The potential for public-transit based atmospheric monitoring to advance air quality and atmospheric chemistry research and to engage urban stakeholders

Logan E. Mitchell  
Erik Crosman  
Ben Fasoli  
Alexander Jacques  
Daniel Mendoza  
Derek Mallia  
John Horel  
John Lin

NOAA GMAC, 2019  
May 22, 2019, Boulder, CO

Contact: Logan.Mitchell@utah.edu
The Big Picture...

Policy

Emissions

Local
- Atmospheric composition
- Human health
- Exposure/dose

Global
- Climate
  - Sea level rise
  - Extreme weather
  - Ecosystem impacts
  - Human health
  - Etc...

Ambient air quality
Simultaneous GHG & Air Quality Monitoring

Salt Lake City’s GHG targets:
2. 80 X 2040: 80% Reduction in Community Greenhouse Gas Emissions by 2040, Compared to 2009 Baseline
   - Goal includes at least 50% reduction in community footprint by 2030

- What monitoring networks & strategies are needed to understand emissions, chemistry, transport & trend detection?
- How can we make research findings applicable to stakeholders & policy makers?
  - Progress towards emission reduction goals
  - Sector based emissions
Monitoring of greenhouse gases and pollutants across an urban area using a light-rail public transit platform

Logan E. Mitchell\textsuperscript{b*}, Erik T. Crosman\textsuperscript{b}, Alexander A. Jacques\textsuperscript{b}, Benjamin Fasoli\textsuperscript{b}, Luke Leclair-Marzolf\textsuperscript{b}, John Horel\textsuperscript{b}, David R. Bowling\textsuperscript{b}, James R. Ehleringer\textsuperscript{b}, John C. Lin\textsuperscript{b}

- CO\textsubscript{2}, CH\textsubscript{4}, O\textsubscript{3}, PM\textsubscript{2.5}, NO\textsubscript{2}
- Inlets 4m (~13') above ground.
- Post data in real time on the web:
  - http://utahaq.chpc.utah.edu/
  - http://air.utah.edu

https://doi.org/10.1016/j.atmosenv.2018.05.044
CO₂ Annual average

Higher CO₂ in urban corridor

Lower CO₂ on urban periphery

Higher CO₂ along roads

CH₄ Annual average

Natural gas power plant

Brick factory

Landfill

PM₂.₅ Case studies

Titration of O₃ by NOx along the I-15 freeway.

Typical patterns during inversions, thermal/terrain circulations, etc.
• CO₂ averages across different time ranges.
  • Seasonal
  • Day of week
  • Time of day

• Illustrates the rich temporal structure of the data.
• Using TRAX data with STILT required updating the hyper-near field mixing parameterization.

• Ongoing work to develop hyper local source apportionment using mobile observations & STILT.
Hot off the press: TRAX footprints & inversion uncertainty reduction.
- \( \text{NO}_2 \) is a criteria pollutant with health impacts.
- \( \text{NO}_x \) contributes to poor air quality in summer & winter.

- Ammonium nitrate (NH\(_4\)NO\(_3\)) accounts for \(~70\%\) of the PM\(_{2.5}\) mass during winter inversions along the Wasatch Front (Kuprov et al., 2014)
NO₂ Relationships

- NO₂ and CO₂ are related through fossil fuel combustion.
  - Strong correlation (r = 0.83)

- NO₂ and O₃ are related through atmospheric photochemistry.
  - Strong correlation (r = -0.96)

- Illustrates the complex signature of fossil fuel combustion on urban atmospheric composition and air quality.
NO$_2$ Relationships

• The excess NO$_2$/CO$_2$ ratio (NO$_2$/CO$_2$ above background conditions) provides insight into emission sources.

• High ratios in the center of the valley occur where the is high NO$_2$ without a corresponding CO$_2$ signal
  • Warrants further investigation.
Proportional change in CO₂ and NO₂ does not affect the NO₂/CO₂ ratio.
• Large NO₂ plume centered on the Union Pacific locomotive rail yard.

• ~3 ppb NO₂ increase from traffic on I-15.

• NO₂/CO₂ ratio is the fingerprint of different emission sources.
NO₂ Relationships

- ~3 ppb NO₂ increase from traffic on I-15
- Observed where TRAX crosses I-15 in three places.
Switcher Locomotives

• Diesel locomotive “switcher” engines operate in rail yards to move rail cars around.

• Operate 24/7 and often idle
  • Avoids difficult start-ups
  • Prevents engine blocks from freezing in the winter

• ~60 switchers in Utah, 49 of which are operated by UPRR.
  • 30% of UPRR’s switchers are Tier 0 and 70% are Tier 0+.
  • (Glade Sowards, UDAQ, personal communication)

• Replacing Tier 0+ with a Tier 4 switcher would reduce NO\(_x\) emissions by 89%.

• Utah Air Quality Board: Considers emission reduction policies up to $6,560/ton for area sources, and higher for large point sources.
  • Repowering switchers have a emissions reduction cost of $3,412/ton (Peter Verschoor, UDAQ, personal communication).

  • States are prohibited from establishing emissions standards for locomotives in the Clean Air Act, but they can offer incentives to encourage clean tech upgrades.

• TRAX measurements could evaluate emission inventories and demonstrate air quality improvements after upgrades.
1. Used public transit to observe spatiotemporal GHG and air pollutant patterns
   - CO₂, CH₄, O₃, PM₂.₅, NO₂

2. Multi-species analysis:
   - Understanding atmospheric chemistry & transport
   - Identifying emission sources & evaluating inventories

3. Future directions:
   - Atmospheric modeling
     - Compare mobile, vs. stationary sites, vs. both
     - Evaluate emissions inventories.
     - Understand atmospheric chemistry, including day vs night
   - Measure more species (NOₓ, BC, etc.)
   - Support field campaigns
     - Google Street View mapping project!

Take home points

- Pollutants and health
  - Improved spatial & temporal exposure maps
  - Spatiotemporal health impacts
- Socioeconomic relationships
- Co-benefits of air quality and GHG mitigation policies
- Expansion
  - Other cities
  - Low cost sensors
  - Electric buses

Contact: Logan.Mitchell@utah.edu
Denver expansion on RTD

• SLC & Denver have similar air quality challenges & GHG reduction goals.

• Contact Isaac Vimont for more information
Two upcoming workshops:

AQUARIUS
(Air Quality Research in the Western US)
Sept 25-26, 2019 in Salt Lake City, UT
• Upcoming aircraft & ground field campaign
• Wintertime PM formation chemistry, relationship to meteorology & co-emitted GHGs in western basins.

http://sites.bu.edu/co2usa/