Cumulative Assessment of Modeled and Measured NO2 Concentrations in North Denver

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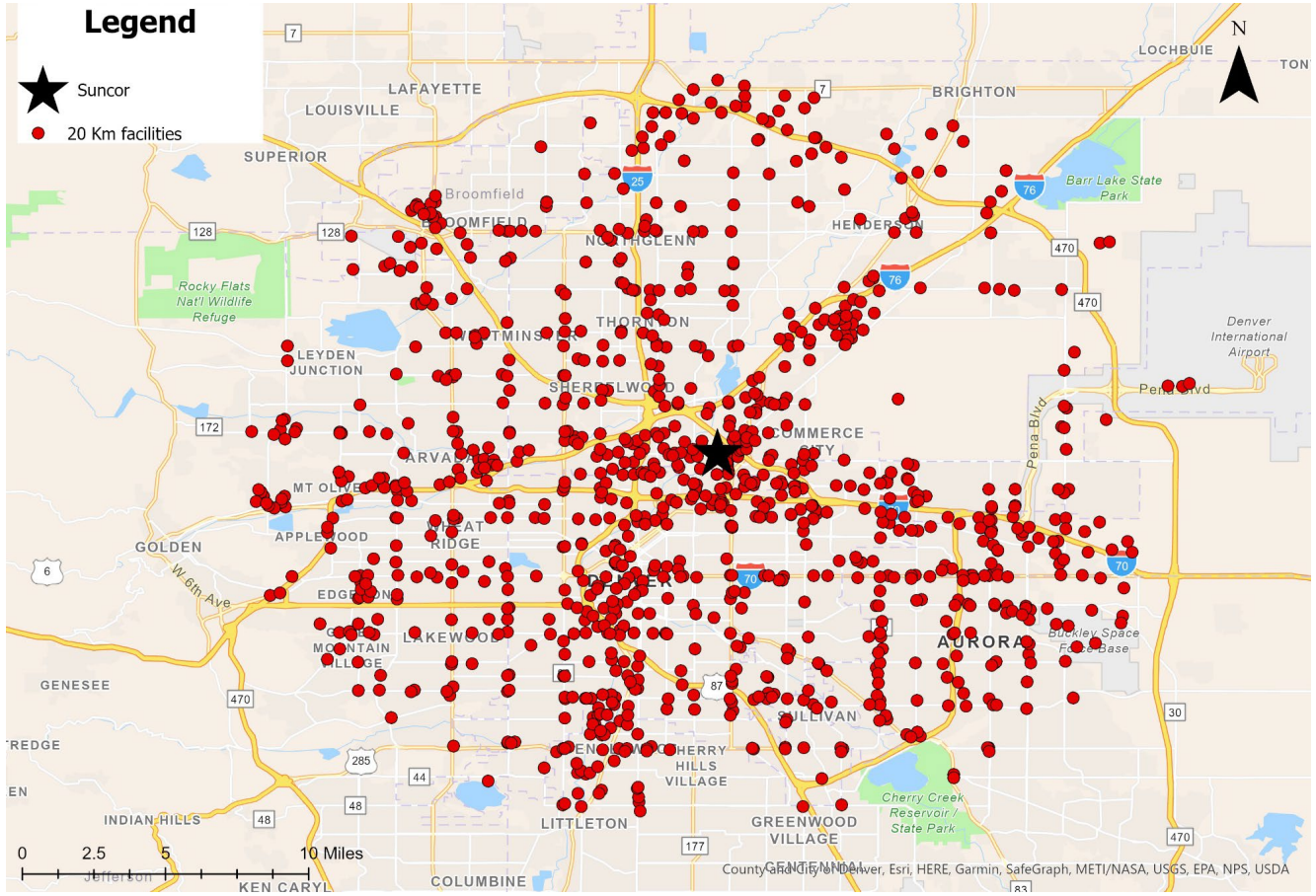
Outline

- Project background and objectives
- Analysis methods and inputs
- Results and discussion
- Future work

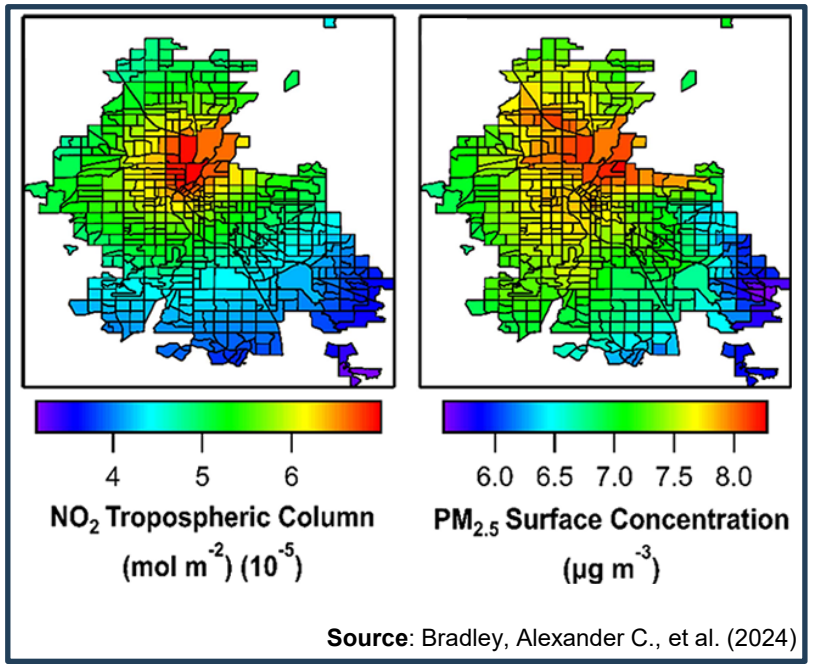
Source: cpr.org

Why Commerce City / North Denver (CCND)?



All NOx emission sources within 20 km radius from Suncor Refinery (based on CDPHE's APEN inventory).

Source: Denver Post, 2024



Source: Bradley, Alexander C., et al. (2024)

Project Objective

- To better understand the possible sources and magnitude of air quality impacts to help inform air quality management policies for the CCND area.

- To achieve this objective, we evaluated the following:

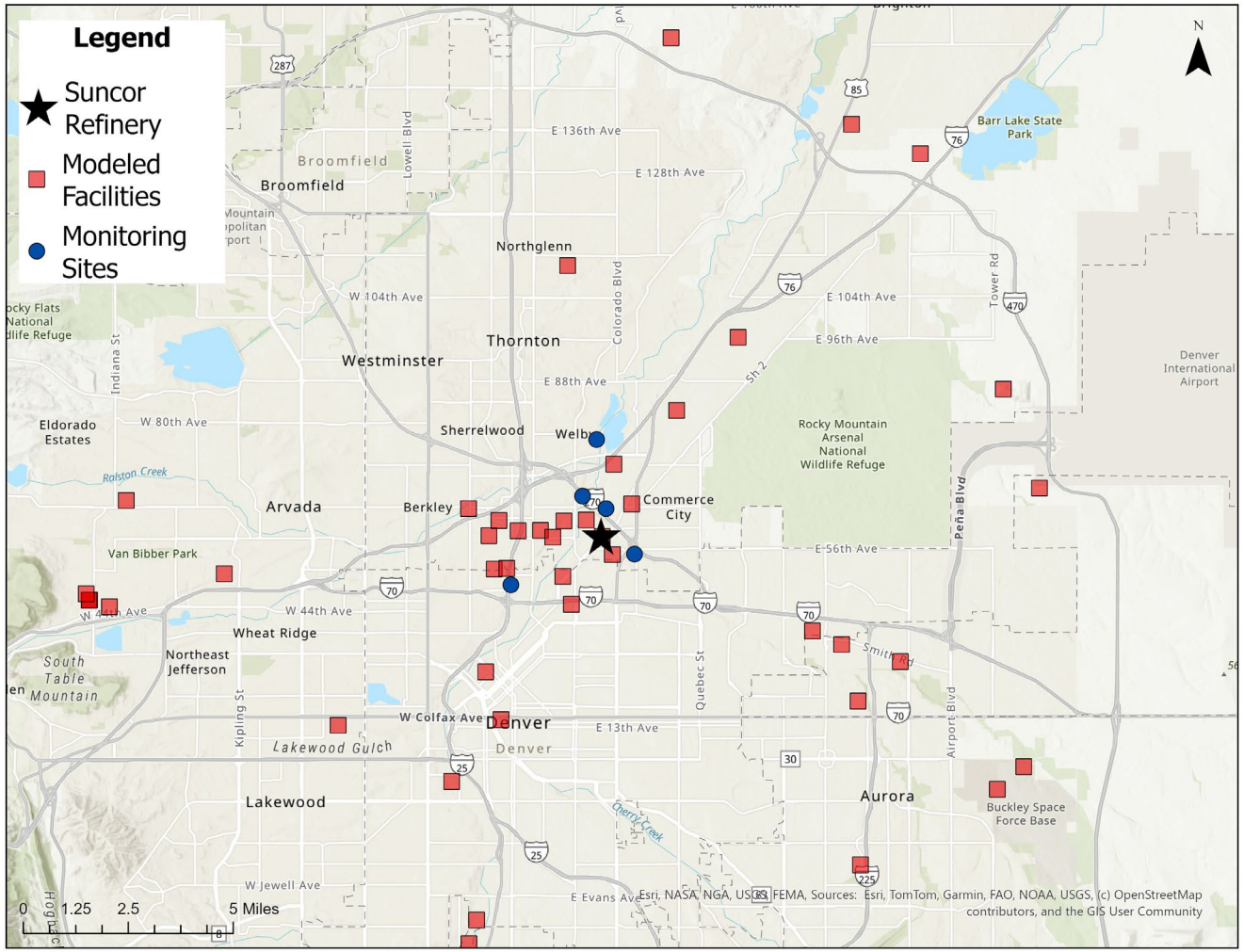
  1) 1-hour NO2 modeled to monitored concentration comparison to assess model performance.
     - Actual (APEN) stationary source and mobile NOx emission sources were modeled and compared to available monitoring data.
     - AERMOD was run using the following NO2 conversion techniques:
       - ❑ Tier I: Full conversion
       - ❑ Tier II: Ambient Ratio Method (ARM2)
       - ❑ Tier III: Ozone Limiting Method (OLM), Plume Volume Molar Ratio Method (PVMRM), General Reaction Set Method (GRSM)

  2) Modeled source contributions at select receptors.

Analysis Methods and Inputs

- Air quality modeling inputs and outputs:
  - Stationary sources of NOx greater than 20 tpy within 20 km of CCND.
  - Mobile source data developed by DDPHE as part of the Good Neighbor Project (2022).
  - Polar grids extending to 20km with discrete receptors placed at the ambient monitoring locations.
  - Site specific 10-m meteorological station operated by CDPHE.
  - Representative background NOx, NO2, and O3 concentration data from CPDHE's Welby station, as applicable.
  - All Tier III options used a default NO2-to-NOx in-stack ratio (ISR) of 0.5 (except for some additional GRSM tests).
  - Ambient air quality monitoring data (CPDHE & CDOT sites).

Modeled Facilities and Ambient Monitoring Sites



Note: Modeled facilities shown above are those that have NOx emissions greater than 20 tpy.

Modeled to Monitored Performance Evaluation Criteria (Objective #1)

- Modeled to monitored 1-hour NO2 Q-Q plots for each NO2 tier.
  - Q-Q plots rank the predicted and observed concentrations from maximum to minimum and then pairs them by their rank.
  - Perfect model performance is represented by the 1:1 line.
  - Q-Q plots allow us to understand how close the model predictions are to the observed ambient monitoring data.
- In addition to Q-Q plots, we calculated the Robust Highest Concentration (RHC) to evaluate model performance. The RHC is calculated using the following equation:

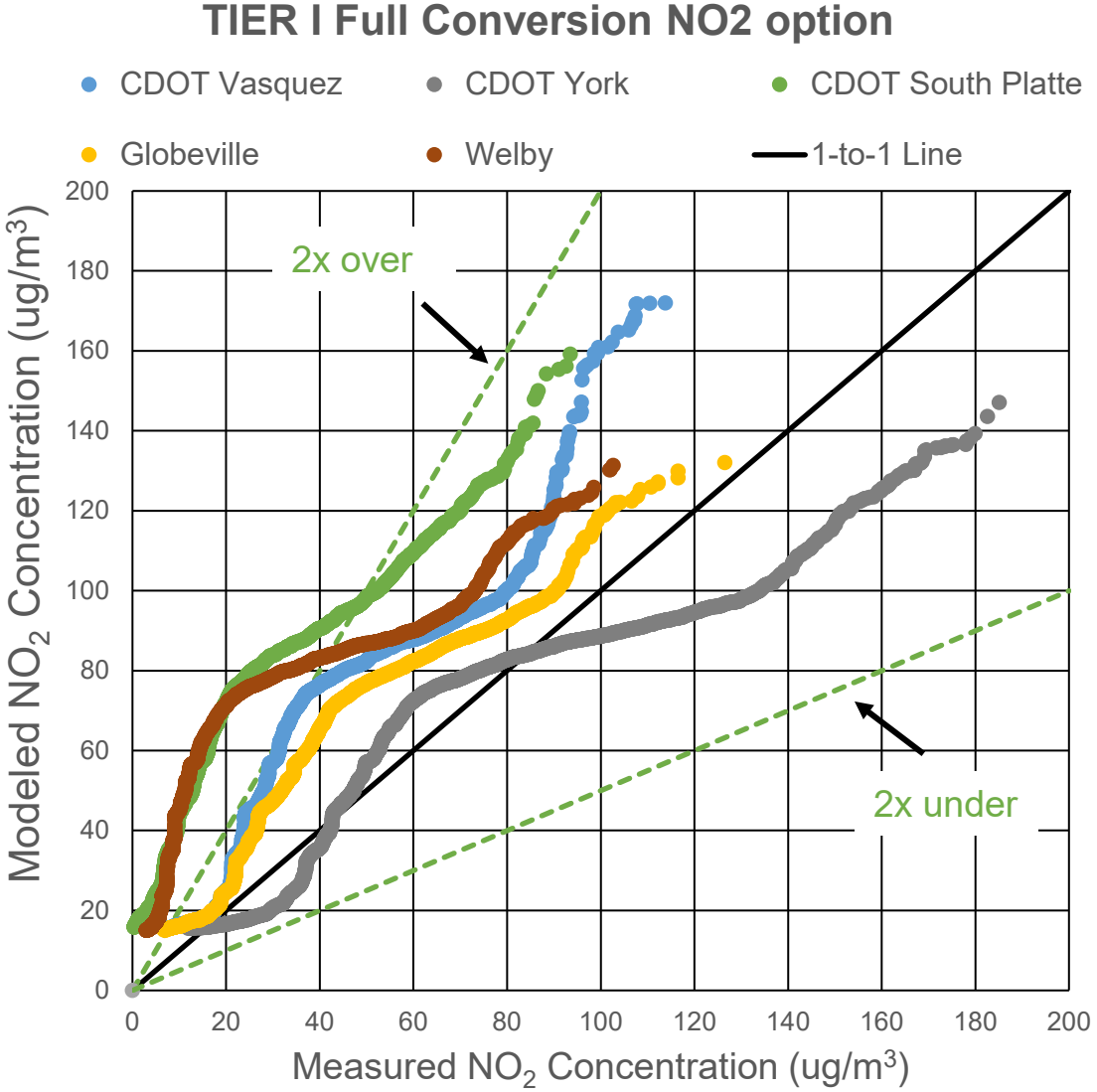
$$RHC = X(N) + [\overline{X} - X(N)] \times \ln [(3N-1)/2]$$

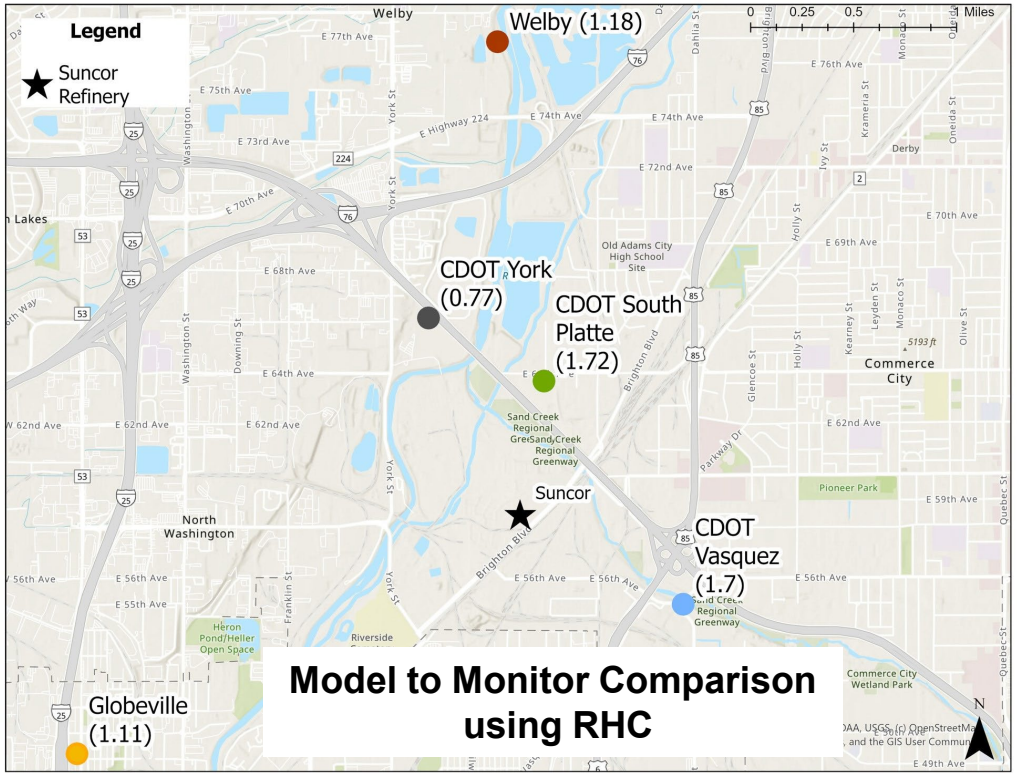
where X(N) is the Nth largest value and $\overline{X}$ is the average of the N-1 values, and N is the number of values exceeding the threshold value, usually 26.

  - RHC of 1 means perfect model to monitor comparison.

Source: Cox, William M., and Joseph A. Tikvart. "A statistical procedure for determining the best performing air quality simulation model." *Atmospheric Environment. Part A. General Topics* 24.9 (1990): 2387-2395.

Modeled to Monitored Comparison: TIER I – Full Conversion

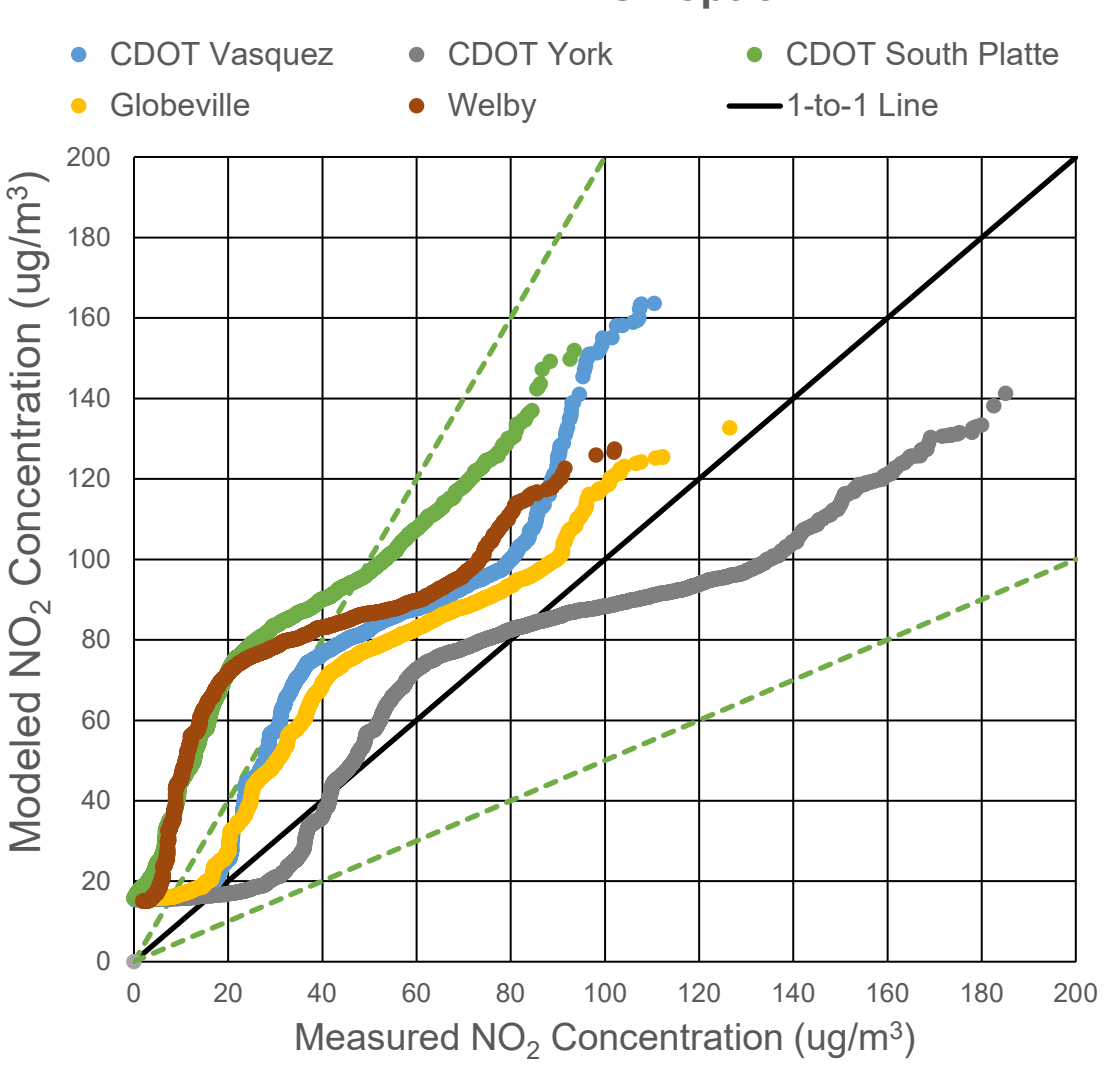


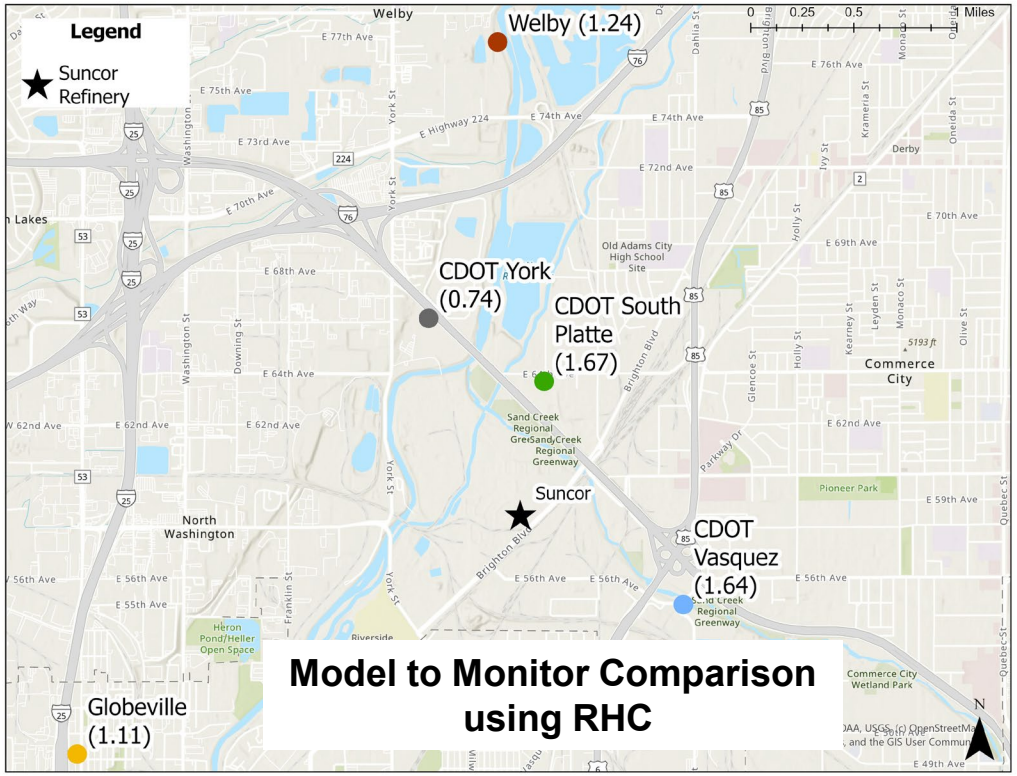


Note: Model to monitor RHC ratio shown in parenthesis

- The model shows overprediction bias for all sites except CDOT York.
- RHCs at the Welby and Globeville sites are near 1.0, suggesting better model performance at these locations.

Modeled to Monitored Comparison: TIER II – ARM2

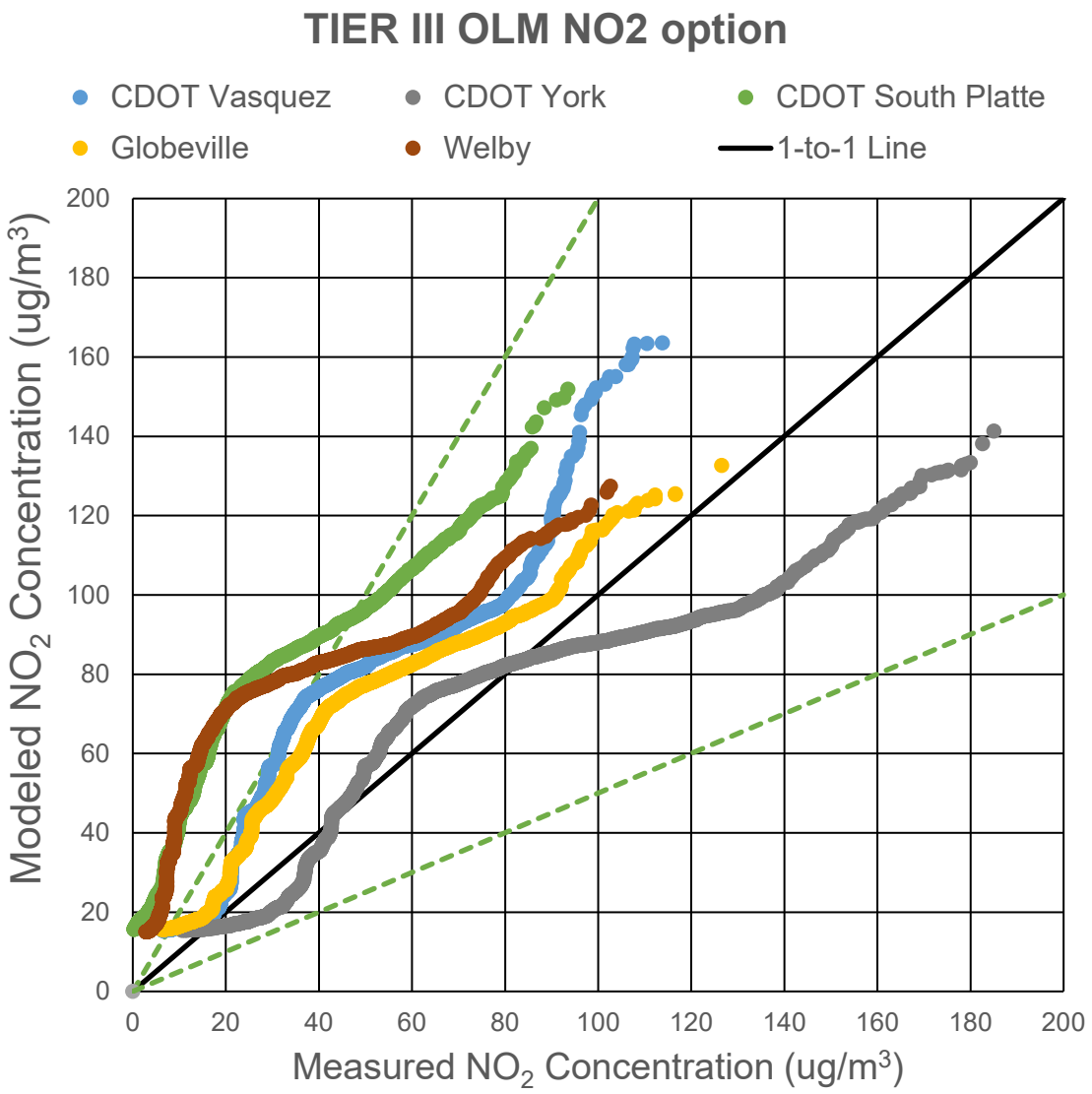


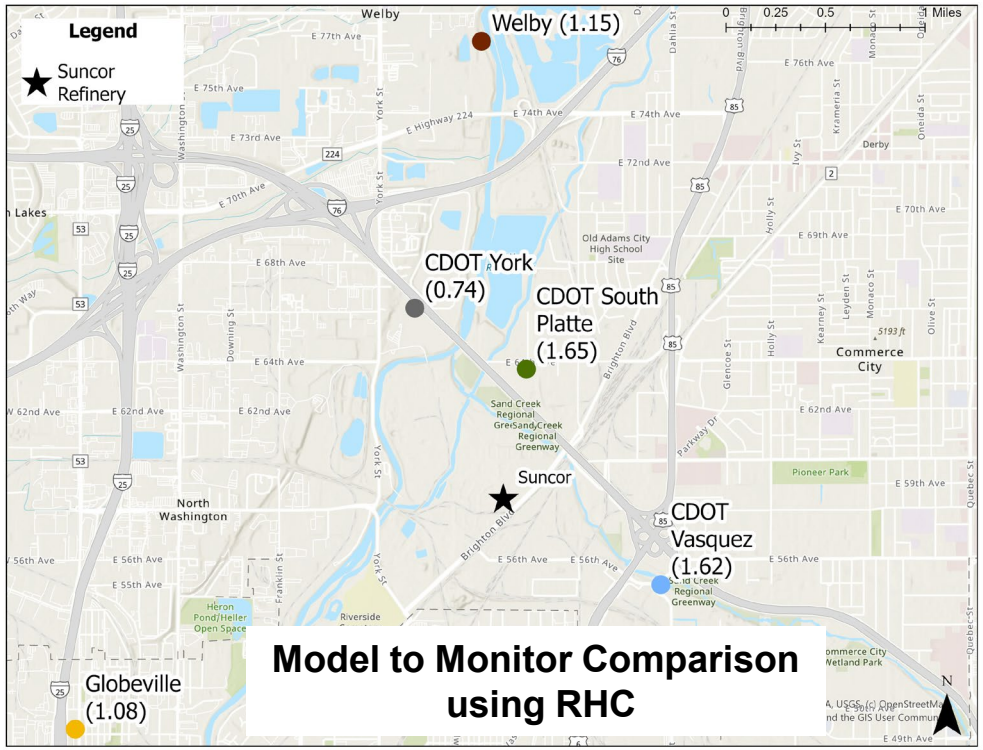


Note: Model to monitor RHC ratio shown in parenthesis

- Compared to Tier I, ARM2 RHCs were 5% lower at each site except at Globeville.
- Overprediction was seen at the CDOT South Platte and CDOT Vasquez sites (for both Q-Q plot and RHCs).

Modeled to Monitored Comparison: TIER III – OLM



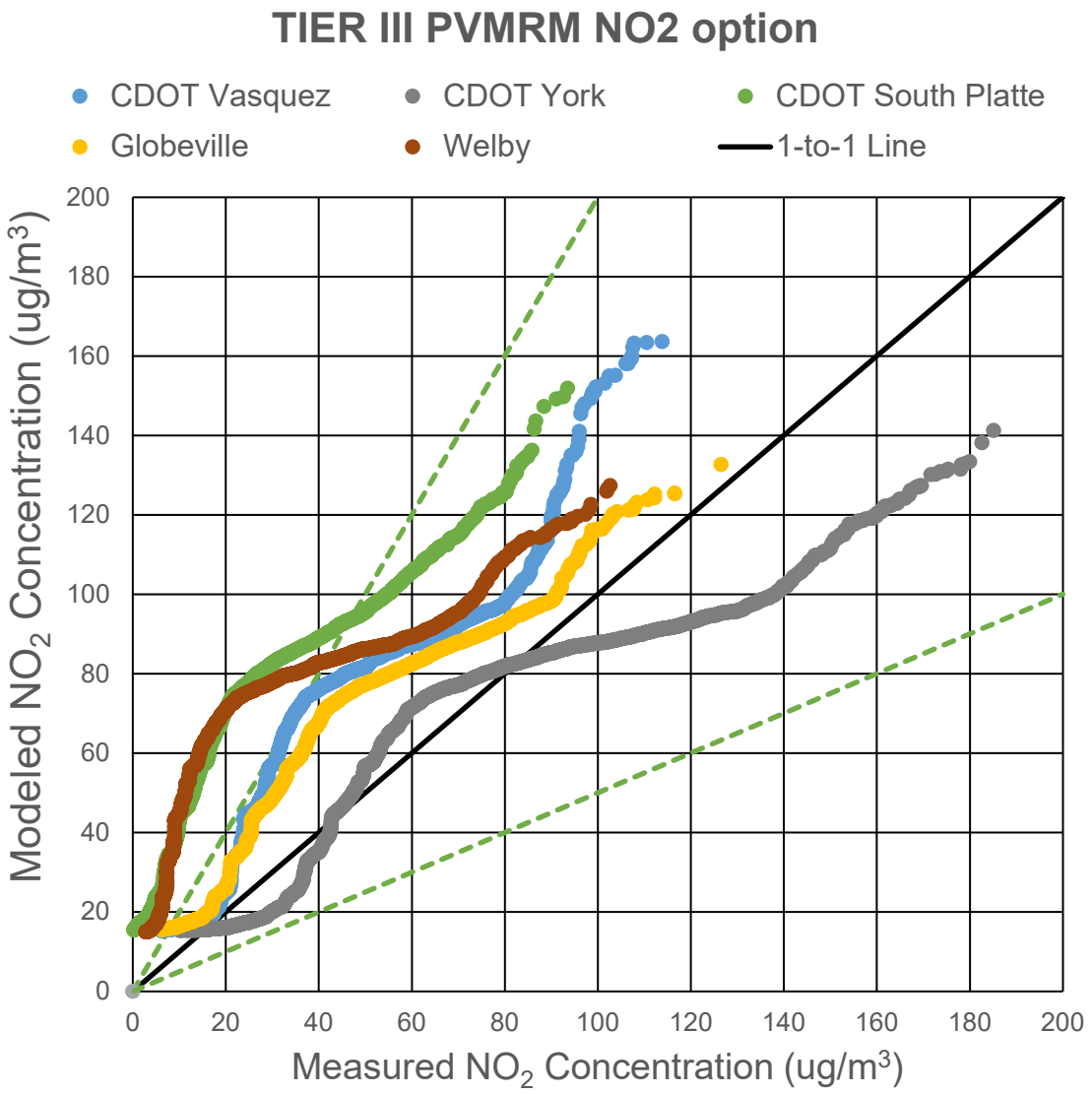


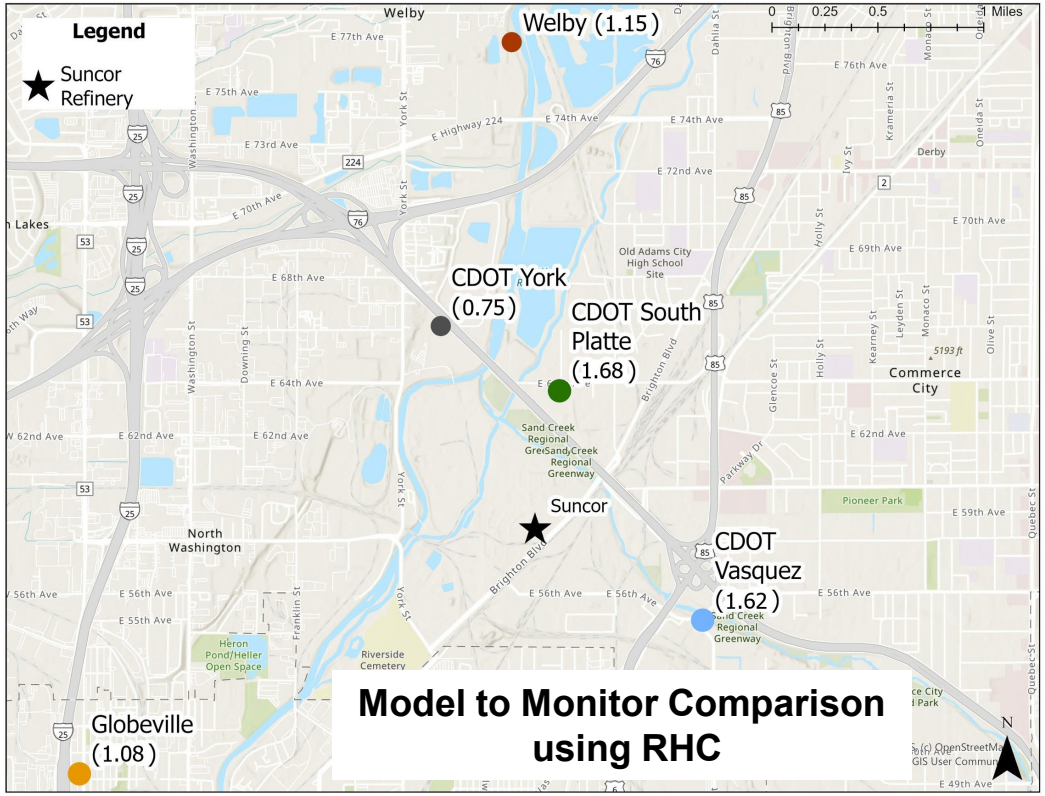
Note: Model to monitor RHC ratio shown in parenthesis

- The Q-Q plots and RHC ratio for both OLM and Tier II ARM2 were very similar.

RHC comparison	Tier III OLM	Tier II ARM2
CDOT South Platte	1.65	1.67
CDOT York	0.74	0.74
CDOT Vasquez	1.62	1.64

Modeled to Monitored Comparison: TIER III – PVMRM



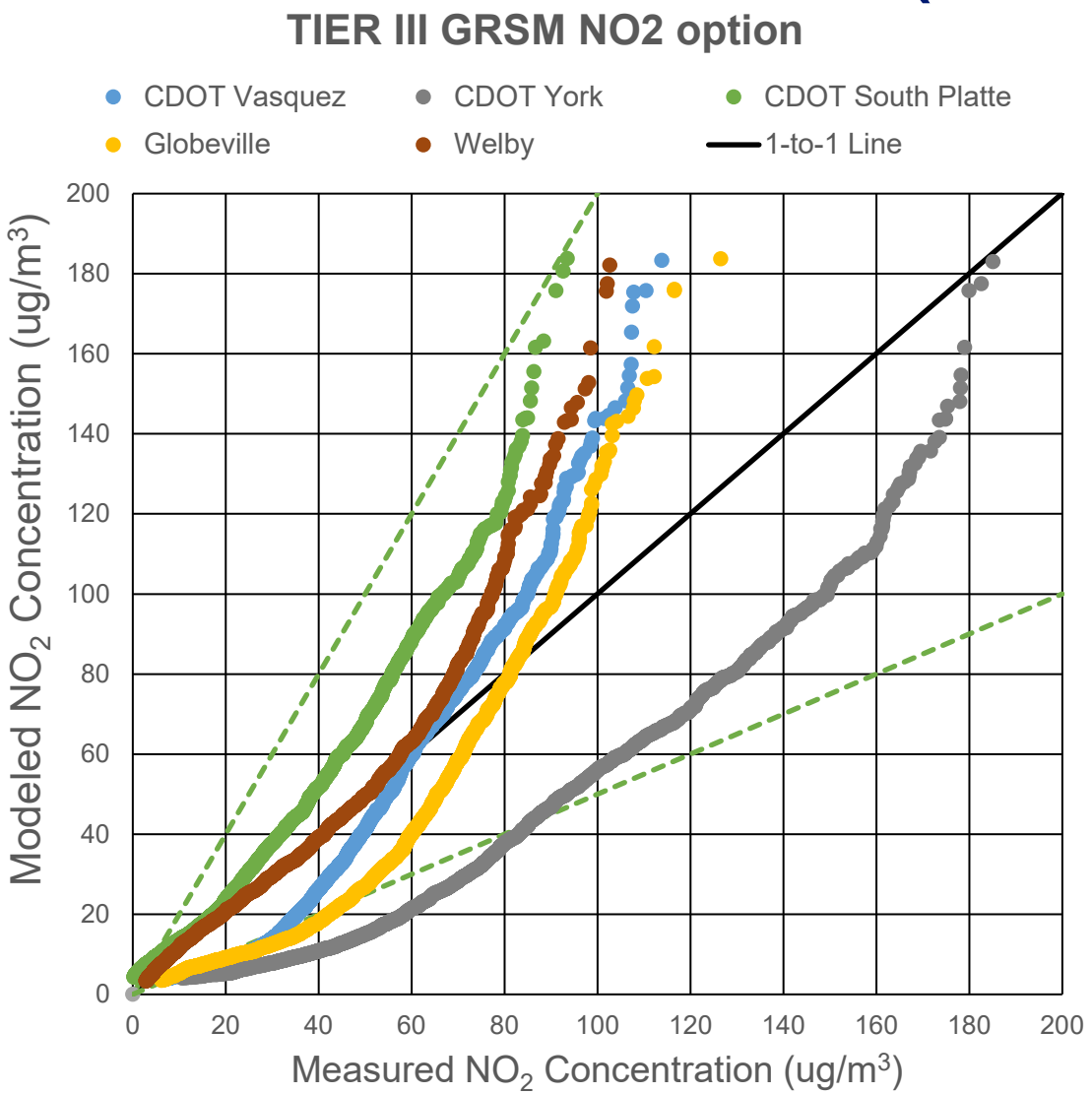


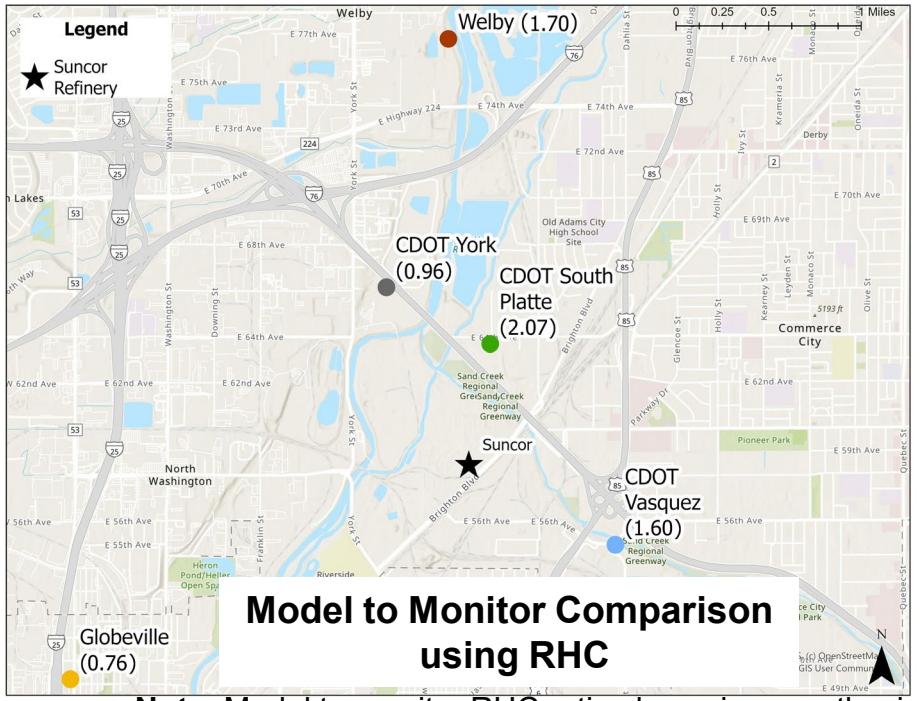
Note: Model to monitor RHC ratio shown in parenthesis

- At Globeville, Welby, CDOT Vasquez and CDOT York sites, PVMRM RHCs were identical to OLM.

RHC comparison	Tier III PVMRM	Tier III OLM
CDOT South Platte	1.68	1.65
CDOT York	0.75	0.74
CDOT Vasquez	1.62	1.62
Welby	1.15	1.15
Globeville	1.08	1.08

Modeled to Monitored Comparison: TIER III – GRSM (Using Default ISR of 0.5)



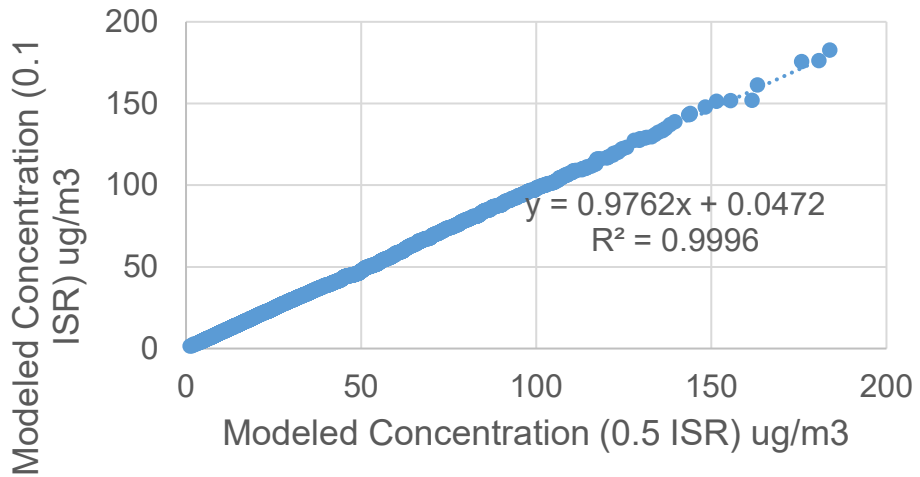


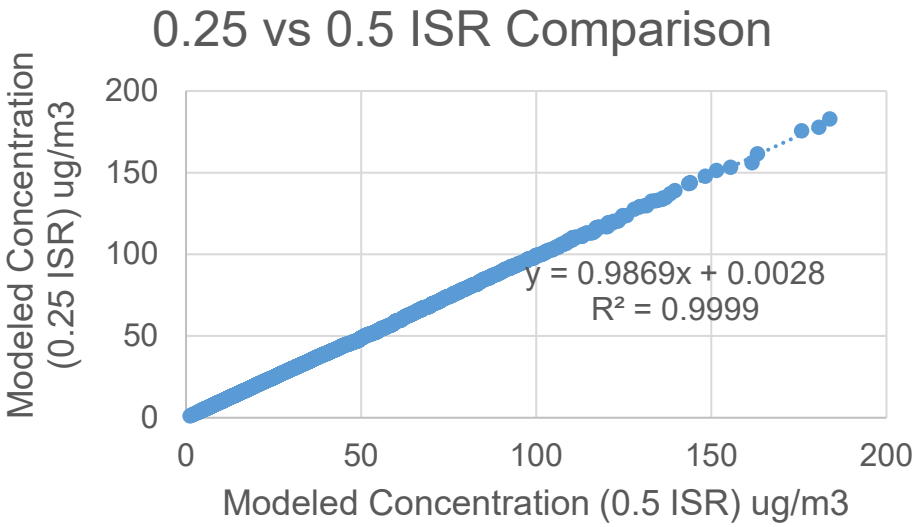
Note: Model to monitor RHC ratio shown in parenthesis

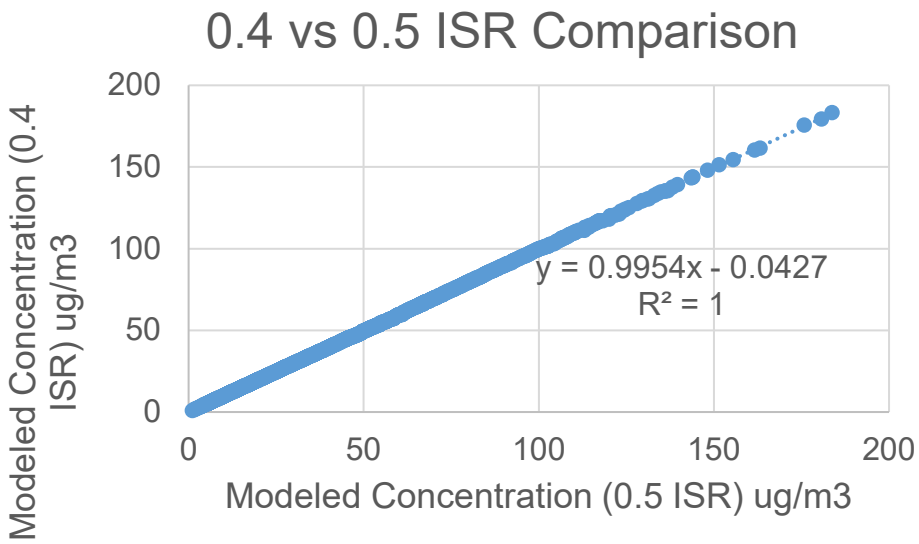
- GRSM overpredicted concentrations at the Welby, CDOT South Platte and CDOT Vasquez sites. Underprediction at York and Globeville.

RHC comparison	Tier III GRSM	Tier III PVMRM
CDOT South Platte	2.07	1.68
CDOT York	0.96	0.75
CDOT Vasquez	1.60	1.62
Welby	1.70	1.15
Globeville	0.76	1.08

Modeling and Monitoring Comparison: TIER III – GRSM (ISR Sensitivity Tests)







- The model concentrations at the CDOT South Platte monitor seem to be independent of ISRs for TIER III GRSM.
- Similar trends were observed at the Welby and CDOT York monitoring stations.

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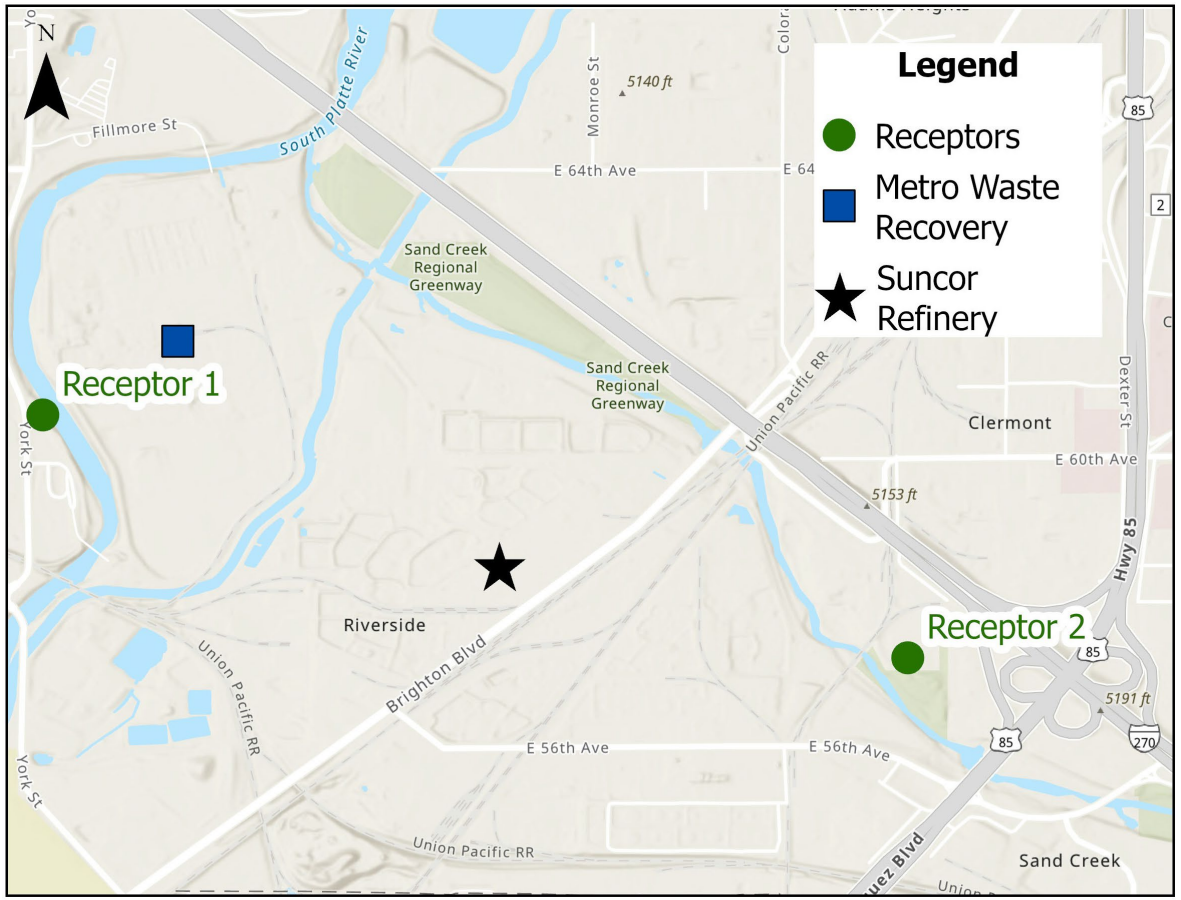
Modeled to Monitored Comparison Summary

- Q-Q plot and RHC evaluations show the best model performance for Tier II, Tier III OLM, and PVMRM.
- GRSM having higher RHCs at the CDOT South Platte, CDOT Vasquez, and Welby sites may be caused various reasons; however, we identified that ISRs do not substantially impact the model concentrations.

Modeled/Monitor Sites	TIER I RHC Ratio	TIER II RHC Ratio	TIER III OLM RHC Ratio	TIER III PVMRM RHC Ratio	TIER III GRSM RHC Ratio
CDOT York St.	0.77	0.74	0.74	0.75	0.96
CDOT South Platte	1.22	1.67	1.65	1.68	2.07
CDOT Vasquez	1.69	1.64	1.62	1.62	1.60
Globeville	1.11	1.11	1.08	1.08	0.76
Welby	1.18	1.24	1.15	1.15	1.70

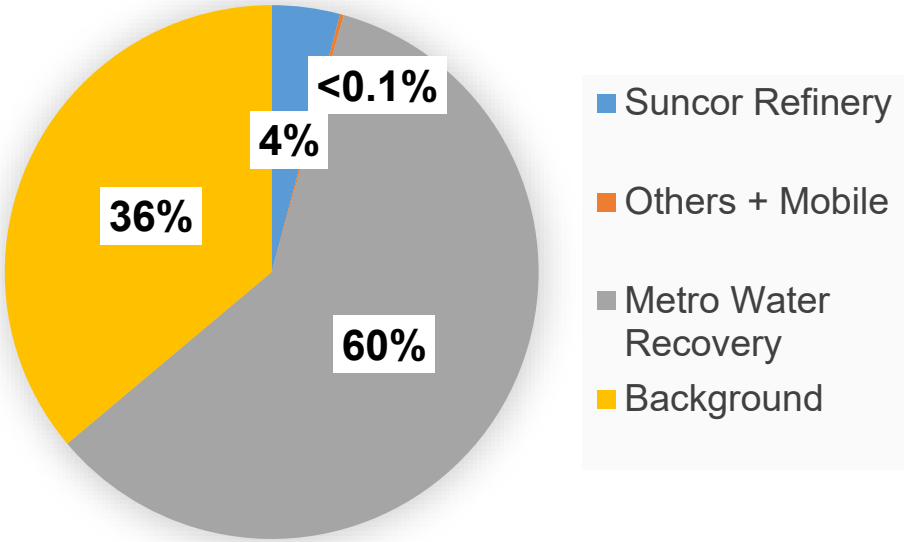
Modeled TIER II NO2 Source Contributions (Objective #2)



- Modeled source contribution analyses were performed using the Tier II NO2 screening technique.
- Receptor locations are within the top five H8H 1-hour NO2 concentrations

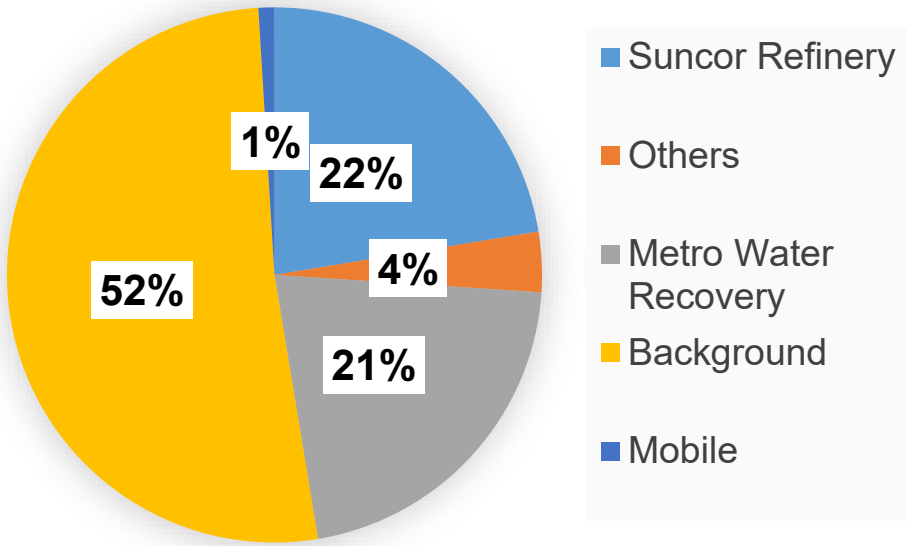
TIER II NO2 Source Contribution Analysis

At receptor location 1: near MWR



Total model concentration: 179.1 ug/m3

At receptor location 2: near Suncor



Total model concentration: 166.1 ug/m3

- At both receptor locations, Metro Water Recovery (MWR) and Suncor Refinery were the top two contributors to the total NO2 concentrations (excluding background).

Note: The "Others" category includes approximately 40 facilities

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NOx Source Contribution Summary

- The majority of the predicted NO2 impacts (60%) at Receptor 1 were associated with NOx emissions from the Metro Water Recovery facility:
  - Sources at Metro Water Recovery facility includes flares, turbines, and engines.
  - 36% of the predicted NO2 impacts were due to background NO2 concentrations.
- The majority of the predicted NO2 impacts (52%) at Receptor 2 were due to background concentrations, with the following observations from the model:
  - The Metro Water Recovery and Suncor Refinery facilities combined contribute 43% of the H8H 1-hour NO2 concentrations at Receptor 2.
- Future work may involve further investigation of these stationary source and background contributions to better understand potential 1-hour NO2 impacts experienced at these receptor locations.
  - The Welby monitor represents “other sources” (per Appendix W) and may under or overpredict that portion of the cumulative NO2 impacts.

Future Work

- We will further evaluate Tier III methods, especially GRSM to better understand the effects of the many inputs and possible limitations.
- We may update the model with more recent mobile data.
- Continue the source contribution work by focusing on individual facilities such as Metro Water Recovery and Suncor Refinery.
- Use Tier III methods for source contribution analysis.

Acknowledgements / Questions

- Gustavo Cuchiara, Elizabeth Wallace, Jenny Turk, Olliander Beucler, Nathaniel Collett, Andy White, and other DMS members.
- I would like to thank the following organizations for providing the supporting data:
  - Denver Department of Public Health and Environment: Mobile data
  - Colorado Department of Transportation/Air Sciences: Monitoring data
  - CDPHE Technical Services Program: Monitoring data

TIER III NO2 Screening Techniques

NO_x chemistry scheme Status	Process	OLM *Regulatory*	PVMRM *Regulatory*	GRSM *ALPHA*
Entrainment of O_3 into the plume	Dispersion	Fully entrained into ensemble plume	Limited entrainment (volume-based approach) into instantaneous plume (unstable conditions only*)	Limited entrainment (cross-sectional area-based approach) into instantaneous plume (all atmospheric conditions)
O_3 titration	Chemistry	100% conversion	100% conversion	Explicit calculation
Photolysis		Neglected	Neglected	Explicit calculation
Background concentrations required		Hourly O_3	Hourly O_3	Hourly O_3, NO_X, NO_2

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Robust High Concentration (RHC)

- The robust highest concentration represents a smoothed estimate of the highest concentrations, based on a tail exponential fit to the upper end of the concentration distribution.
  - Using this analysis, the effect of extreme values on the model comparison is reduced.
  - The RHC can be calculated as:

$$RHC = X(N) + [\overline{X} - X(N)] \times \ln [(3N-1)/2]$$

where X(N) is the Nth largest value and $\overline{X}$ is the average of the N-1 values.

Source: Cox, William M., and Joseph A. Tikvart. "A statistical procedure for determining the best performing air quality simulation model." *Atmospheric Environment. Part A. General Topics* 24.9 (1990): 2387-2395.

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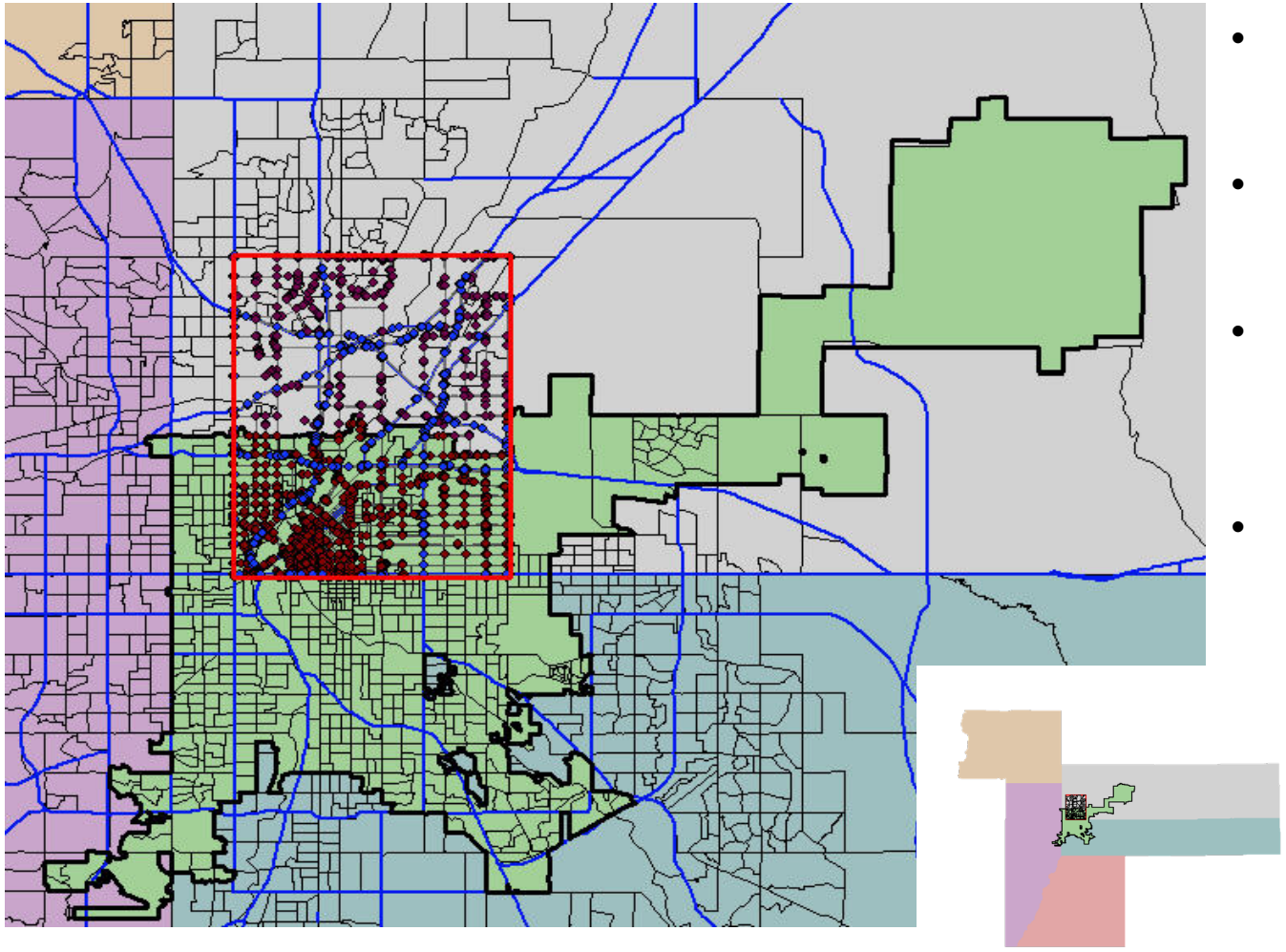
Mobile Sources: DDPHE Good Neighbor Project



- Mobile sources were adapted from the Good Neighbor Project conducted by DDPHE.
- 2020 National Emissions Inventory & emissions Inventories from CDPHE.
- DDPHE used Vehicle Miles Traveled (VMT) to apportion county level emissions into more refined areas designated as Traffic Area Zones.
- MOBILE6.2 Onroad Emission Estimates - use local data (VMT, fuels, registration data)

<u>Good Neighbor Area Facts</u>:

Area = ~1% of metro Denver

VMT= 11% of metro Denver

4 Interstates (25, 70, 76, 270)

Source: Eltarkawe, M., Thomas, G., & Miller, S. L. (2022). Modeling county-level benzene emissions using transportation analysis zones in the Denver metro area. *Atmospheric Environment: X*, *15*, 100180.

DDPHE Good Neighbor Project

- Refined modeling assessment – north Denver and Commerce City (FHWA funding)
  - Conducted partially in response to community concerns about planned highway expansion (I-70)
- On-road mobile source emissions confined to roadway footprints (major roadways)
  - Interstates, freeways, major arterials and collectors
  - Separated and adjusted cold/hot start emissions, exclude some evaporative emissions from highways
- MOBILE6.2 Onroad Emission Estimates - use local data (VMT, fuels, registration data)

Source: Eltarkawe, M., Thomas, G., & Miller, S. L. (2022). Modeling county-level benzene emissions using transportation analysis zones in the Denver metro area. *Atmospheric Environment: X*, *15*, 100180.