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

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National Ambient Air Monitoring Conference
August 25, 2022

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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 NO₂, CO and PM₂.₅ 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 PM₂.₅ increment was ~1.0 μg/m³ (~5 - 10%)
- Differed between sites (up to 3 μg/m³, 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
• 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 NO₂ (not PM₂.₅)
• EPA/ORD Detroit I-96 Near-Road Study
  • 5 min. PM₂.₅ and wind speed/direction data available at multiple sites for evaluating approach for PM₂.₅ at single near road site
• 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
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
- Site 2 (100 m North)
- Site 4 (100 m South)

PM$_{2.5}$ Concentrations
- Nov. 7 - 18
- Roadway impacts?

Wind Direction and Wind Speed
- Wind from North
- Wind from South
- High Background PM$_{2.5}$
`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 ($\mu g/m^3$)**

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

July 2021 – June 2022
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
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
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
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
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
• 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
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)
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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