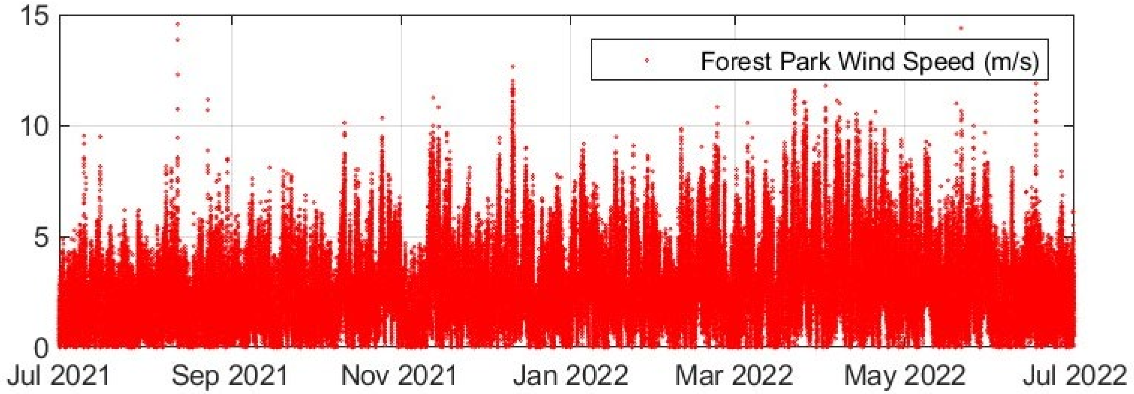


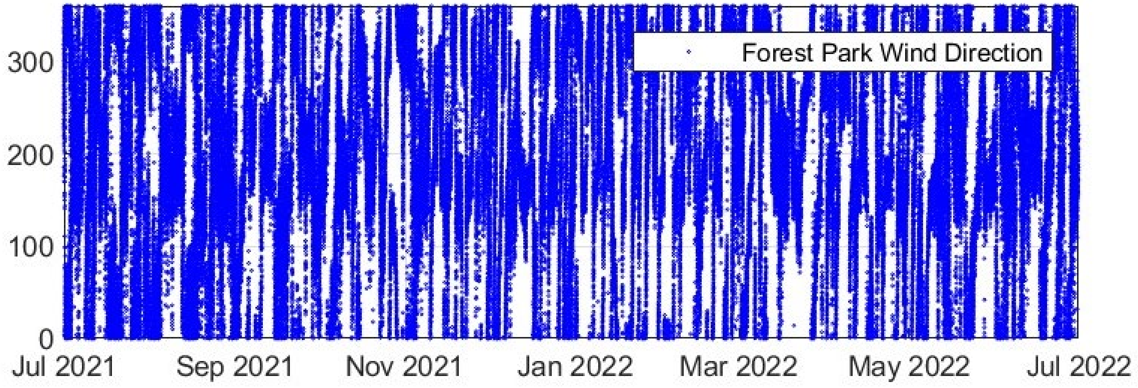
Wind Direction and Speed for NTA

- NTA uses high time resolution wind data as input
- Forest Park site has two primary wind directions
  - From South-Southeast with lower wind speeds
  - From Northwest with higher wind speeds



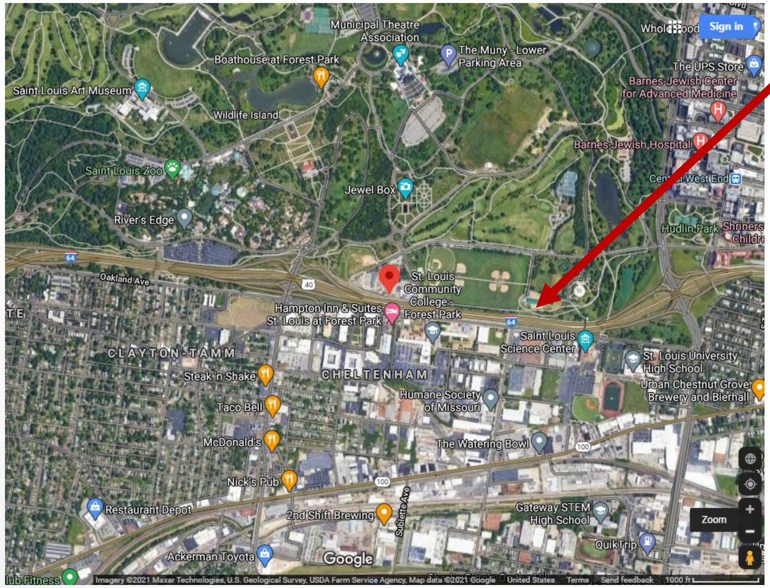




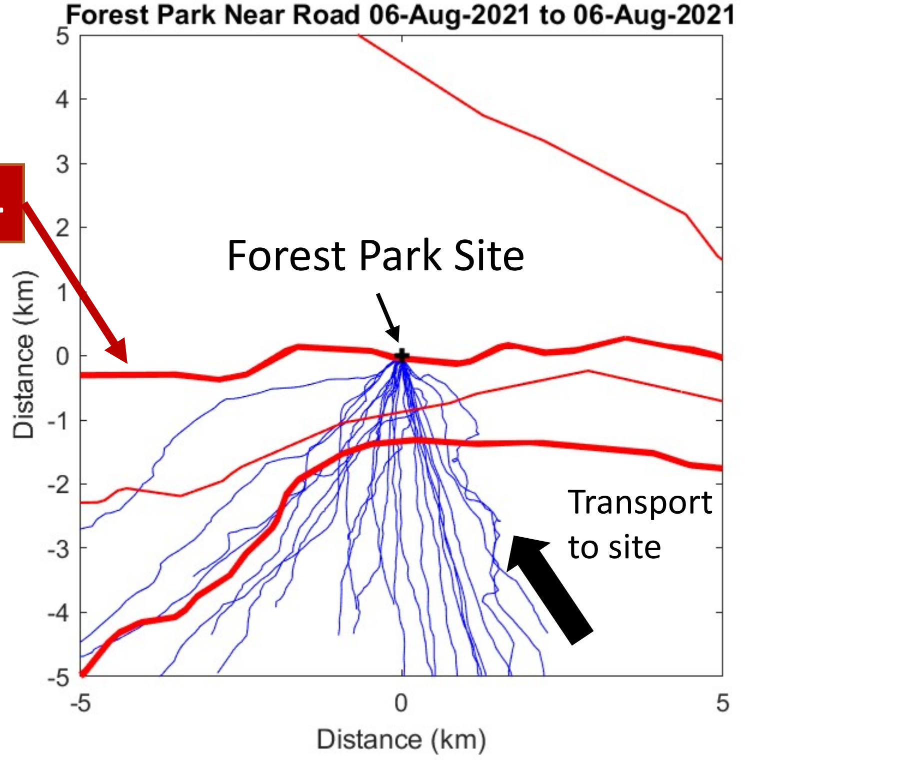


Non-parametric Trajectory Analysis (NTA)

- Generates local back trajectories using wind speed and direction
- Each trajectory combined with pollutant concentrations for each time step
- Non-parametric regression used to summarize over time
- Results displayed as maps that identify local source areas impacting concentrations measured at a receptor site

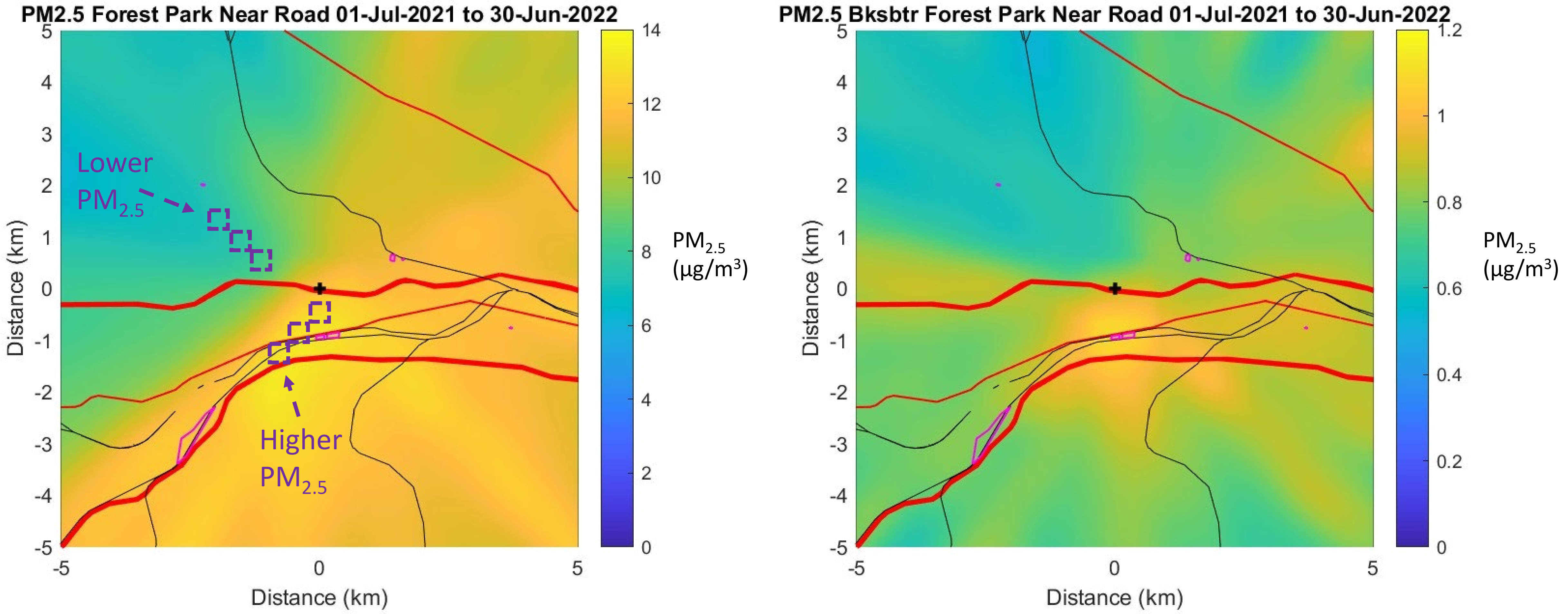


Example Trajectories Crossing I-64: Aug. 2021



NTA Results: Forest Park

- **Comparison of NTA for $PM_{2.5}$ and $PM_{2.5}$ Background Subtracted**
  - Full year of data: July 2021 – June 2022



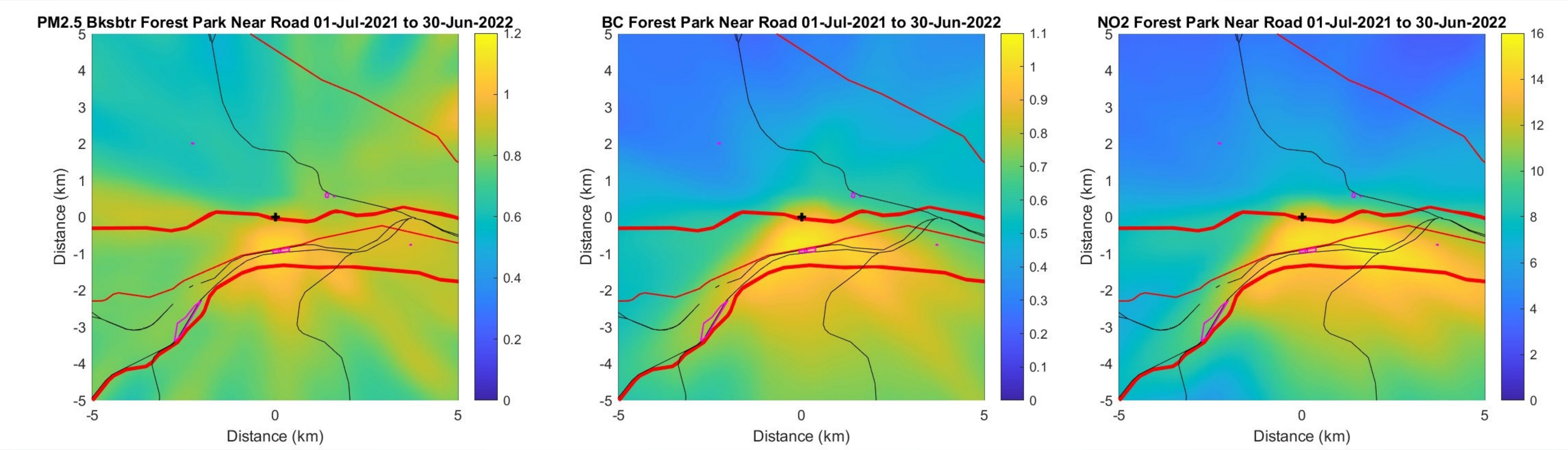
NTA Results: Forest Park

- **Comparison of $PM_{2.5}$ Background Subtracted to BC and NO_2 NTA Results**
  - Identifying same areas as contributing higher concentrations for $PM_{2.5}$, BC and NO_2
  - Lower concentration areas for BC and NO_2 are close to zero, minimum for $PM_{2.5}$ above zero

$PM_{2.5}$ Bksbtr ($\mu g/m^3$)

BC ($\mu g/m^3$)

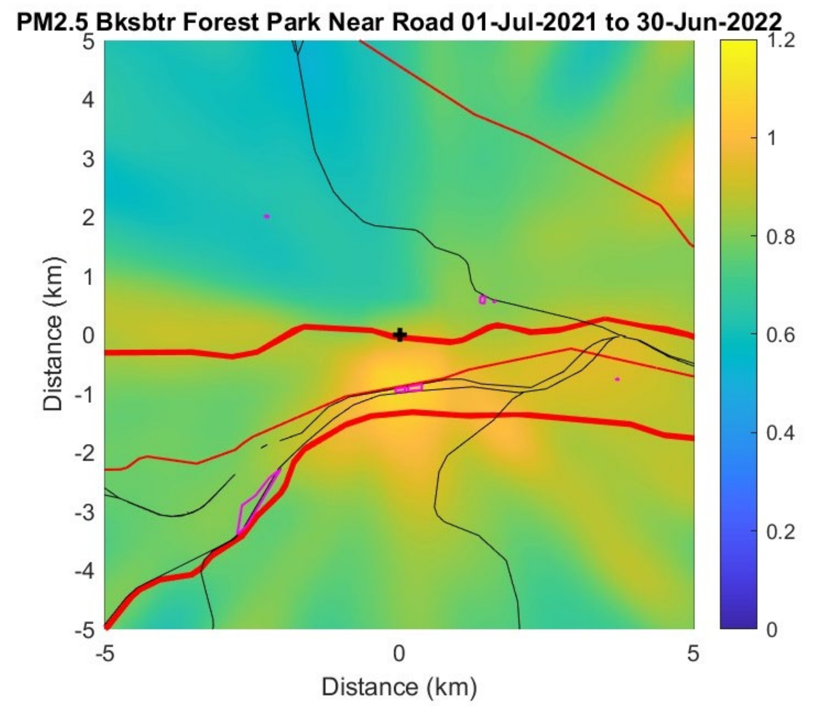
NO_2 (ppb)



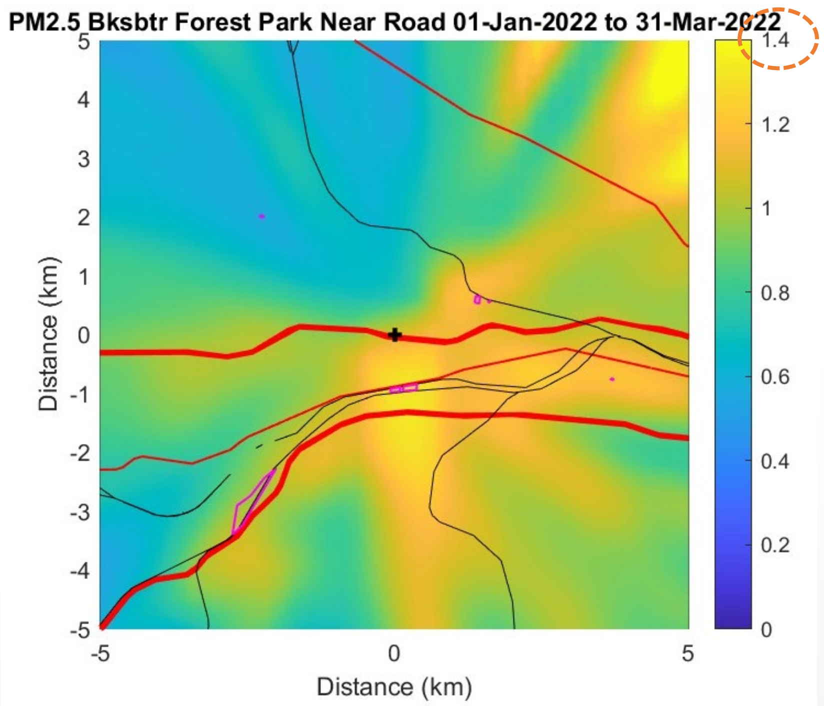
NTA Results: Forest Park

- **Comparison of $PM_{2.5}$ Background Subtracted by Season**
  - Winter > Fall > Summer > Spring
  - Predominant wind directions consistent across seasons, wind speeds differ

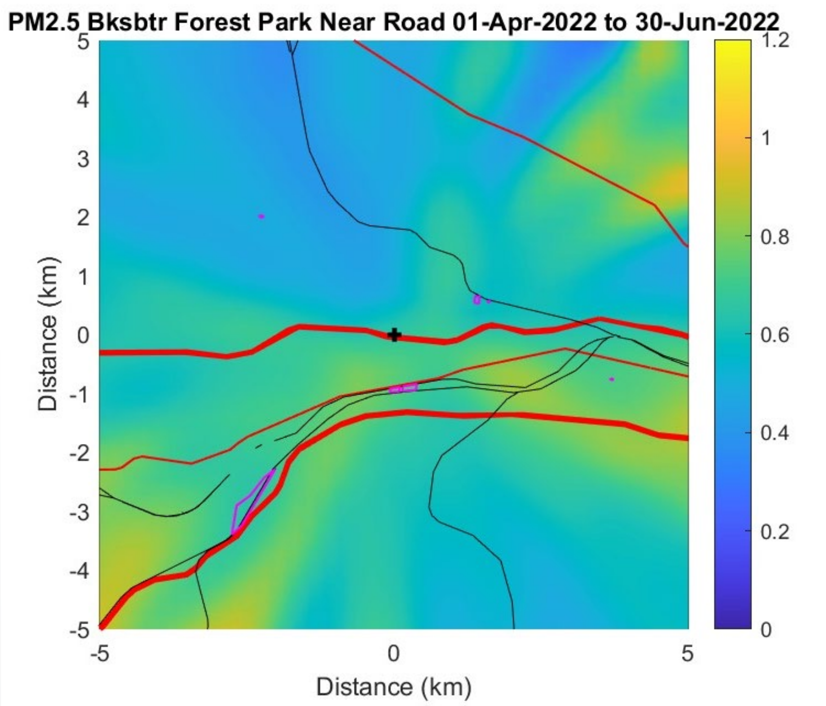
All Year



Winter



Spring



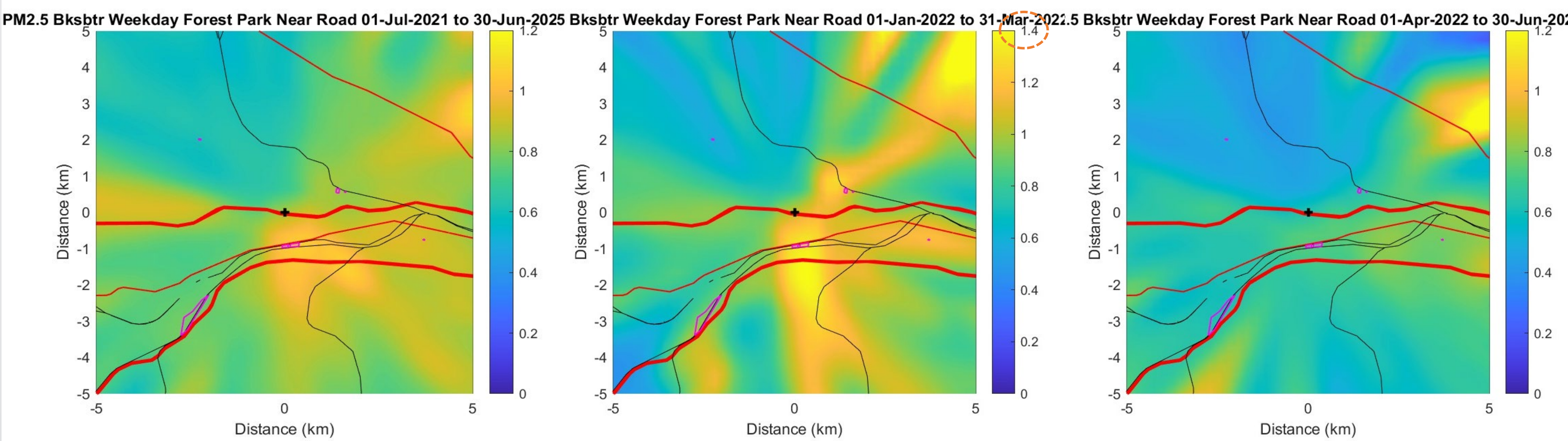
NTA Results: Forest Park

- **Comparison of $PM_{2.5}$ Background Subtracted by Season for Weekdays Only**
  - Weekdays only results similar to all days of year
  - Higher during winter months, other upwind sources more evident weekdays

All Year - Weekdays

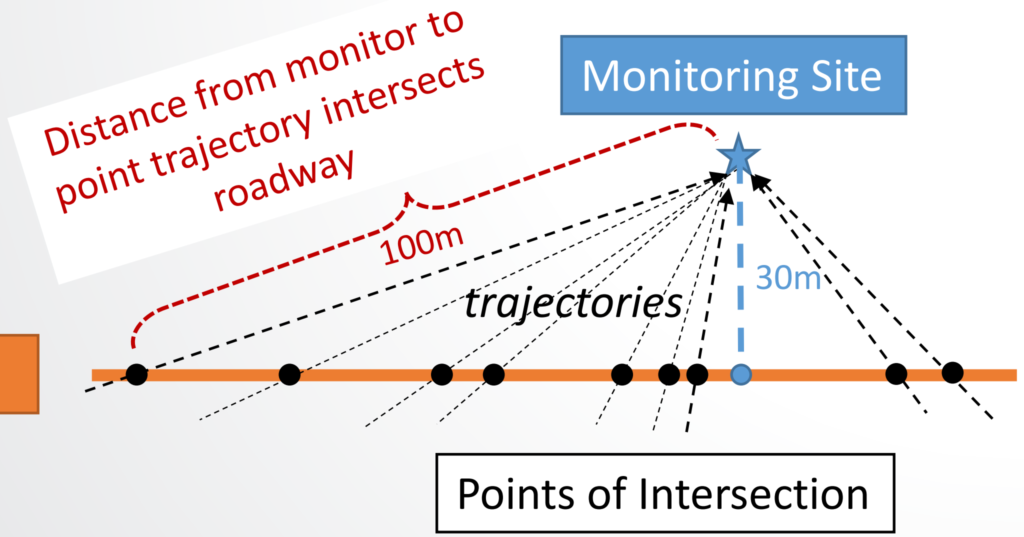
Winter - Weekdays

Spring - Weekdays

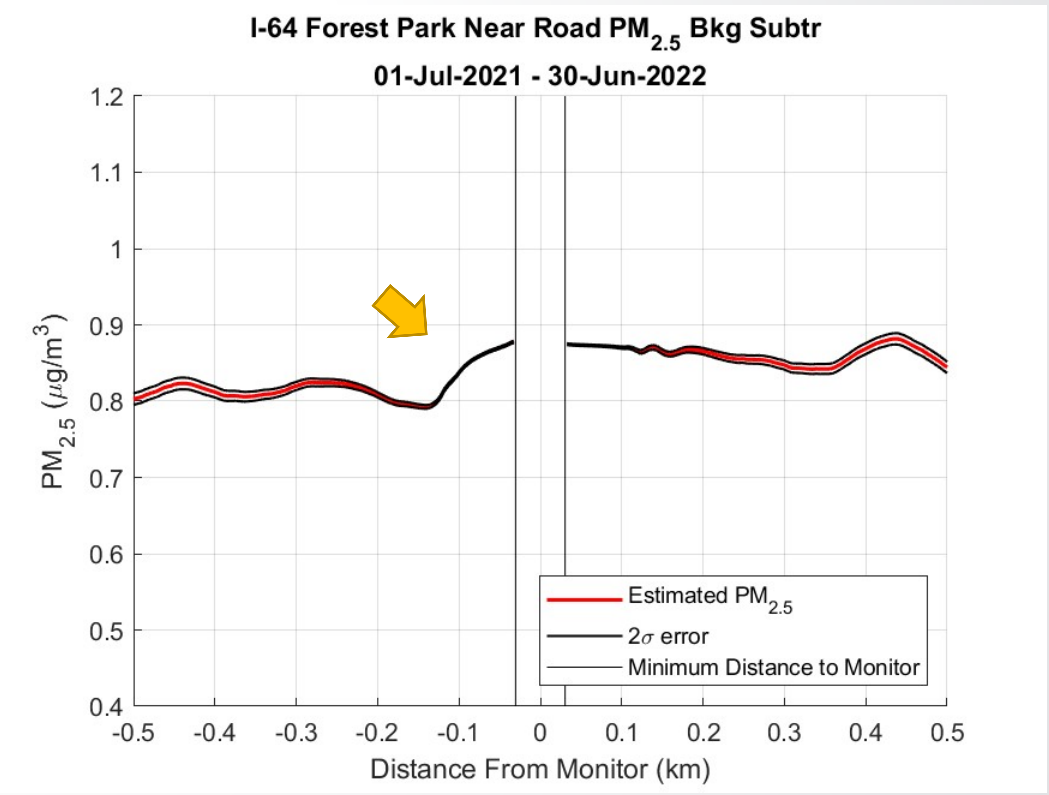


NTA Results: Highway Contribution

- **Apportionment of highway contribution**
  - Only trajectories that intersect roadway (site is downwind of roadway)
  - Calculate distance between monitor and point that trajectory intersects roadway
  - Non-parametric regression of concentration with distance from monitor



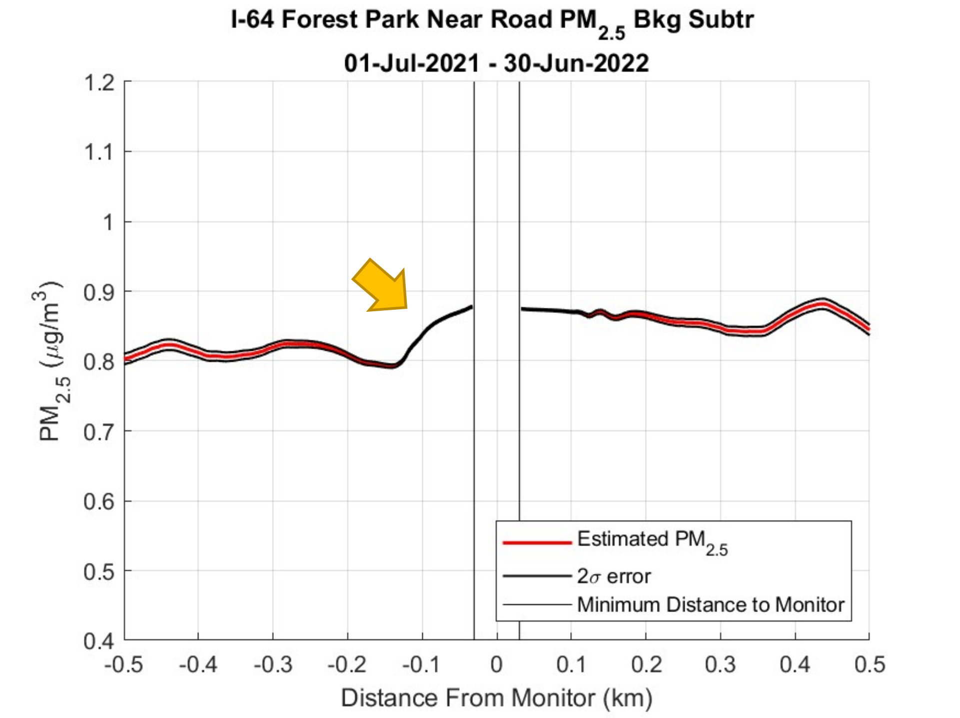
$PM_{2.5}$ Bksbtr (µg/m³)



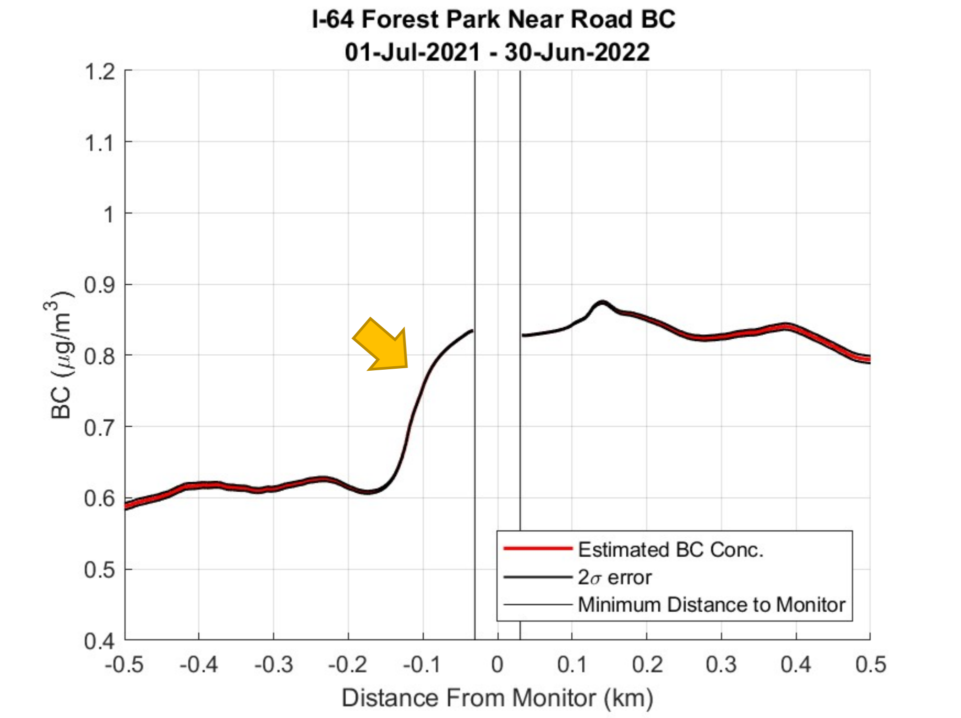
NTA Results: Highway Contribution

- **Apportionment of highway contribution**
  - Decrease in concentration with distance evident only for trajectories that intersect I-64 within 150 m to west (transport from S-SW) for background subtracted $PM_{2.5}$ and BC
  - More gradual decreasing trend for trajectories that intersect I-64 from east

$PM_{2.5}$ Bksbtr (µg/m^3)



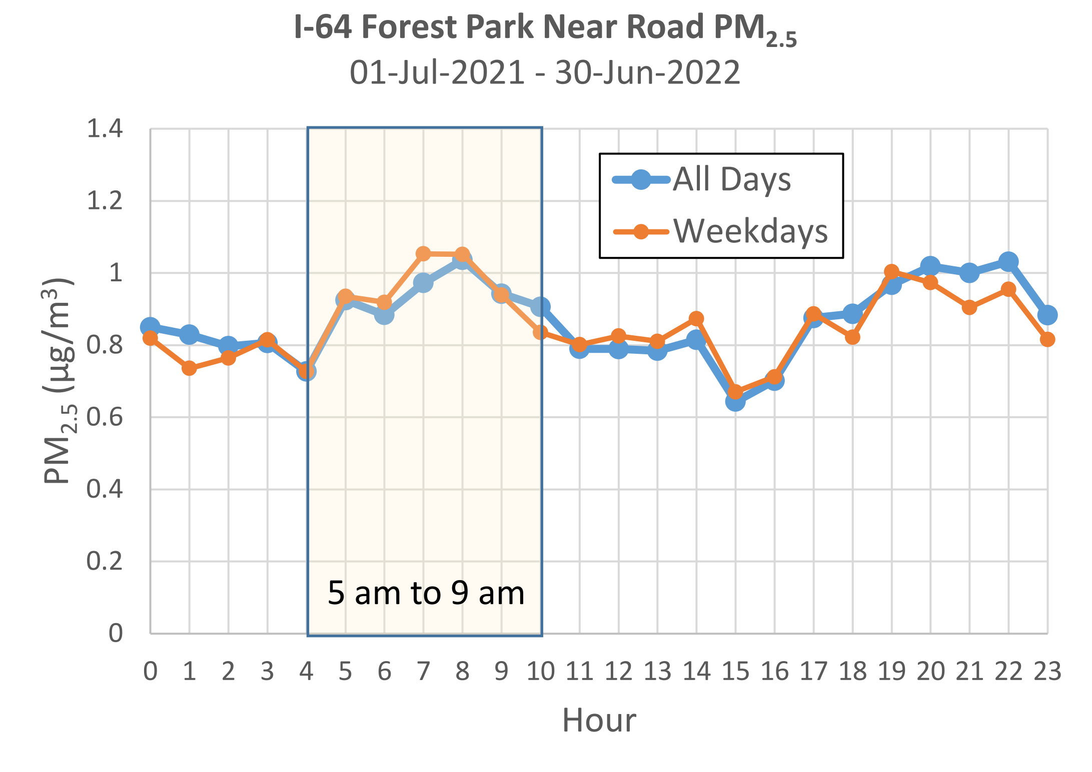
BC (µg/m^3)



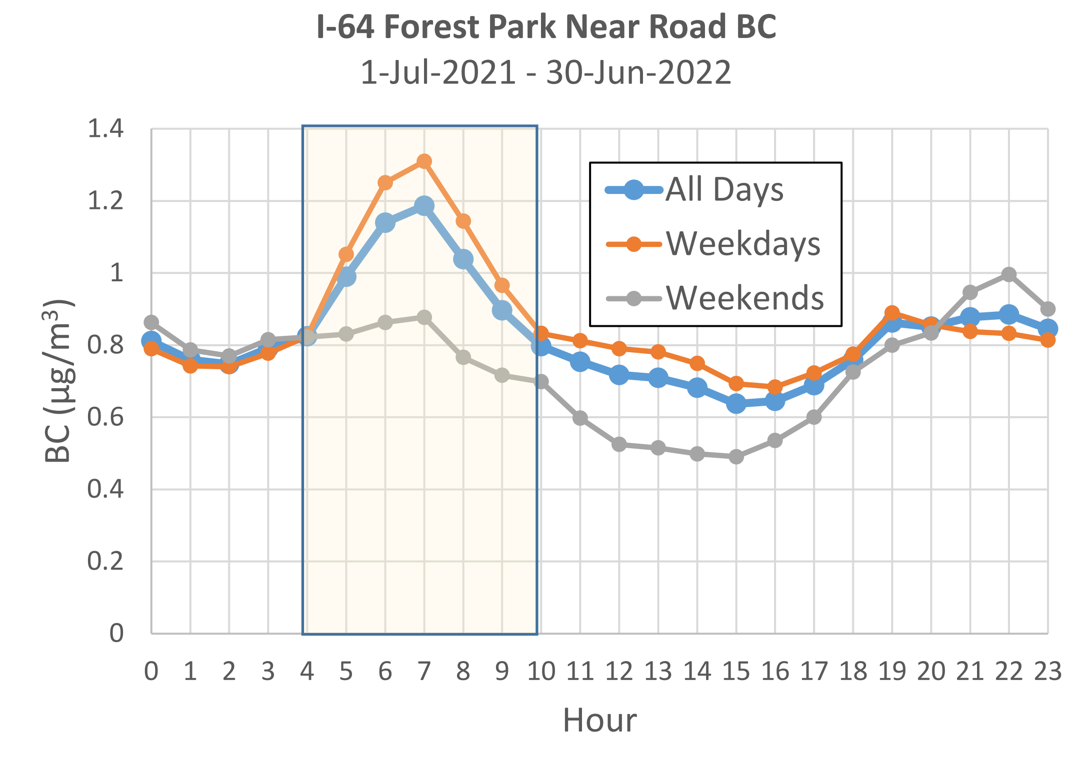
NTA Results: Highway Contribution

- **Apportionment of highway contribution by hour**
  - Comparison of estimated highway contribution at distance closest to site (30 m) for each hour
  - Diurnal trend by hour of day shows higher contribution of $PM_{2.5}$ during AM and PM rush hours
  - $PM_{2.5}$ diurnal trend less than BC during AM, but contribution during PM hours similar (due to weekends)

$PM_{2.5}$ Bksbtr ($\mu g/m^3$)



BC ($\mu g/m^3$)



NTA Results: Summary

- **Estimated $PM_{2.5}$ roadway contribution for Forest Park**
  - NTA Maps:
    - 1.0 – 1.2 µg/m^3 for 1 year average
    - Differed by season
      - Winter (Jan – Mar) high of 1.4 µg/m^3 to Spring (Apr-Jun) low of 0.7 µg/m^3
    - Weekdays similar for 1 year average
      - By season higher near roadway during winter and fall
    - Other sources nearby contributing $PM_{2.5}$ of similar magnitude during winter months, but not evident for BC and NO_2
  - NTA Highway Apportionment:
    - 0.8 - 0.9 µg/m^3 for trajectories that intersected highway within 150 m of site (1 year average)
    - Varied by hour of day from ~1 µg/m^3 during AM and PM peak to 0.6 µg/m^3 midday

Conclusions

- Using high time resolution data at near road monitoring sites able to apply NTA approach to quantify impact of roadway on $PM_{2.5}$
  - Quantified $PM_{2.5}$ background using moving minimum algorithm and appropriate window size for data
  - NTA applied with background subtracted $PM_{2.5}$ had estimates of roadway impact consistent with traffic related air pollutants (BC, NO_2)
  - Local meteorology important influence on roadway impacts
- Demonstrated an alternative approach to estimating roadway impacts using $PM_{2.5}$ data from single site vs. comparison to urban background site
- Approach can be useful for identifying and quantifying source impacts for any site with high time resolution concentration and wind speed/direction data

Questions?

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