Spatiotemporal Patterns of Urban Trace Gases and Pollutants Observed with a Light Rail Vehicle Platform in Salt Lake City, UT

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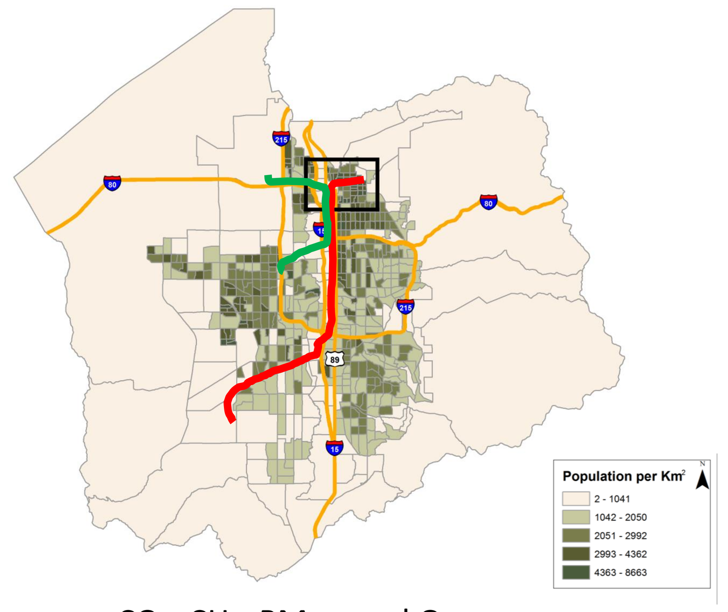
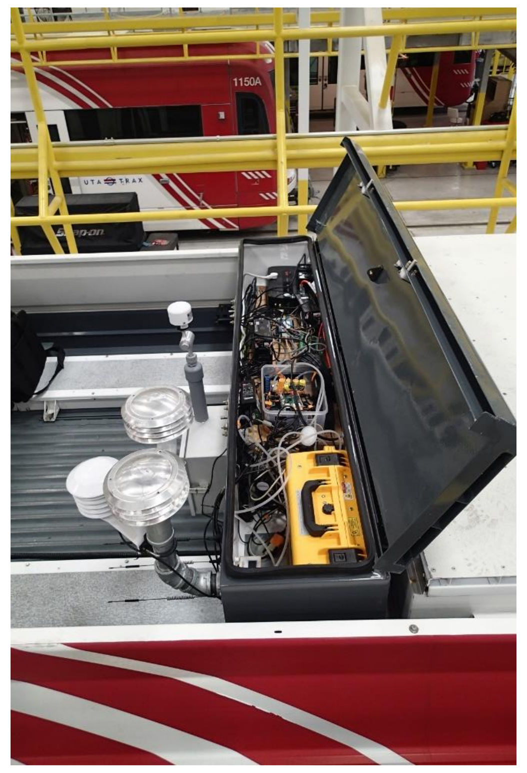
1. Introduction

Urban environments are characterized by both spatial complexity and temporal variability, each of which present challenges for measurement strategies aimed at constraining estimates of greenhouse gas emissions and air quality. To address these challenges we initiated a project in December 2014 to measure trace species (CO_2, CH_4, O_3, and Particulate Matter) by way of a light rail vehicle (Utah Transit Authority) whose fixed route traverses the entire Salt Lake Valley in Utah on an hourly basis through commercial, residential, suburban, and rural typologies. Light rail vehicles offer three advantages as a measurement platform: the absence of in situ fossil fuel emissions, repeated transects across urban typologies that provides both spatial and temporal information, and relatively low operating costs. We present initial results of the spatiotemporal patterns of greenhouse gases and pollutants across the Salt Lake Valley from the first year of operations.

2. Experimental Setup

- Operates on the Utah Transit Authority (UTA) TRAX light rail system:
- Red Line: traverses the entire Salt Lake Valley (northeast to southwest, including a symmetric elevation profile) at hourly intervals.
- Green Line: runs from the SLC airport to West Valley with two legs perpendicular to the dominant north-south transport providing plume characterization opportunities.





- Measures CO_2, CH_4, $PM_{2.5}$, and O_3.
- Dec 2014 to present.
  - > 1500 transects on the Red Line
  - > 1300 transects on the Green Line.
- Sensors and sampling on roof.
- Expanded $PM_{2.5}$ observations to a second rail car in January 2016.
- Upcoming Possibilities:
  - Expand this setup to additional rail cars to increase spatial & temporal coverage.
  - Additional trace gas species that could be added include: (a) NOx (NO_2 and N_2O) would assist in closing the ozone budget, (b) ethane (C_2H_6) would provide a distinction between biogenic & fossil CH_4 sources, and (c) radon (^{222}Rn) would constrain local atmospheric mixing.

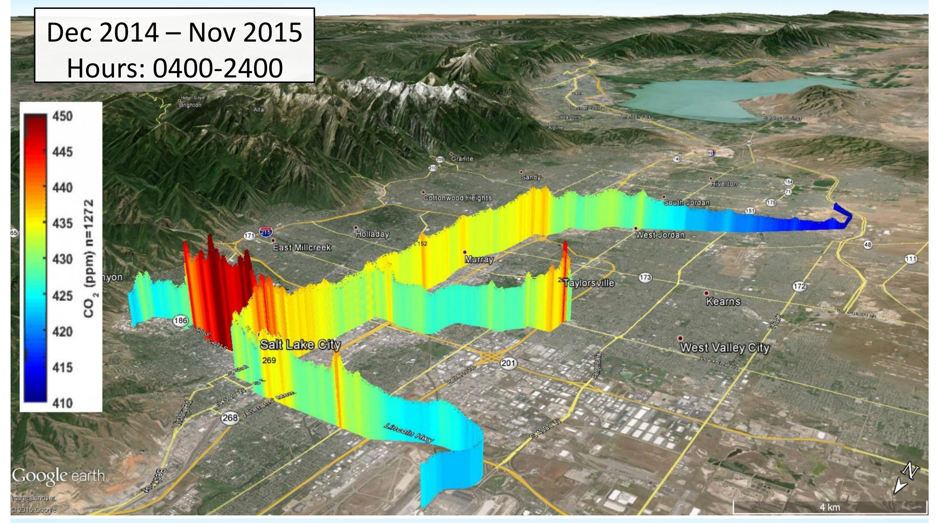
3. Greenhouse Gases

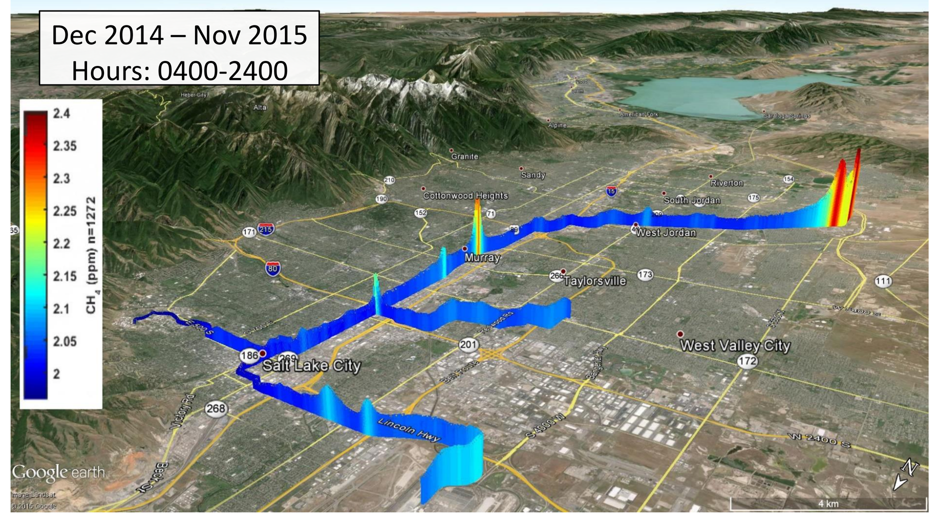
Carbon Dioxide

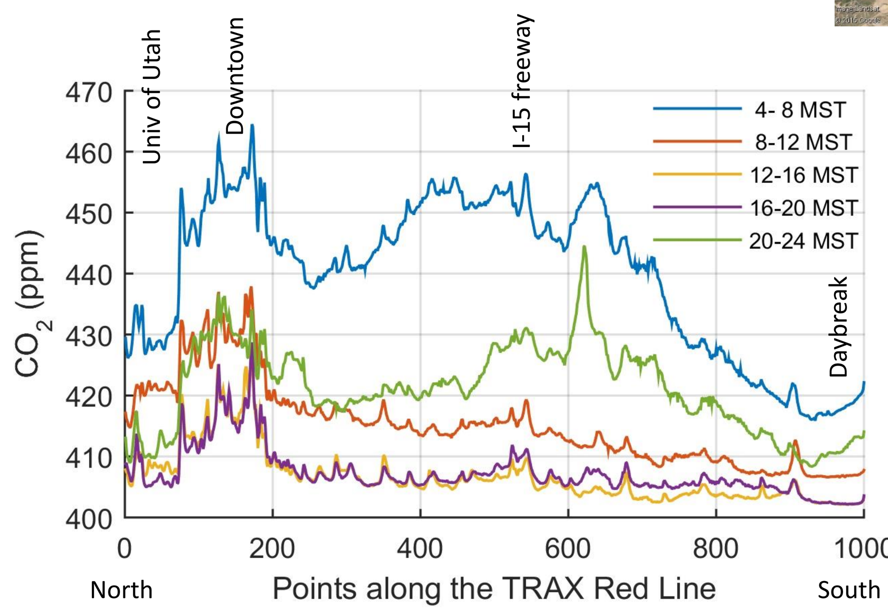
- Elevated mixing ratios observed in the urban core where rail line is in the middle of traffic and along the whole urban corridor.
- Lower CO_2 on the urban periphery.
- Local enhancement of CO_2 along every road.
- Diel profile shows influence of convective mixing during the day and stable boundary layer at night.

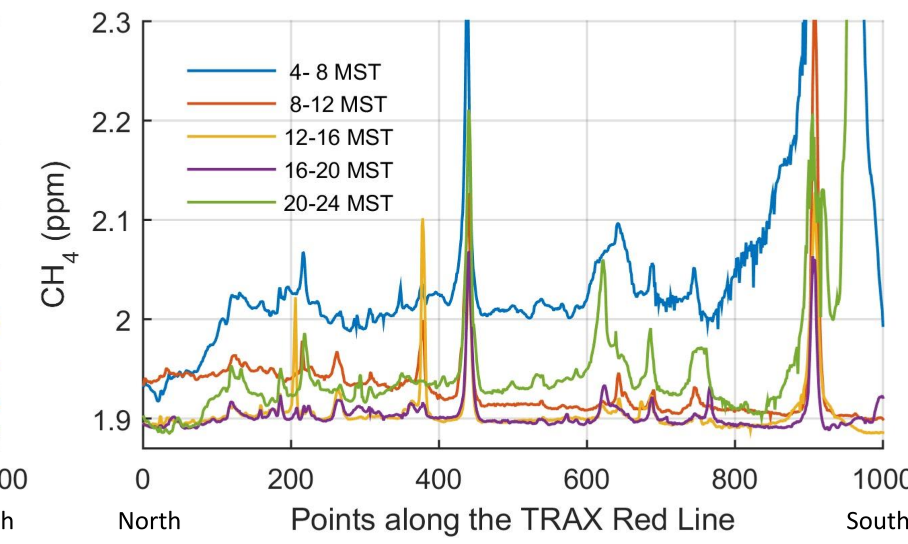
Methane

- Plumes associated with natural gas power plants, landfills, and a brick factory.
- Intermittent plumes visible during discrete times of day.
- Morning profile shows influence of stable nighttime boundary layer in northern part of valley (points 0-100 on Red Line).

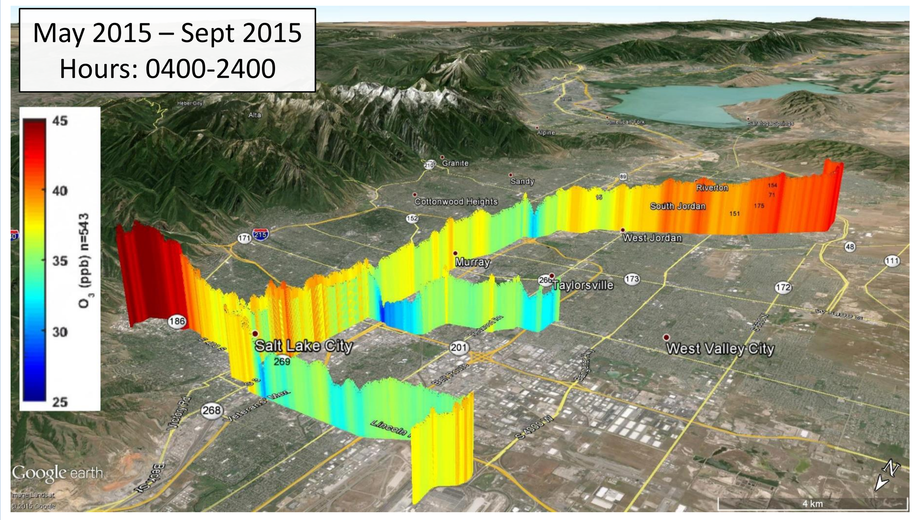


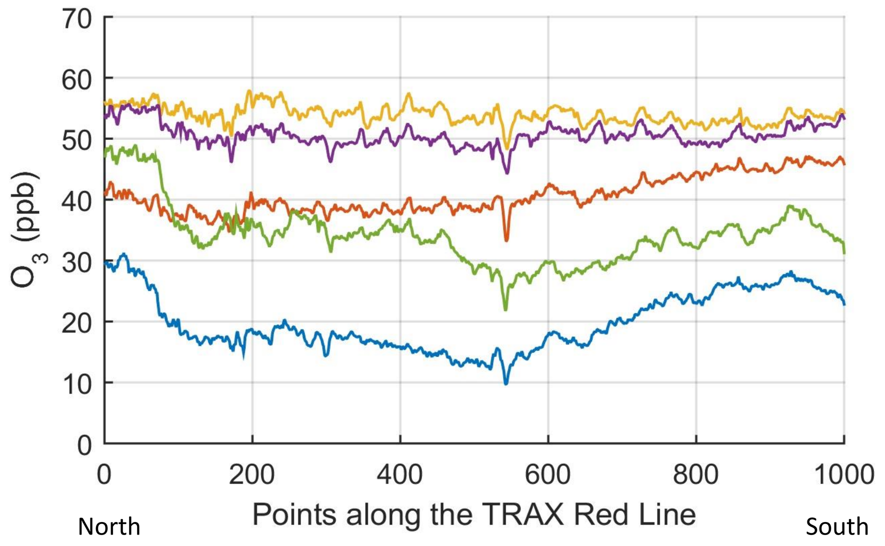






4. Ozone





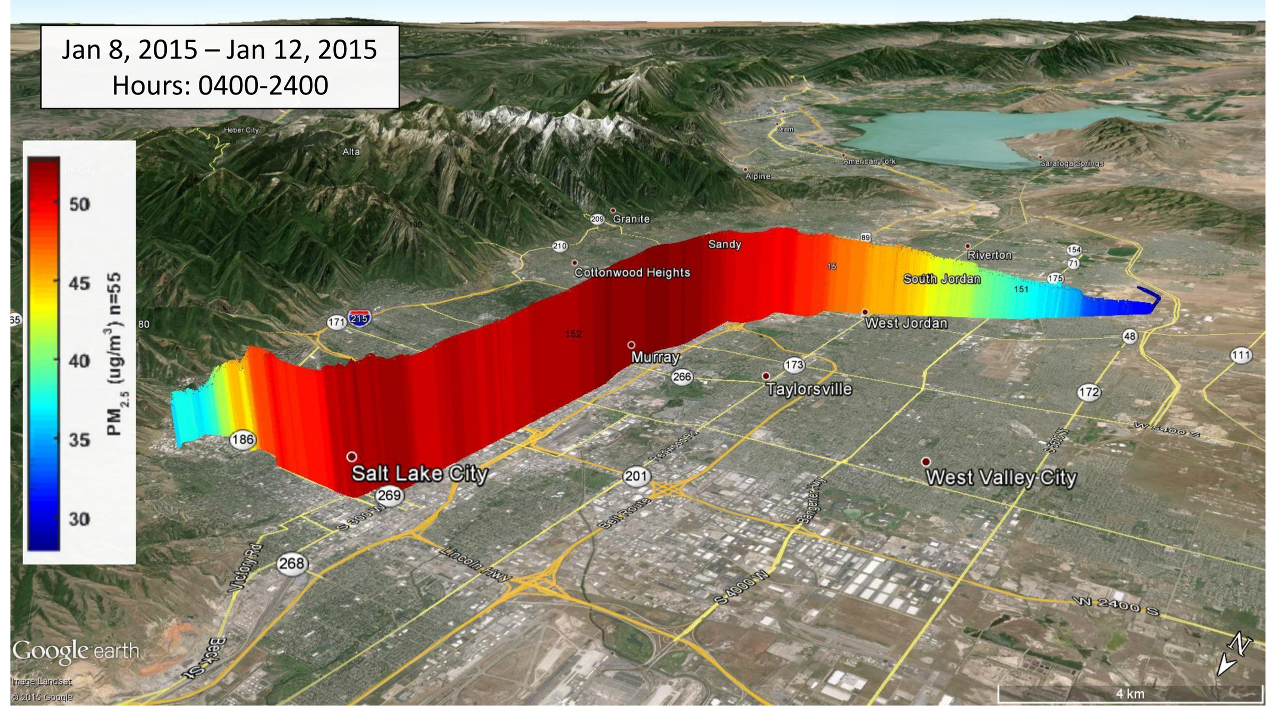
Seasonal Averages

- Highest mixing ratios on the valley benches, lowest along the urban corridor.
- Local depletions due to NOx scavenging associated with higher traffic.
- Valley benches & suburbs are exposed to higher mean summertime O_3 than central urban corridor.

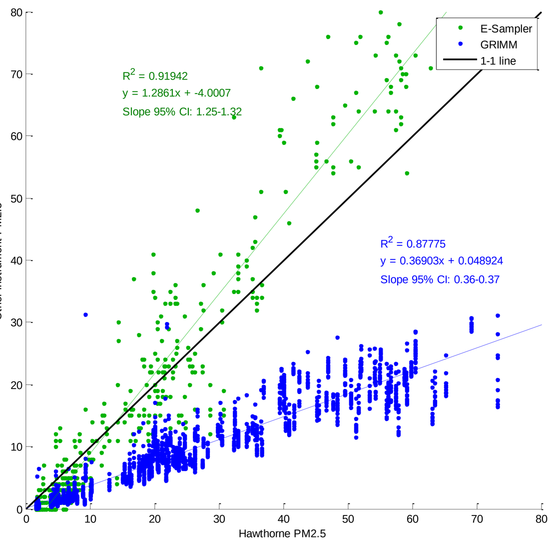
Afternoon vs. Nighttime Exposure

- O_3 is highest in the afternoon and is uniformly distributed due to convective mixing.
- At night & in the early morning the prominent spatial pattern between valley benches & urban corridor is evident.
- Low urban corridor O_3 suggests that O_3 is destroyed nocturnally by NOx, particularly in the nighttime boundary layer.
- Health implications: do mean values or peak values cause greatest health impacts? Spatial pattern of health impacts could inform this question.

5. Particulate Matter



- Frequent wintertime atmospheric inversions trap pollutants and lead to exceedances of National Ambient Air Quality Standards.
- Excellent correlation during these episodes between rail-mounted instruments and DAQ measurements (~2 km away).
- Spatial pattern is opposite that of O_3.
- Strong influence of topography.
- Do the intraurban spatial patterns of health impacts track the spatial pattern of $PM_{2.5}$?



6. Conclusions & Future Directions.

- We used a light-rail platform to observe and characterize patterns of GHGs and air pollutants.
- There are large, abrupt intra-urban gradients associated with sources and sinks.
- Future Directions:

Inverse modeling of GHGs
- Integrate mobile platforms.
- Uncertainty using stationary sites vs. mobile vs. both.
- Use multiple species to leverage divergent emission patterns.

Intra-urban relationships
- Pollutants and health.
- Co-benefits of GHG and pollutant mitigation policies.
- Socio-institution relationships.

Expansion
- Other cities.
- Low cost sensors.
- Electric buses.

7. Salt Lake Valley Measurement Programs

(a) TRAX light rail network (http://meso1.chpc.utah.edu/mesotrax/)
(b) 5-station, urban CO_2 network (http://co2.utah.edu)
(c) MesoWest (http://mesowest.utah.edu/)
(d) Utah Dept. of Environmental Quality (http://air.utah.gov/)
(e) RACCOON mountaintop observatory (http://www.eol.ucar.edu/homes/stephens/RACCOON/)

Real Time TRAX Data:

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