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

Global Change & Sustainability Center
THE UNIVERSITY OF UTAH

NSF

UTA TRAX


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**Derek Mallia**
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NOAA GMAC, 2019

May 22, 2019, Boulder, CO


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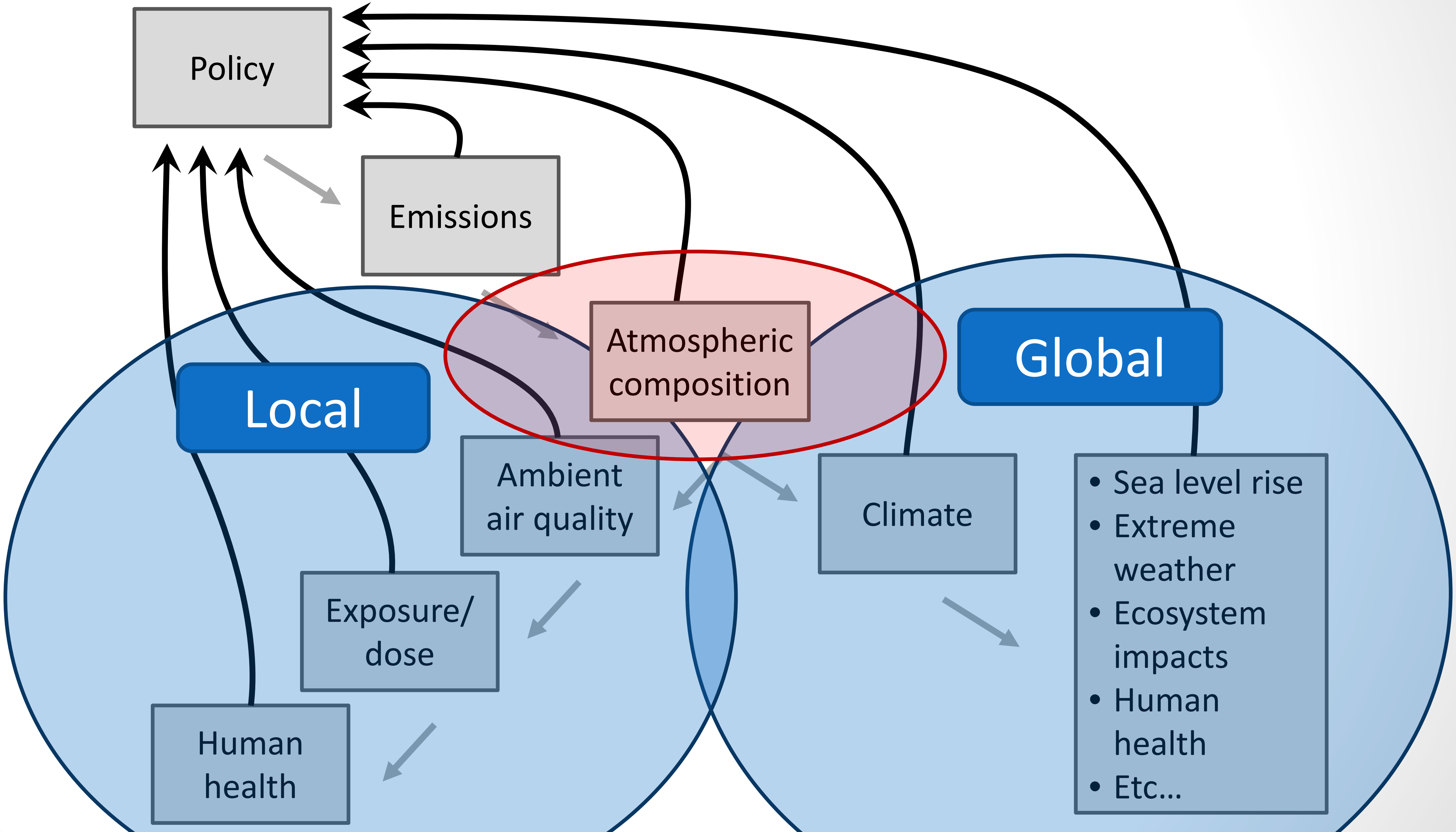
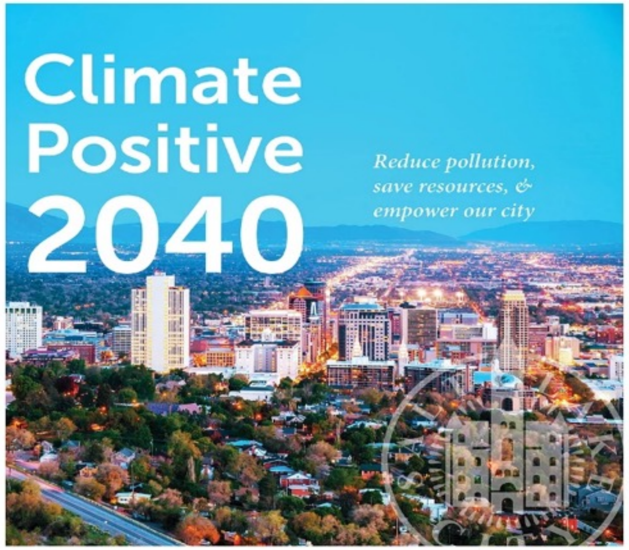
# The Big Picture…



# Simultaneous GHG & Air Quality Monitoring





UTAH DEPARTMENT of ENVIRONMENTAL QUALITY

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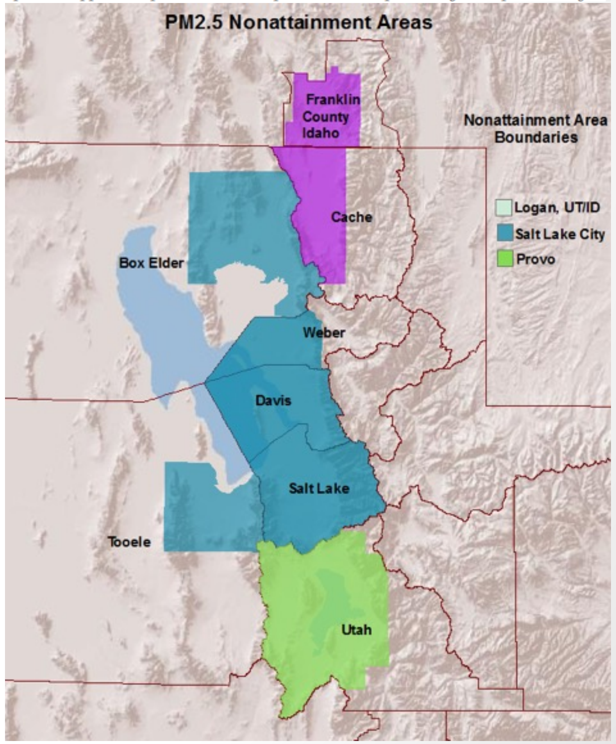
**Serious Area $PM_{2.5}$ SIP Links**
Background
Technical Analysis
Control Strategies
Public Participation

**PM and SIP Links**
Particulate Matter
Overview

DEQ Home > Pollutants > Particulate Matter > $PM_{2.5}$ > Serious Area $PM_{2.5}$ State Implementation Plan Development > Control Strategies

**Control Strategies**
**Serious Area $PM_{2.5}$ State Implementation Plan (SIP) Development**

**Disclaimer**
*The Serious $PM_{2.5}$ SIP Development is very much an iterative process. The technical foundation of any SIP involves numerous emissions inventories, air quality modeling assumptions, potential emission controls, and ever-fluctuating design values recorded throughout the air monitoring network. The $PM_{2.5}$ Implementation Rule is very prescriptive about how these numbers must fit together to comprise an approvable plan. Various components are compiled early in the process only*




*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**

Contents lists available at ScienceDirect

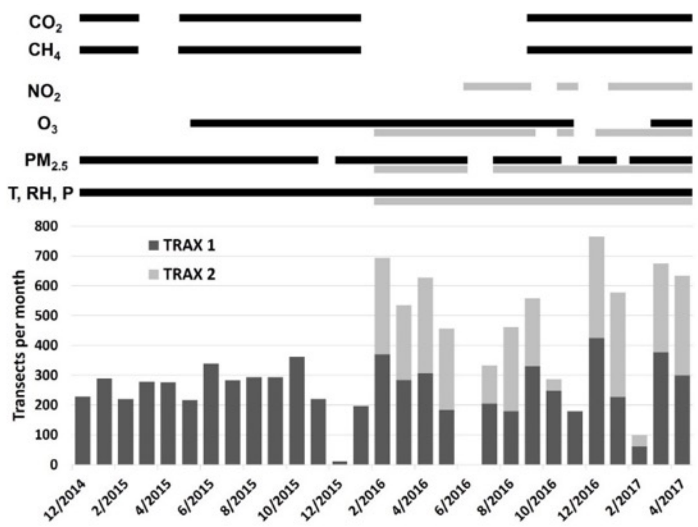
Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

# Monitoring of greenhouse gases and pollutants across an urban area using a light-rail public transit platform

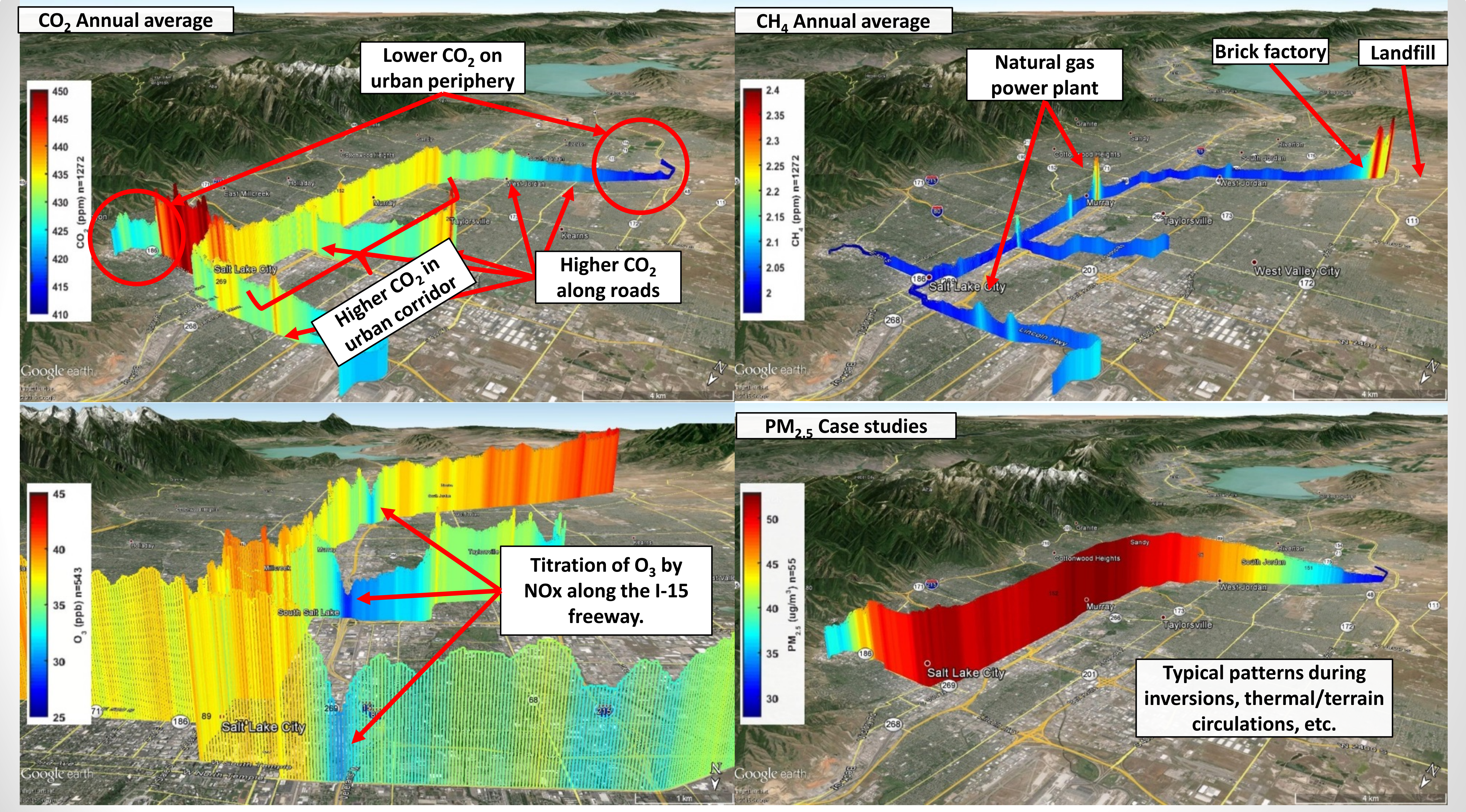
Logan E. Mitchell[a,*], Erik T. Crosman[a], Alexander A. Jacques[a], Benjamin Fasoli[a], Luke Leclair-Marzolf[a], John Horel[a], David R. Bowling[b], James R. Ehleringer[b], John C. Lin[a]

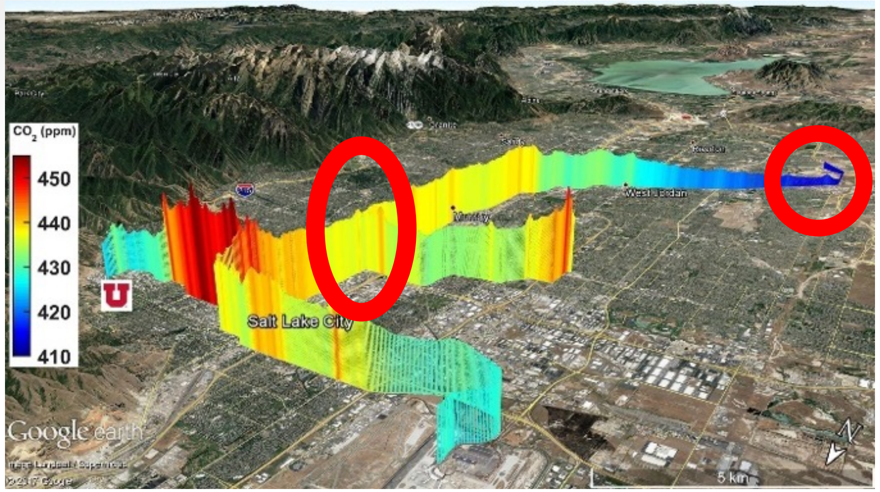
- **$CO_2$, $CH_4$, $O_3$, $PM_{2.5}$, $NO_2$**
- Inlets 4m (~13’) above ground.
- Post data in real time on the web:
- http://utahaq.chpc.utah.edu/
- http://air.utah.edu





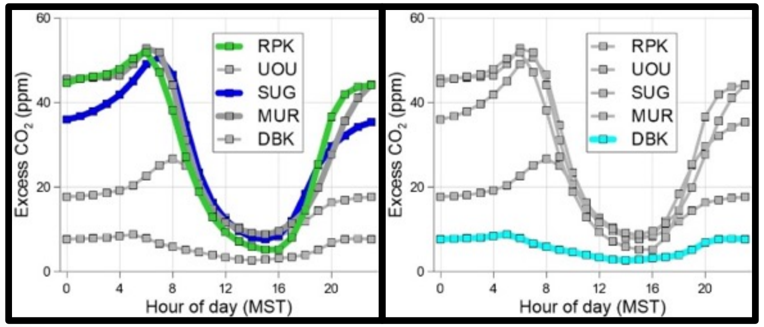
https://doi.org/10.1016/j.atmosenv.2018.05.044

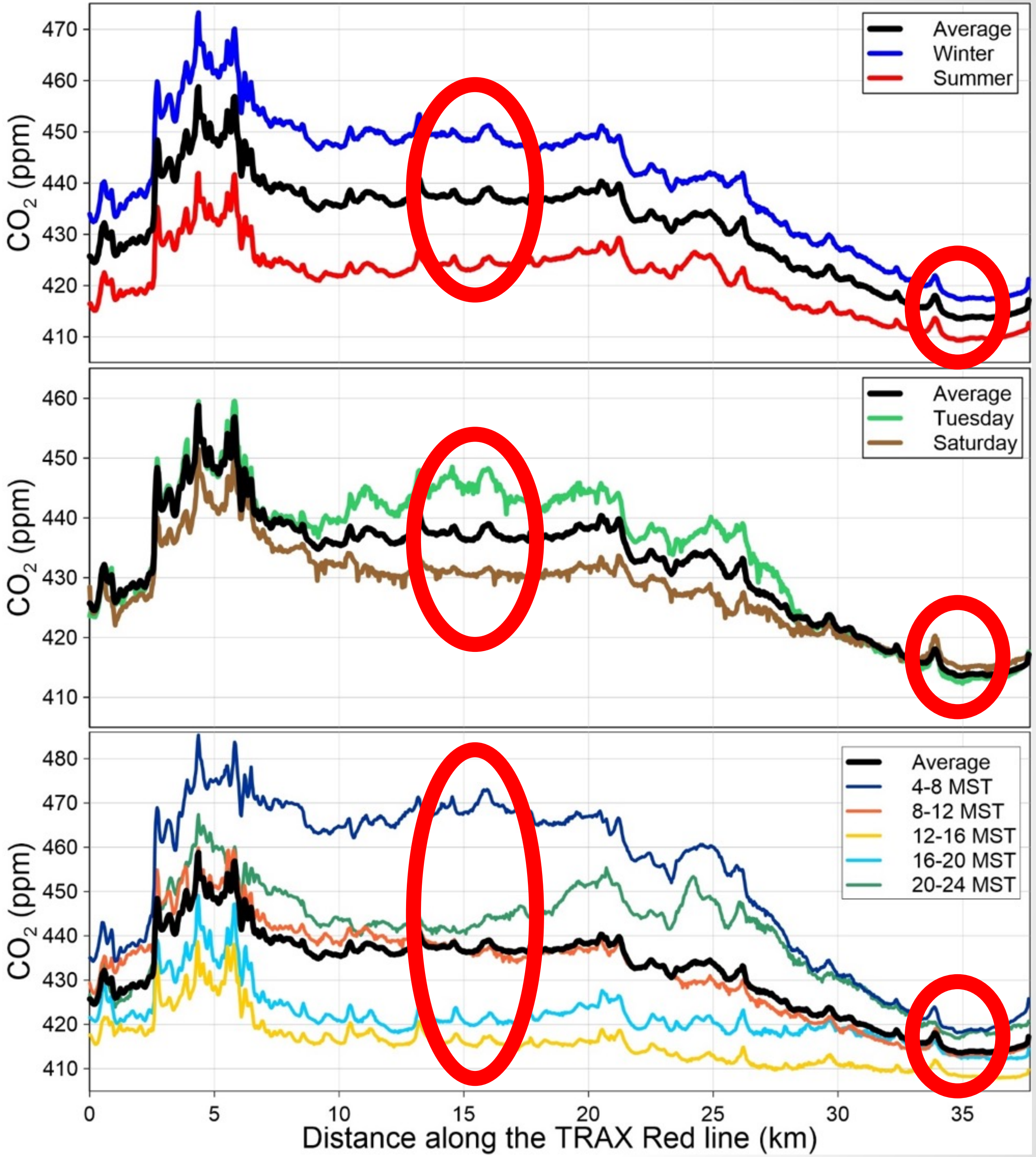

CO2 Annual average
Lower CO2 on urban periphery
Higher CO2 along roads
Higher CO2 in urban corridor
CO2 (ppm) n=1272
450
445
440
435
430
425
420
415
410
Salt Lake City
Holladay
East Millcreek
Murray
Taylorsville
West Jordan
Kearns
Google earth
4 km
CH4 Annual average
Natural gas power plant
Brick factory
Landfill
CH4 (ppm) n=1272
2.4
2.35
2.3
2.25
2.2
2.15
2.1
2.05
2
Salt Lake City
Murray
Taylorsville
West Jordan
West Valley City
Google earth
4 km
O3 (ppb) n=543
45
40
35
30
25
Titration of O3 by NOx along the I-15 freeway.
South Salt Lake
Salt Lake City
Google earth
1 km
PM2.5 Case studies
PM2.5 (ug/m3) n=55
50
45
40
35
30
Typical patterns during inversions, thermal/terrain circulations, etc.
Salt Lake City
Cottonwood Heights
Murray
Taylorsville
Sandy
South Jordan
West Jordan
Google earth
4 km




- $CO_2$ 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.**

Geosci. Model Dev., 11, 2813–2824, 2018
https://doi.org/10.5194/gmd-11-2813-2018


Geoscientific Model Development
Open Access

## Simulating atmospheric tracer concentrations for spatially distributed receptors: updates to the Stochastic Time-Inverted Lagrangian Transport model's R interface (STILT-R version 2)

**Benjamin Fasoli**[1], **John C. Lin**[1], **David R. Bowling**[2], **Logan Mitchell**[1], **and Daniel Mendoza**[1,3]

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**Correspondence:** Benjamin Fasoli (b.fasoli@utah.edu)

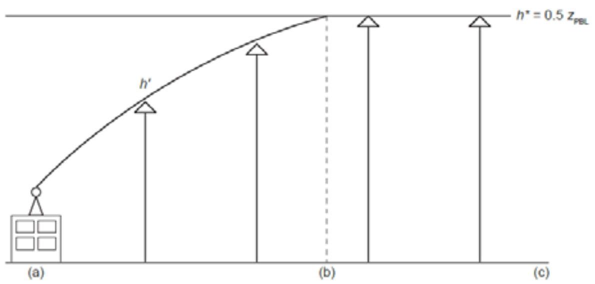
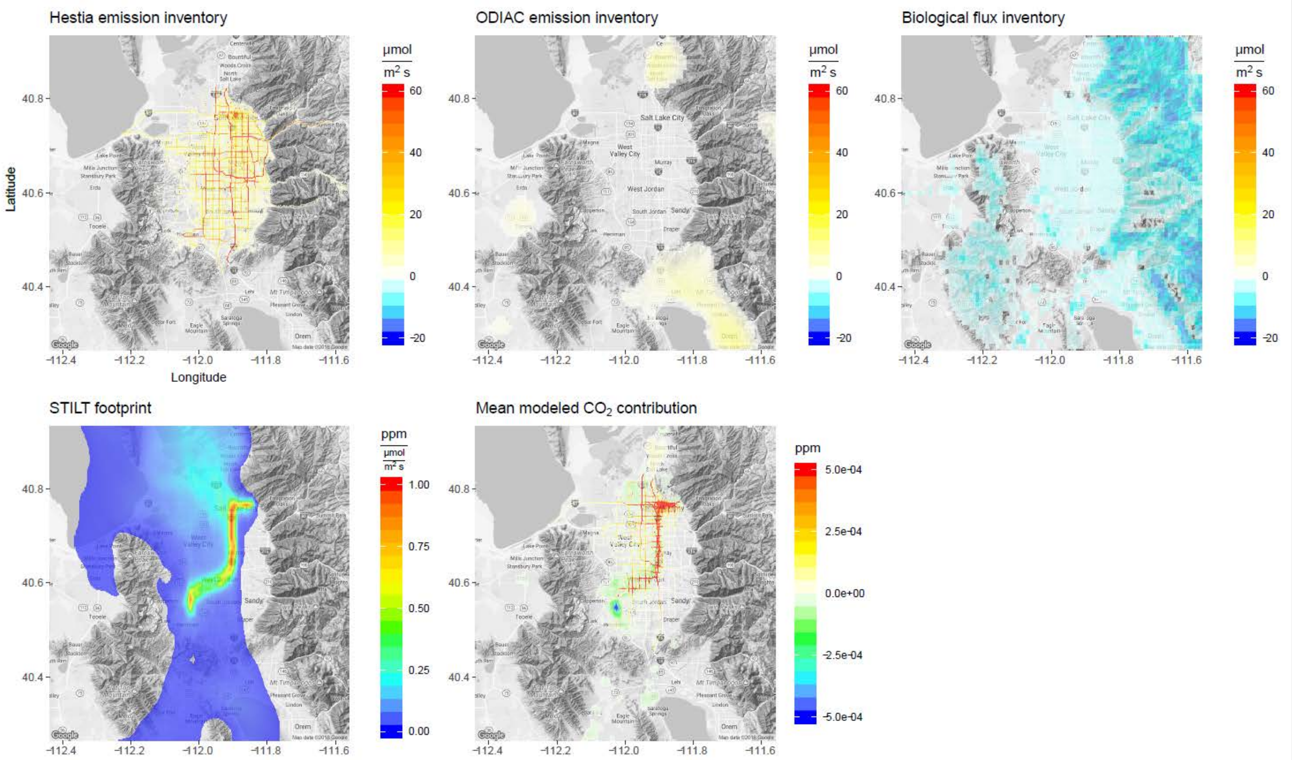
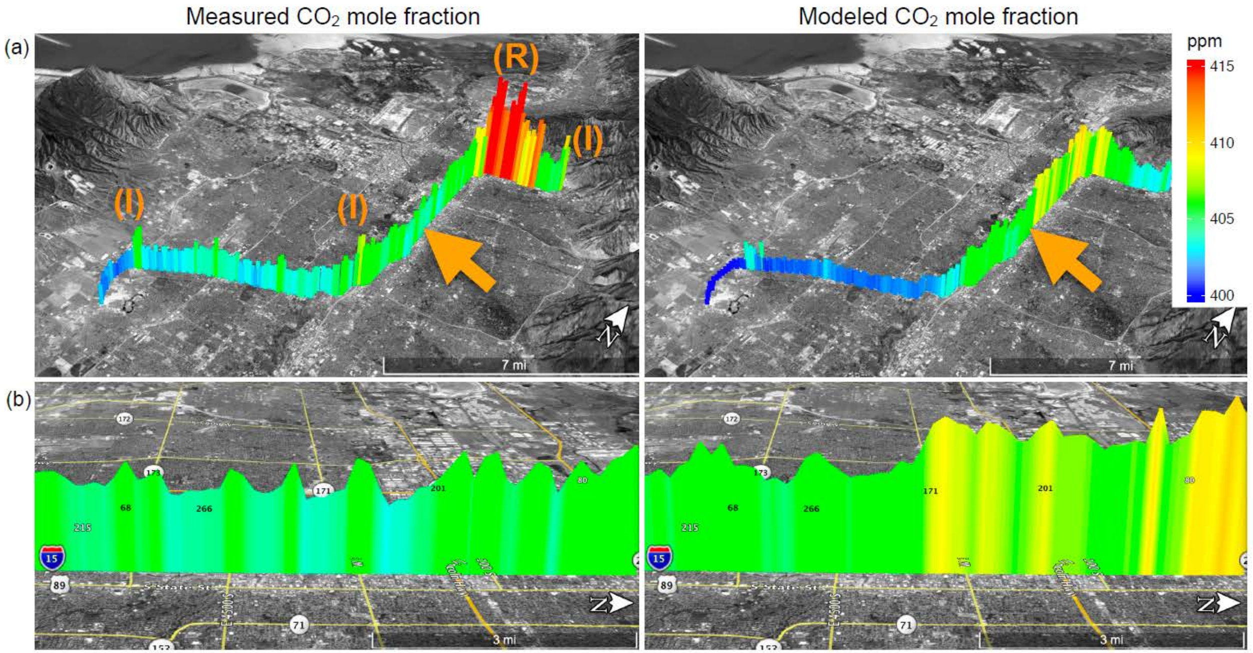
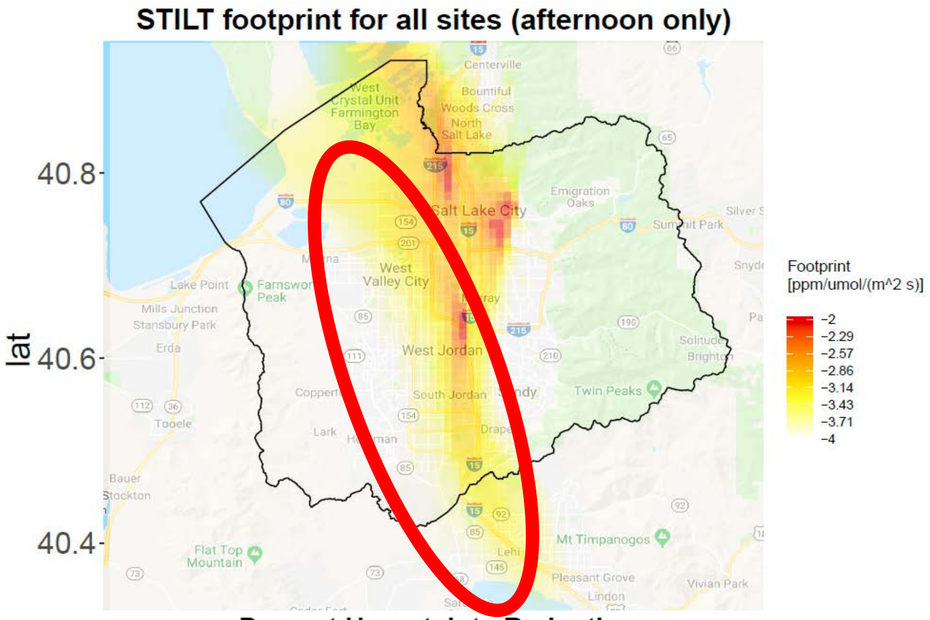


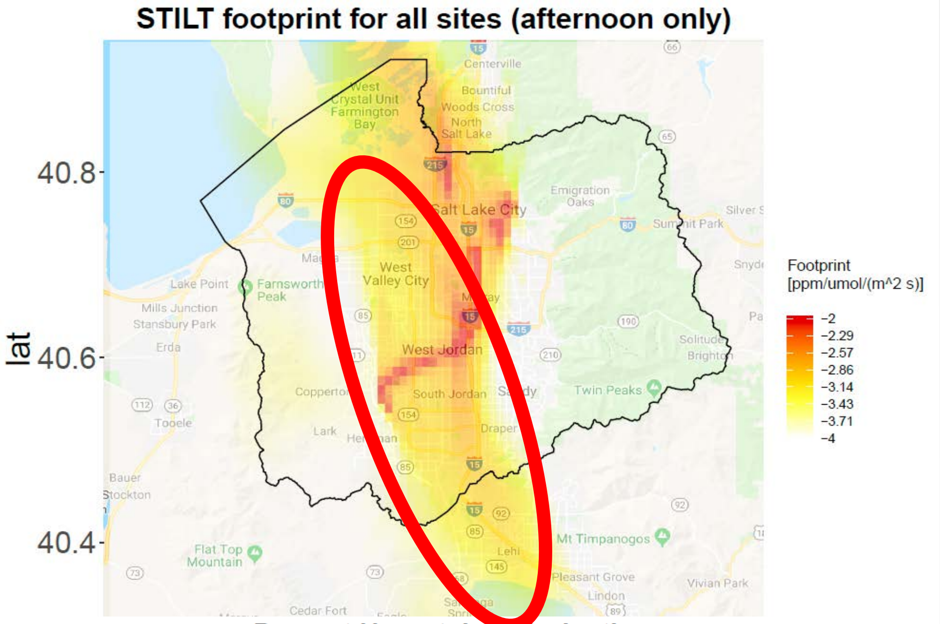

**Figure 3.** Growth of the effective mixing depth. From the receptor **(a)**, surface fluxes are diluted within an atmospheric column depth of $h'$ in the HNF until $h' = h^*$ **(b)**, amplifying the contribution of hyper near-field (HNF) sources and sinks to the receptor. Once $h'$ has reached $h^*$, surface fluxes are diluted to depth $h^*$ until the end of the simulation **(c)**.

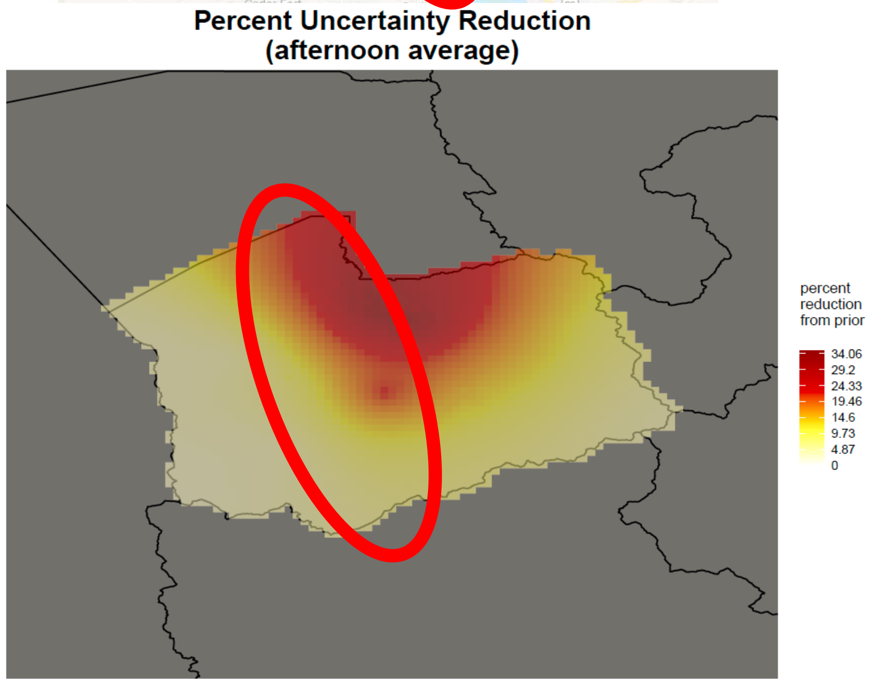


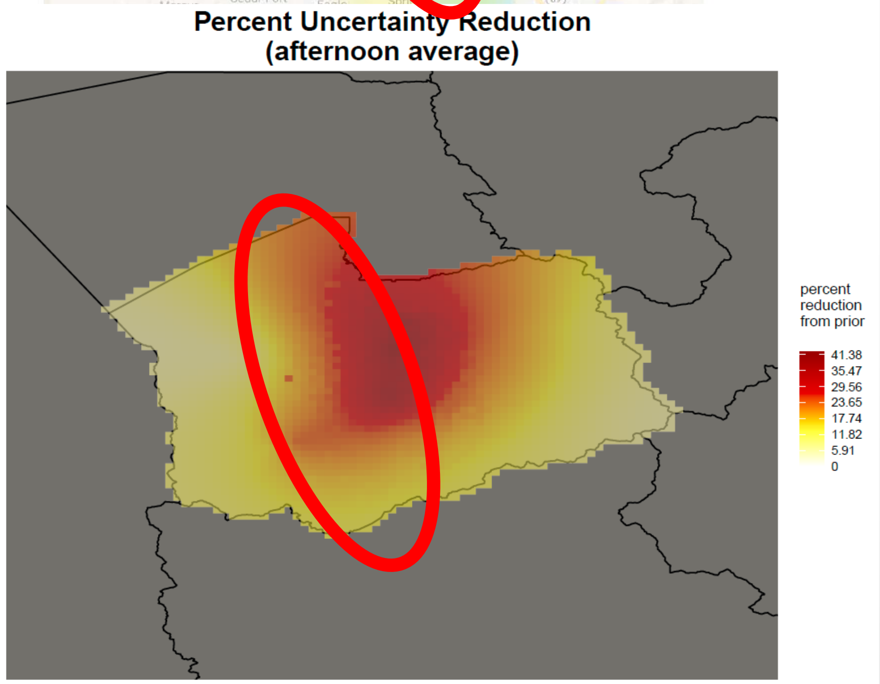



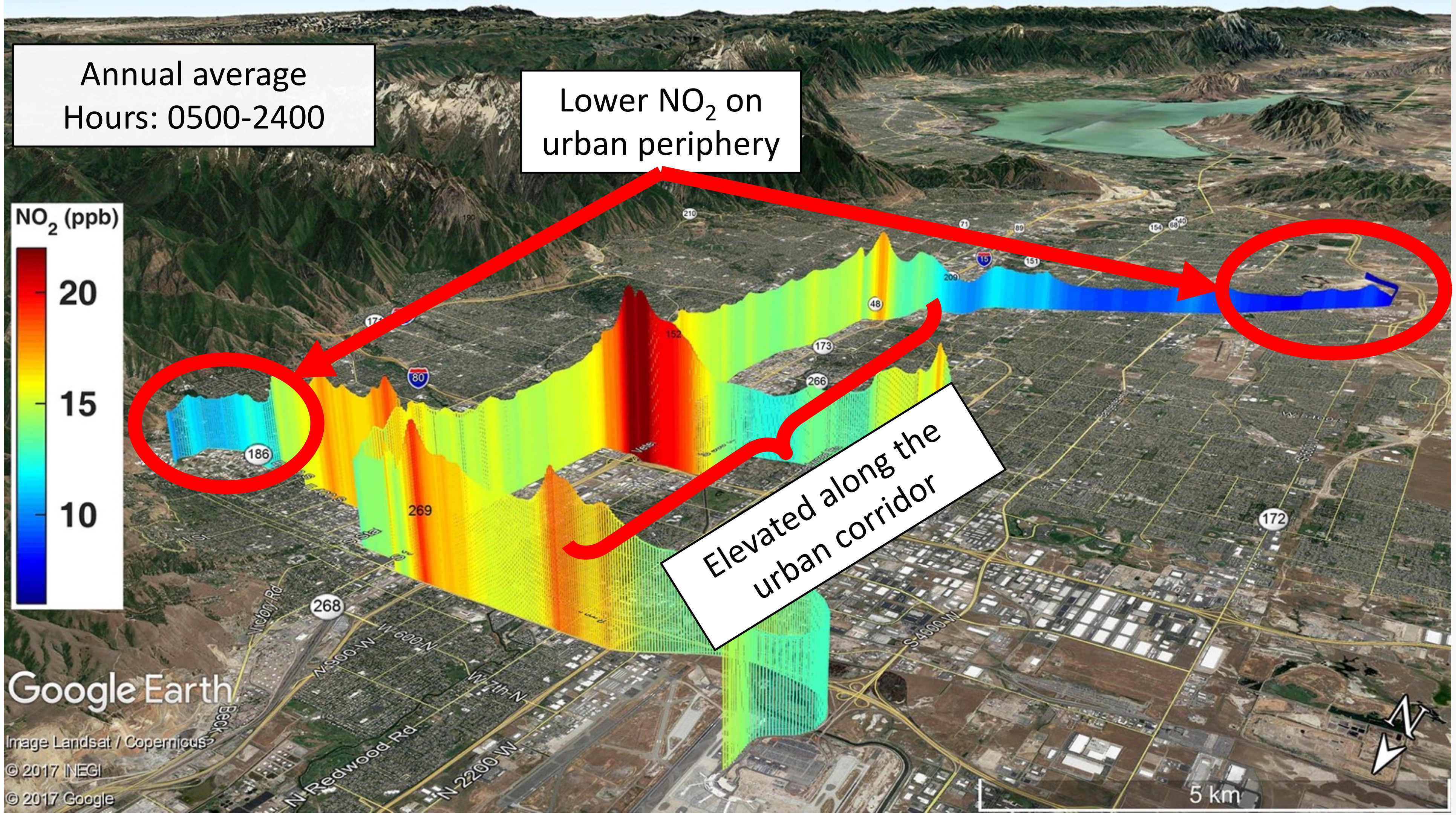
# Hot off the press: TRAX footprints & inversion uncertainty reduction.





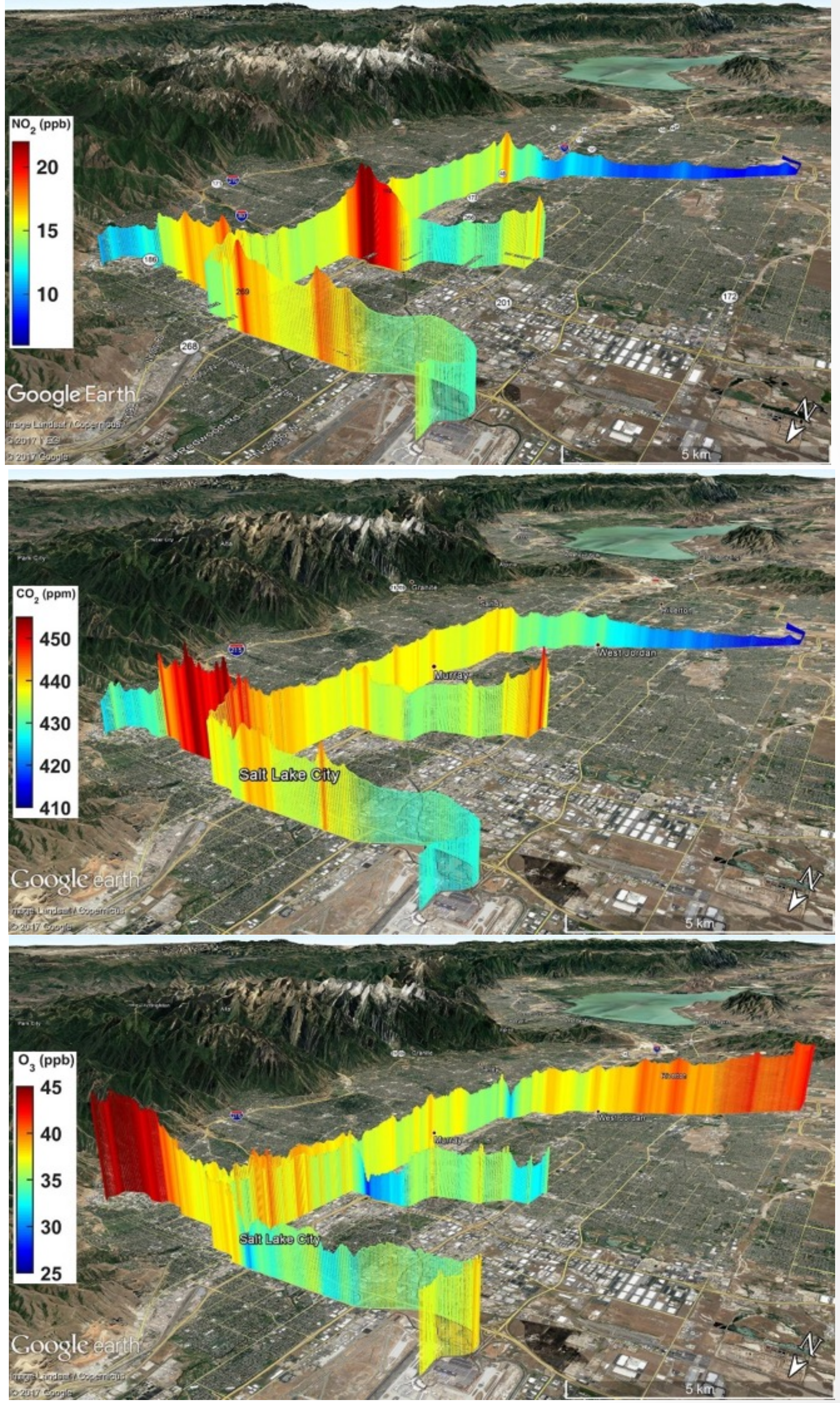

- $NO_2$ is a criteria pollutant w/ health impacts.
- $NO_x$ contributes to poor air quality in summer & winter.
- Ammonium nitrate ($NH_4NO_3$) accounts for ~70% of the $PM_{2.5}$ mass during winter inversions along the Wasatch Front (Kuprov et al., 2014)

# $NO_2$ Relationships

- $NO_2$ and $CO_2$ are related through fossil fuel combustion.
  - Strong correlation ($r = 0.83$)

- $NO_2$ and $O_3$ are related through atmospheric photochemistry.
  - Strong correlation ($r = -0.96$)

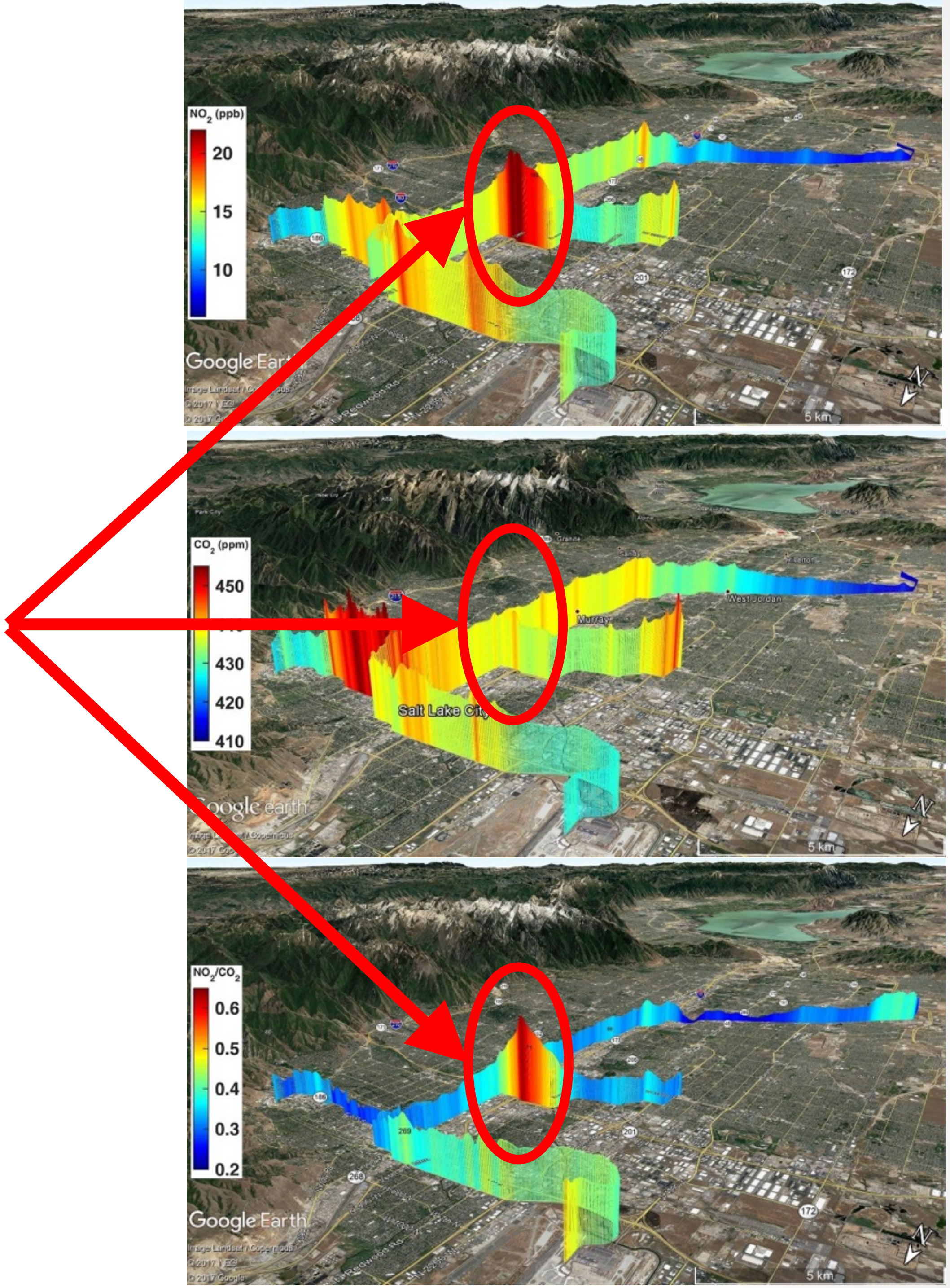
- Illustrates the complex signature of fossil fuel combustion on urban atmospheric composition and air quality.

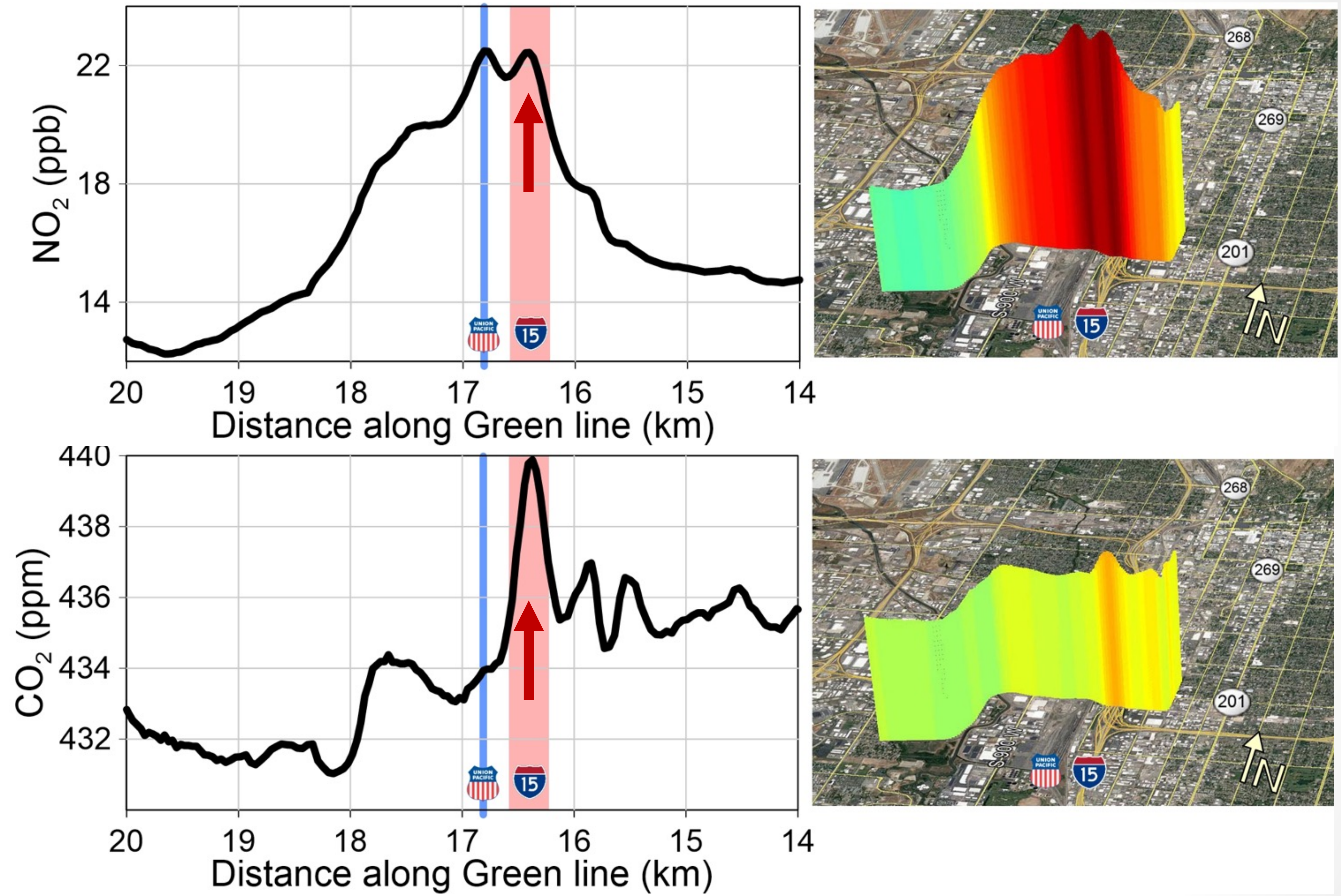


# $NO_2$ Relationships

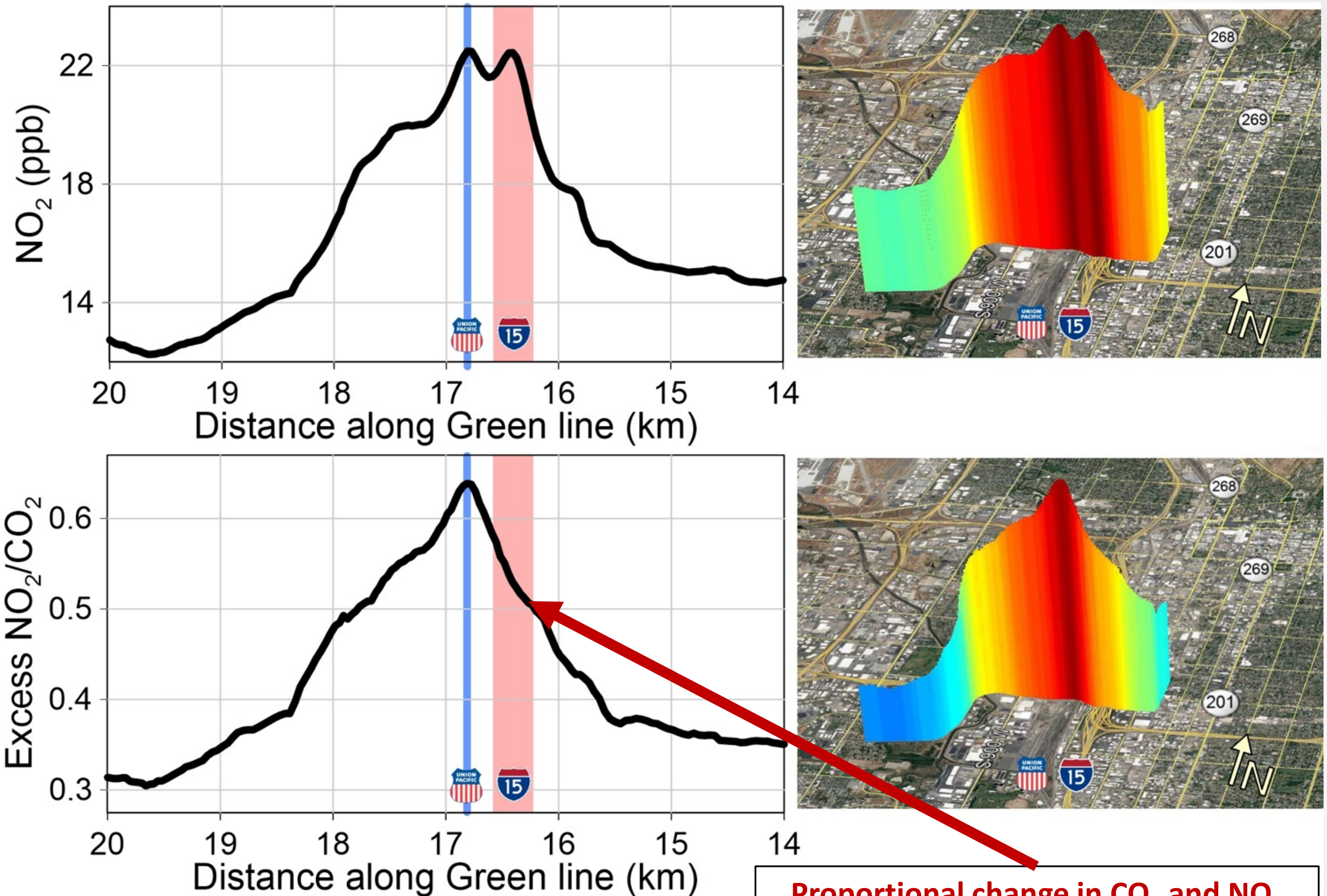
- The excess $NO_2/CO_2$ ratio ($NO_2/CO_2$ above background conditions) provides insight into emission sources.

- High ratios in the center of the valley occur where the is high $NO_2$ without a corresponding $CO_2$ signal
  - Warrants further investigation.



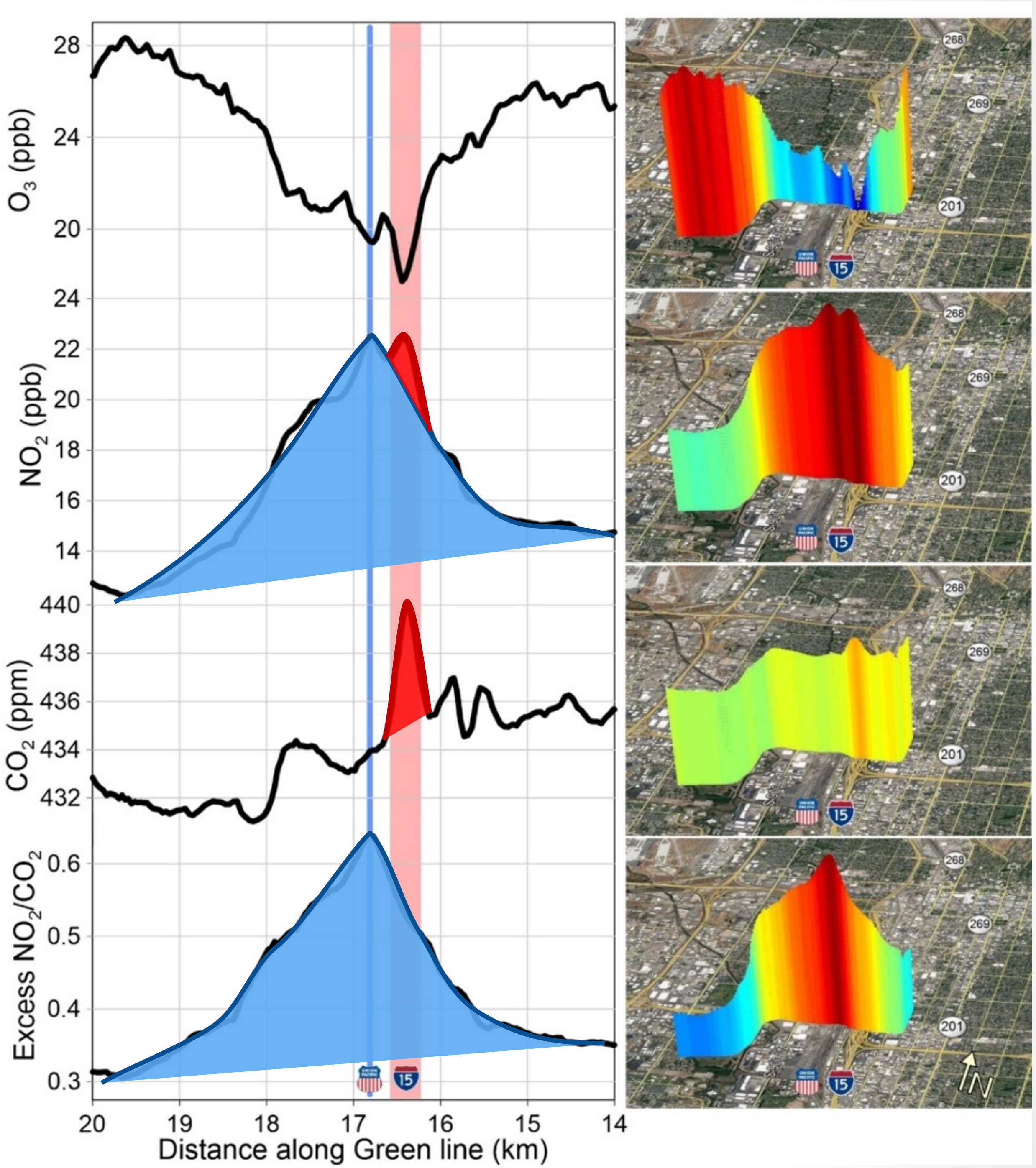


$NO_2$ (ppb)
22
18
14
20
19
18
17
16
15
14
Distance along Green line (km)
UNION PACIFIC
15
268
269
201
N
$CO_2$ (ppm)
440
438
436
434
432
20
19
18
17
16
15
14
Distance along Green line (km)
UNION PACIFIC
15
268
269
201
N



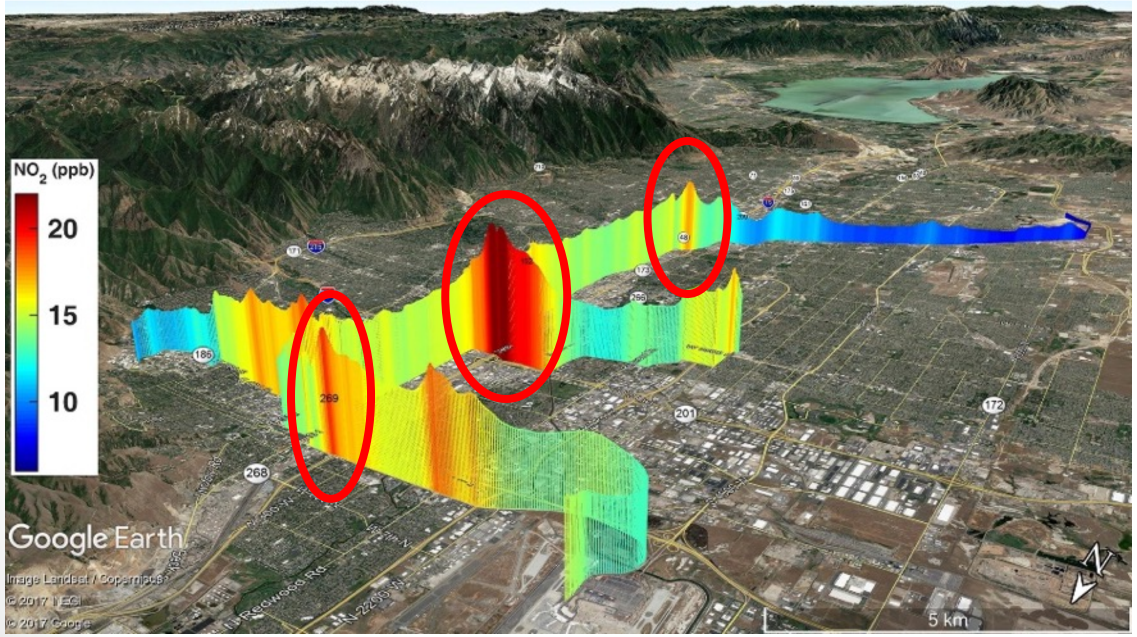

**Proportional change in $CO_2$ and $NO_2$ does not affect the $NO_2/CO_2$ ratio**

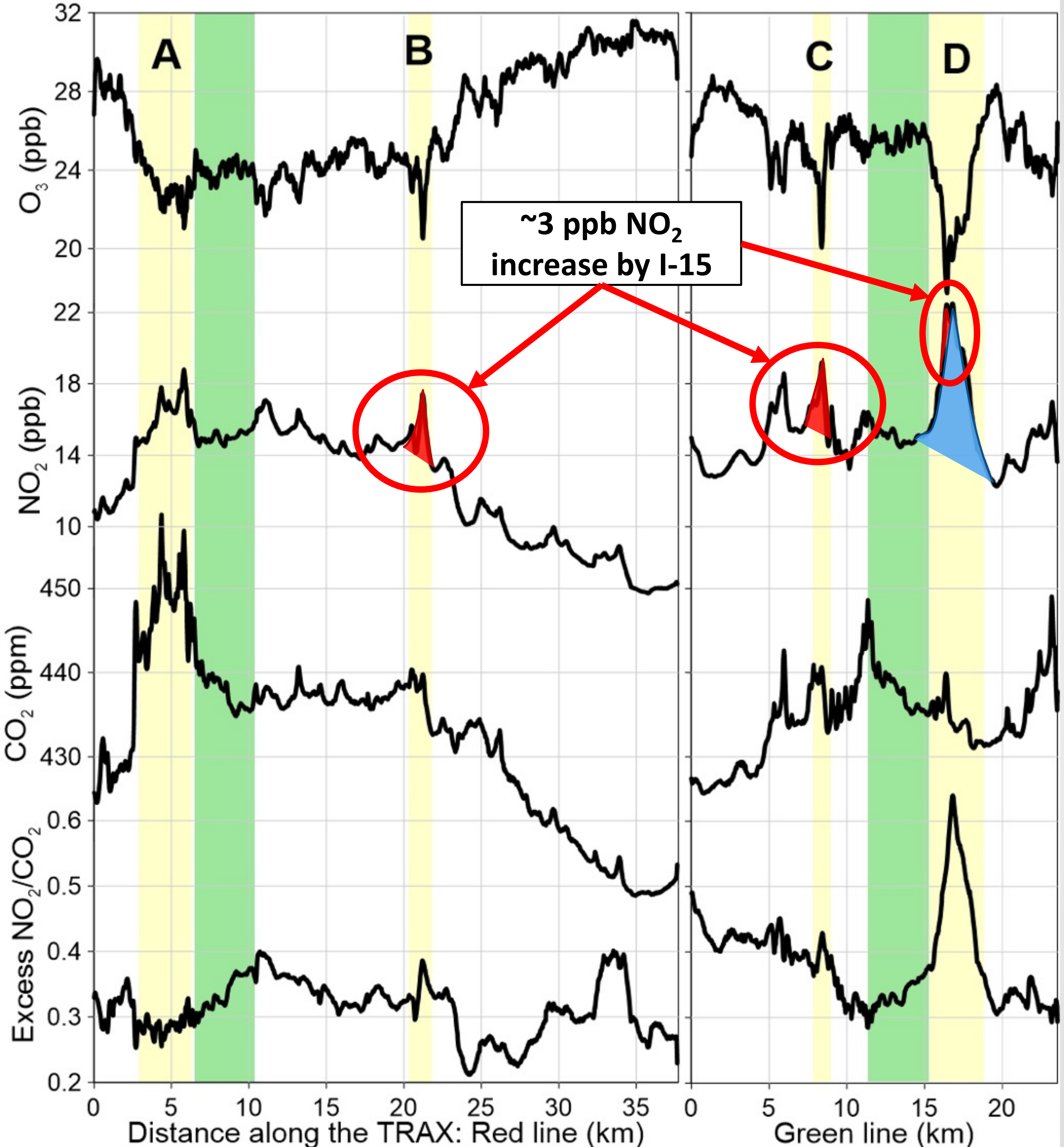
- Large $NO_2$ plume centered on the Union Pacific locomotive rail yard.
- ~3 ppb $NO_2$ increase from traffic on I-15.
- $NO_2/CO_2$ ratio is the fingerprint of different emission sources.



# $NO_2$ Relationships

- ~3 ppb $NO_2$ 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.

# Take home points

1. Used public transit to observe spatiotemporal GHG and air pollutant patterns
   - $CO_2$, $CH_4$, $O_3$, $PM_{2.5}$, $NO_2$

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!**

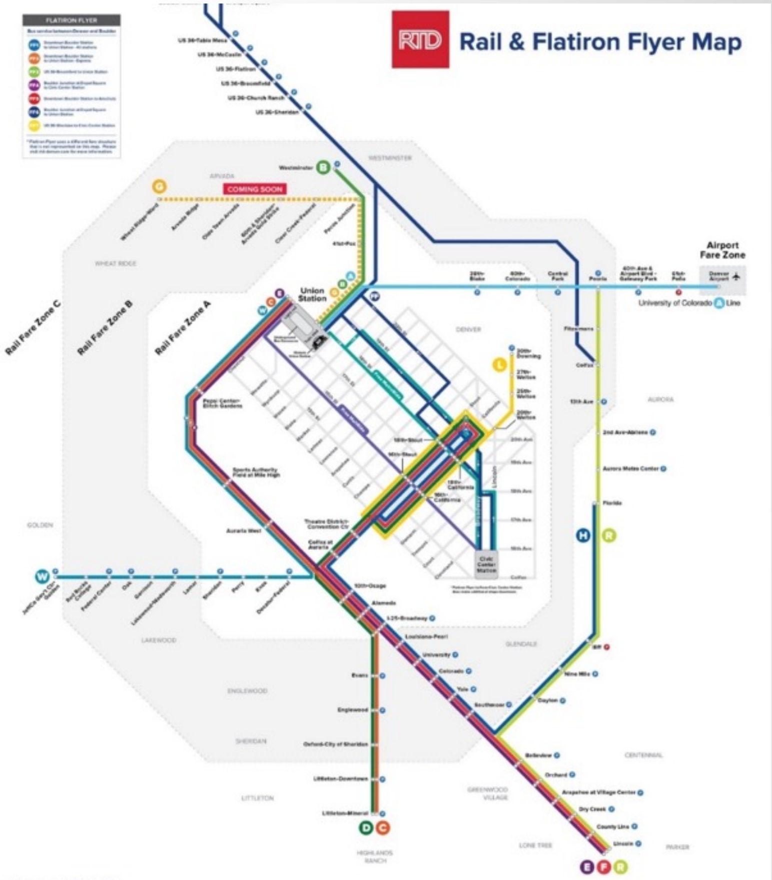


- Expansion
  - Other cities
  - Low cost sensors
  - Electric buses

**ontact:** Logan.Mitchell@utah.edu

# Denver expansion on RTD

- SLC & Denver have similar air quality challenges & GHG reduction goals.
- Contact **Isaac Vimont** for more information

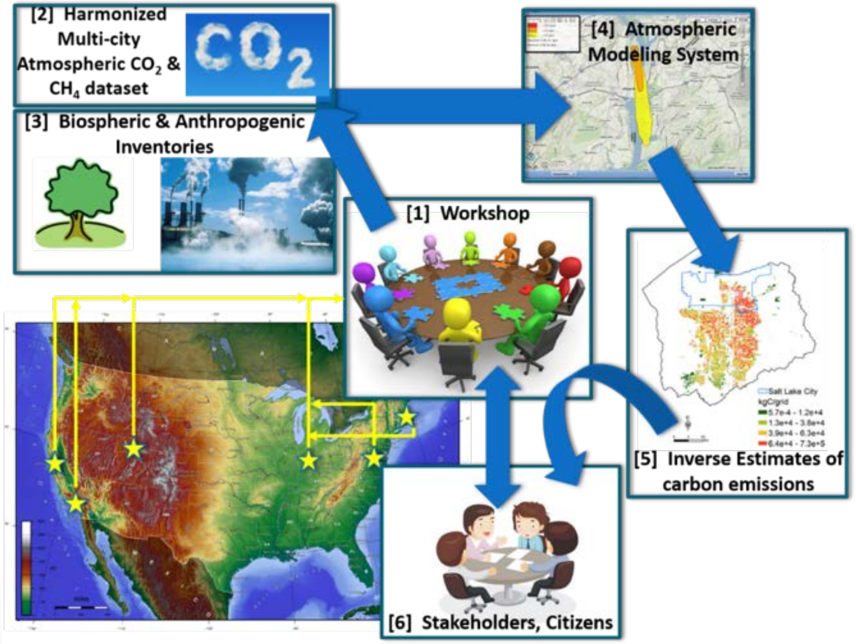

STATE OF THE AIR 2019
20th ANNIVERSARY
AMERICAN LUNG ASSOCIATION.

**People at Risk In 25 Most Ozone-Polluted Cities**

| 2019 Rank[1] | Metropolitan Statistical Areas | Total Population[2] | Under 18[3] | 65 and Over[3] | Pediatric Asthma[4,6] | Adult Asthma[5,6] | COPD[7] | CV Disease[8] | Poverty[9] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Los Angeles-Long Beach, CA | 18,788,800 | 4,317,234 | 2,511,924 | 267,954 | 1,142,240 | 636,210 | 7,806 | 1,479,796 |
| 2 | Visalia, CA | 464,493 | 143,726 | 51,669 | 8,921 | 25,149 | 13,466 | 193 | 30,984 |
| 3 | Bakersfield, CA | 893,119 | 259,120 | 95,307 | 16,083 | 49,617 | 26,076 | 373 | 60,013 |
| 4 | Fresno-Madera-Hanford, CA | 1,296,246 | 365,661 | 155,133 | 22,695 | 73,023 | 39,469 | 540 | 90,788 |
| 5 | Sacramento-Roseville, CA | 2,598,377 | 598,140 | 399,007 | 37,124 | 158,830 | 92,789 | 1,079 | 216,432 |
| 6 | San Diego-Chula Vista-Carlsbad, CA | 3,337,685 | 728,528 | 454,826 | 45,217 | 205,392 | 113,301 | 1,389 | 261,785 |
| 7 | Phoenix-Mesa, AZ | 4,790,771 | 1,155,134 | 738,748 | 93,121 | 360,835 | 227,133 | 2,243 | 372,324 |
| 8 | San Jose-San Francisco-Oakland, CA | 9,658,361 | 2,098,636 | 1,400,989 | 130,254 | 598,339 | 340,714 | 4,015 | 793,588 |
| 9 | Houston-The Woodlands, TX | 7,078,523 | 1,883,271 | 773,341 | 149,026 | 383,590 | 242,452 | 3,571 | 604,115 |
| 10 | New York-Newark, NY-NJ-CT-PA | 23,035,605 | 4,945,052 | 3,552,752 | 448,996 | 1,651,293 | 996,592 | 13,532 | 1,881,665 |
| 11 | Redding-Red Bluff, CA | 243,847 | 54,095 | 48,761 | 3,357 | 15,277 | 9,848 | 101 | 23,119 |
| 12 | Denver-Aurora, CO | 3,515,374 | 802,822 | 443,992 | 63,790 | 253,103 | 115,044 | 1,440 | 193,028 |
| 13 | Las Vegas-Henderson, NV | 2,248,281 | 521,582 | 330,243 | 40,464 | 180,576 | 118,876 | 1,047 | 175,054 |
| 14 | Salt Lake City-Provo-Orem, UT | 2,559,350 | 771,143 | 252,835 | 46,981 | 159,617 | 68,111 | 662 | 121,102 |
| 15 | El Centro, CA | 182,830 | 52,296 | 23,042 | 3,246 | 10,266 | 5,654 | 76 | 13,022 |

# Two upcoming workshops:


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




## 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.