

Evaluation of 2026 O₃ Precursor Emission Source Sectors using Weighted Emissions Potential

Denver Metro/North Front Range Ozone Nonattainment Area

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2023 International Emissions Inventory Conference

Tools for Improving Development, Display, and Review of Emission Inventories Session

September 28, 2023 – 120 pm



Outline

- Method
- Emission Inventory
- Residence Time Analysis
- Weighted Emission Potential initial results
- Potential Source Contribution initial results
- Project next steps

- Team effort - acknowledgements:
 - Ramboll: Ross Beardsley, Fiona Jiang, Tejas Shah, Ralph Morris
 - RAQC: Mike Silverstein

Background and Objectives

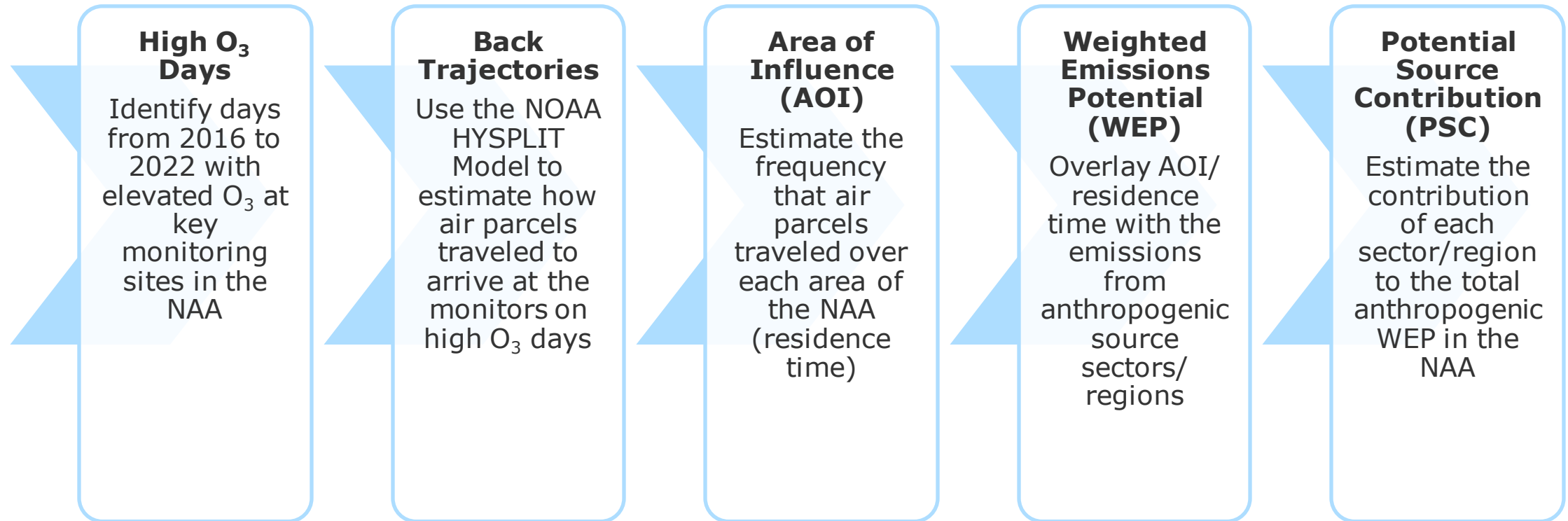
Background

- Piloting new approach to estimate potential ozone precursor source contributions to monitoring sites with elevated O₃ concentrations in the Colorado Denver Metro/North Front Range (DM/NFR) ozone (O₃) Nonattainment Area (NAA)
- Use the HYSPLIT back trajectory model and 2026 emissions to perform an empirical analysis of the transport of NO_x and VOC emissions to evaluate the potential relative contributions of source sectors and regions to monitors in the NAA
- Screening tool to understand potential transport and source/region contributions, and designed to improve settings photochemical modeling (e.g., source apportionment techniques)

Objectives

- Estimate the potential contributions of NO_x and VOC emissions from various source sectors that arrive at key monitoring sites in the 2015 Colorado DM/NFR ozone NAA 9-county region at times of observed elevated O₃ concentrations
- Evaluate the potential effects of 2026 alternative emission control strategies on estimated source contributions

Overview of Approach



Advantages and Disadvantages

Advantages

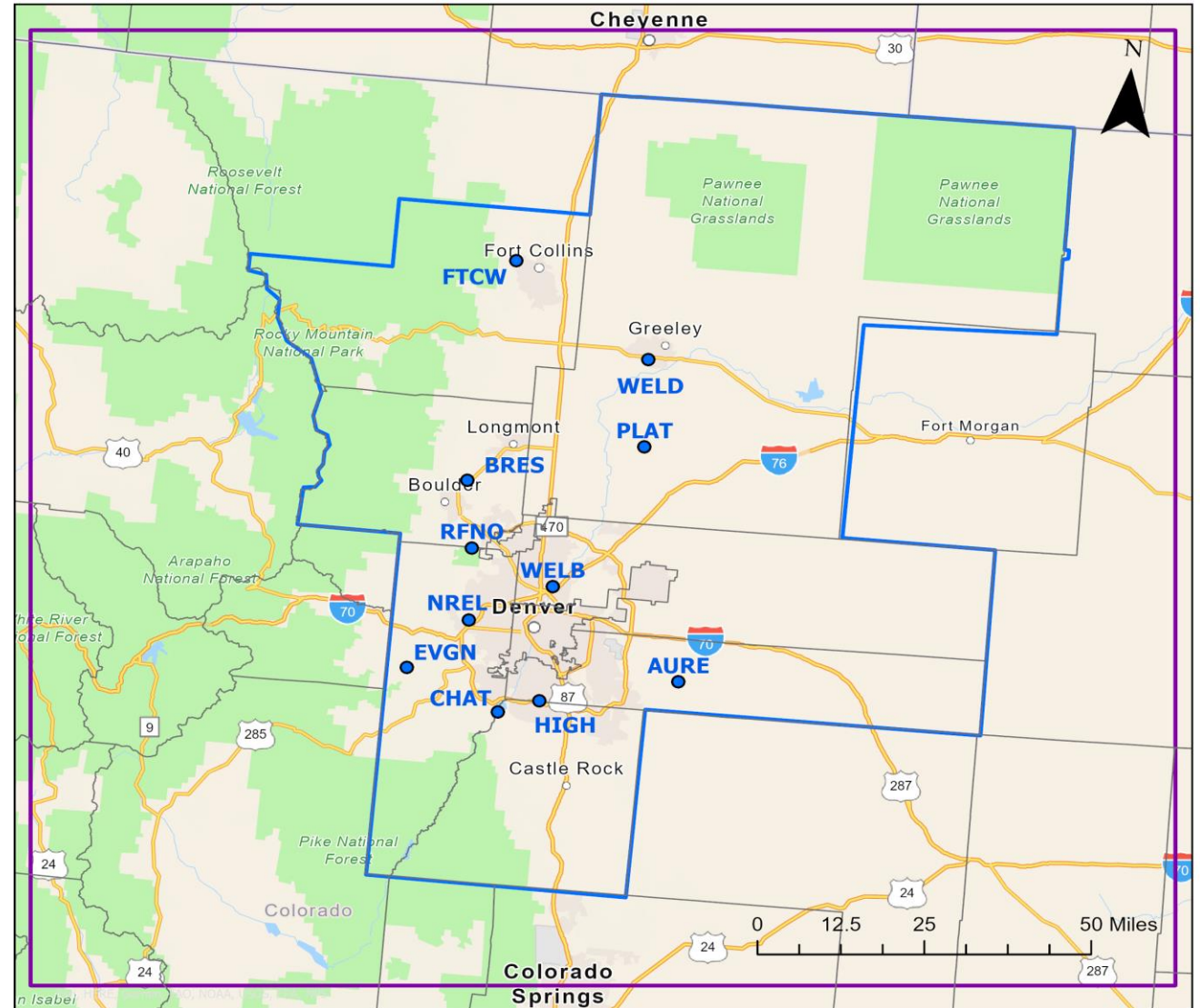
- Uses relatively simple methods to infer relative contributions of NO_x or VOC emissions from various source sectors to elevated O₃ concentrations in the NAA
- Significantly faster and less costly than PGM modeling
- Accounts for geography and transport paths to monitors in the NAA on high O₃ days
- Can be quickly applied to a range of meteorological conditions across multiple years (2016 to 2022) that PGM cannot do

Disadvantages

- HYSPLIT back trajectories are uncertain
- Photochemistry is not accounted for and thus NO_x/VOC emissions can not directly be related to O₃ concentrations
- Source parameters and other emission characteristics are not represented
- Analysis is limited to monitored locations
- Compared to CAMx ozone source apportionment, WEP/PSC overestimates ozone precursor contributions for point sources and underestimates dispersed emission sources and overstates close source contributions

Site Selection

Site ID	Site Name	2020-2022 Design Value
NREL	NREL - South Table Mtn.	84
RFNO	Rocky Flats - North	83
CHAT	Chatfield Park	83
HIGH	Highland	80
FTCW	Fort Collins - West	77
WELB	Welby	77
WELD	Greeley - Weld Co. Tower	72
BRES	Boulder Reservoir	76
PLAT	Platteville	77
EVGN	Evergreen	NA
AURE	Aurora - East	74



- Ozone Monitors included in the WEP/AOI Analysis
- 2015 Denver Ozone Nonattainment Boundary
- WEP/AOI Analysis Domain (4 km resolution)
- County



Selection of Elevated O₃ Days

- **Day Selection Criteria:** Maximum daily average 8-hour (MDA8) ozone concentrations \geq 70 ppb
- **Analysis Period:** 2016 to 2022, June to August

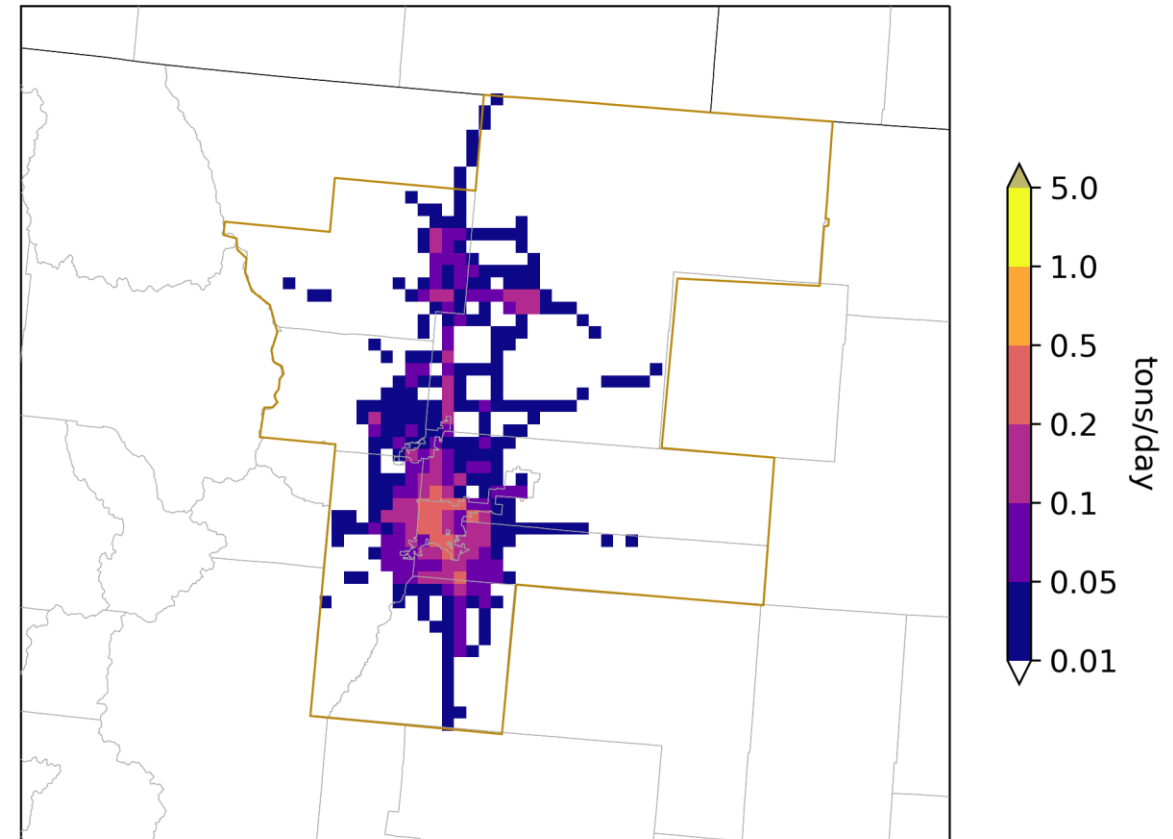
Site ID	Site Name	2020-2022 DV	Days with MDA8 \geq 70 ppb						
			2016	2017	2018	2019	2020	2021	2022
NREL	NREL – South Table Mtn.	84	19	14	26	16	22	43	23
RFNO	Rocky Flats - North	83	15	16	32	9	16	42	20
CHAT	Chatfield Park	83	17	17	28	10	14	36	17
HIGH	Highland	80	6	8	15	6	13	34	12
FTCW	Fort Collins – West	77	10	11	29	4	9	32	9
WELB	Welby	77	1	1	2	0	10	23	18
WELD	Greeley – Weld Co. Tower	72	1	8	7	0	5	17	4
BRES	Boulder Reservoir	76	0	8	28	2	10	30	8
PLAT	Platteville	77	*	*	*	*	6	31	13
EVGN	Evergreen	NA	*	*	*	*	*	20	9
AURE	Aurora - East	74	1	2	6	1	7	22	6

* Site not in operation

Emission Inventory

- **Ozone Precursors:** Nitrogen oxides (NO_x) and volatile organic compounds (VOC)
- **Emission Inventory:** Colorado 2026 “On The Books” (OTB) base case emissions by source sector with RFG+EV
- **Source sectors:**
 - Lawn & Garden Equipment and other Non-road Mobile (separately)
 - On-road Mobile
 - Rail
 - O&G area, point, pre-production (separately)
 - EGU Point
 - Non-EGU Point
 - Non-Point
 - Total Anthropogenic

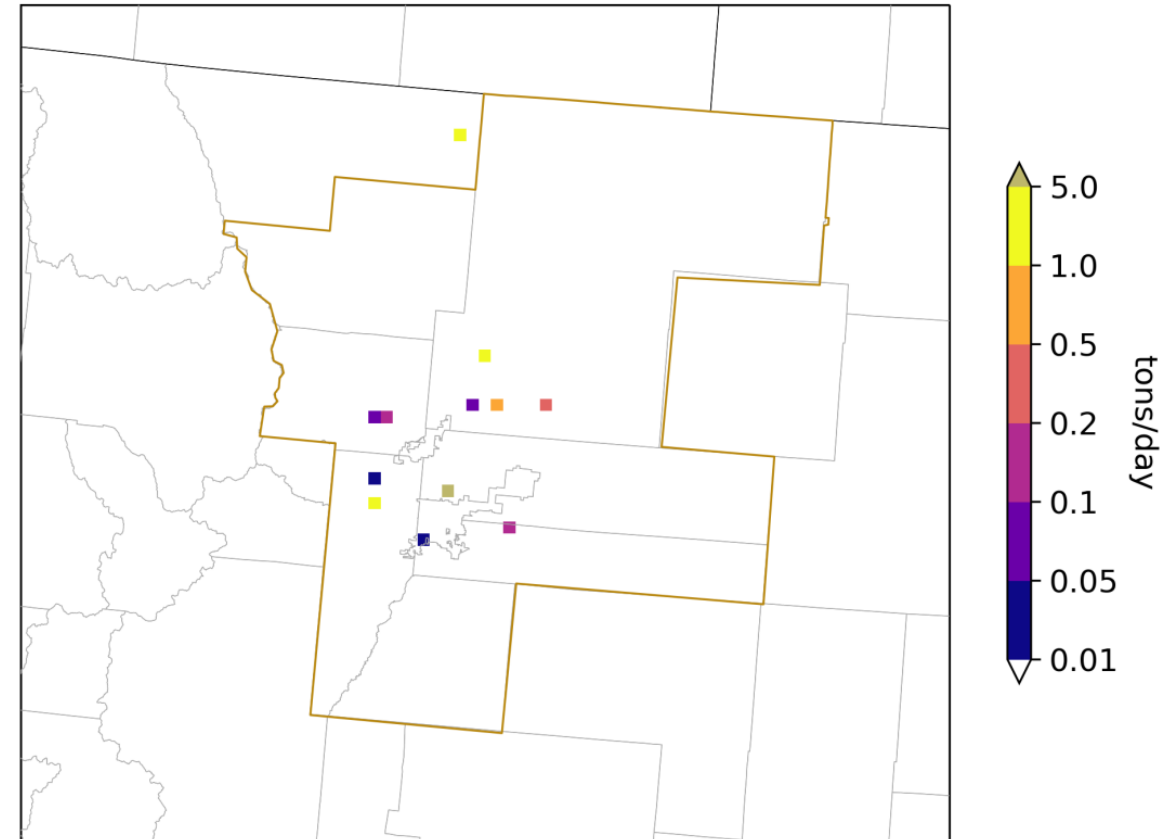
Denver NAA 2026 Episode NO_x Emissions
On-road Mobile



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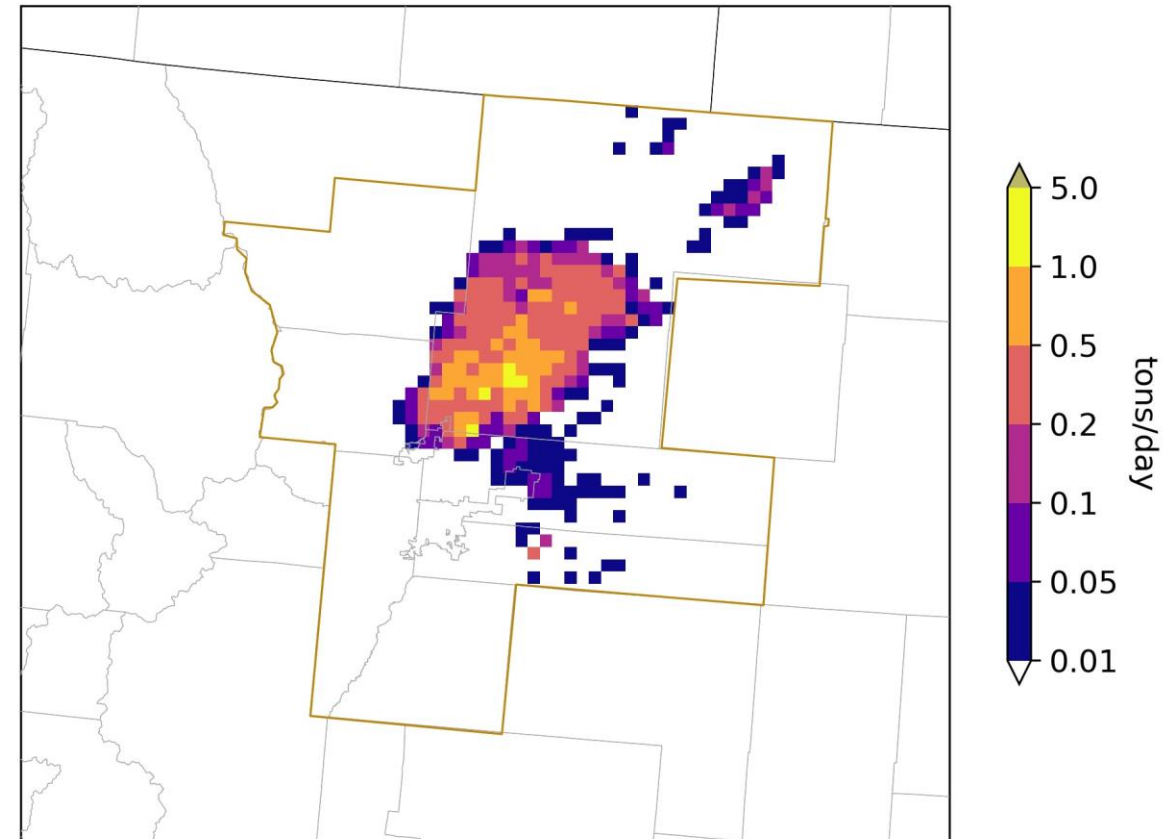
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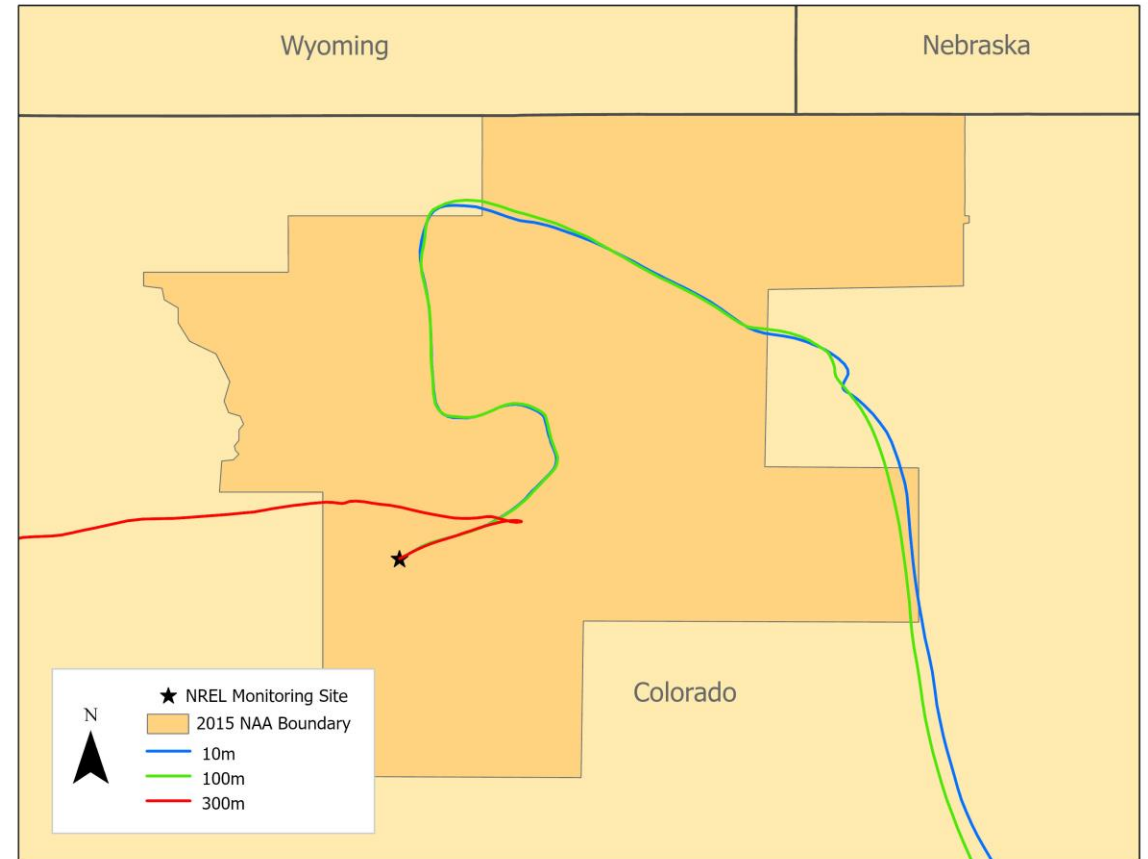
Denver NAA 2026 Episode VOC Emissions
O&G Area



HYSPLIT Back Trajectory Analysis

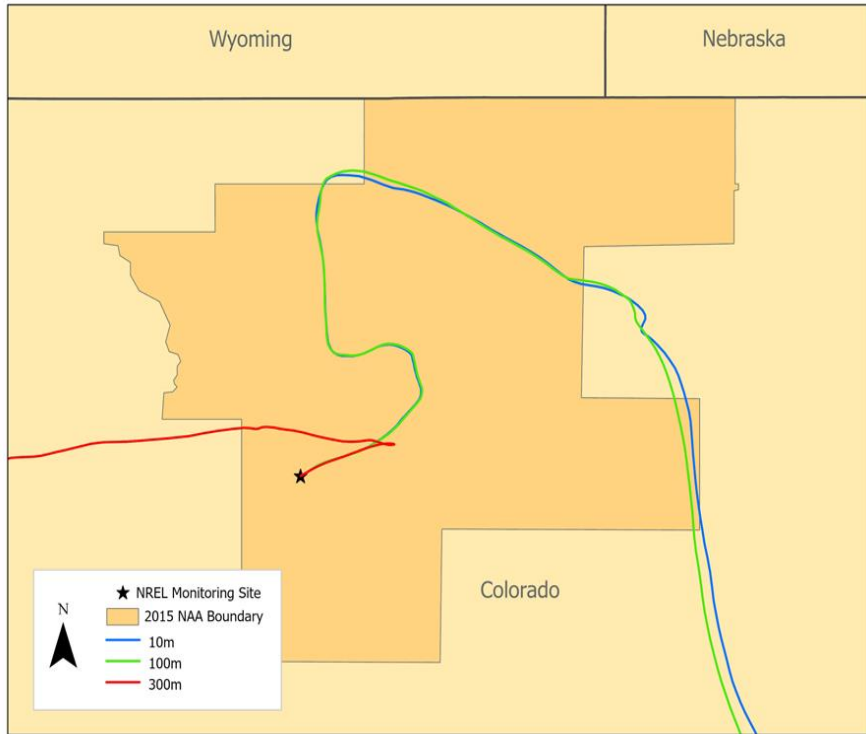
For the high O₃ days at each monitor, simulate 48-hour back trajectories with NOAA HYSPLIT model

Ending times	1 pm, 3 pm, 5 pm MDT
Ending elevations	10 m, 100 m, 300 m
Duration	48 hours
Meteorology data	3-km High-Resolution Rapid Refresh data set (2019 and earlier data are no longer maintained)
Timestep	10 minutes

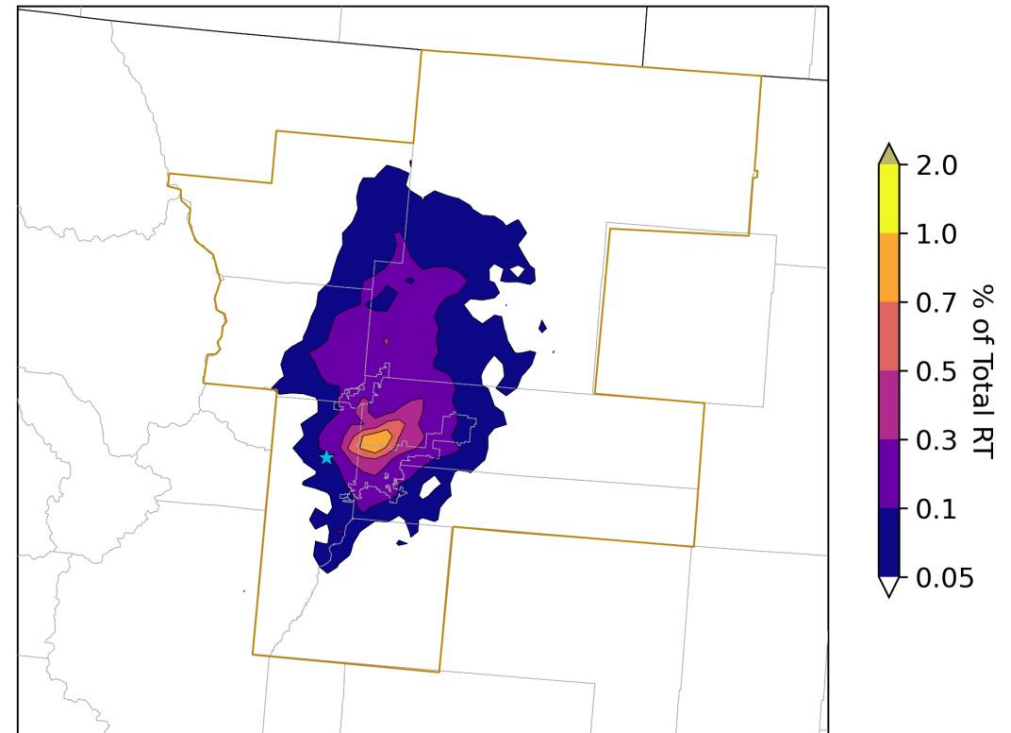


HYSPLIT Back Trajectories Plot Starting at NREL Monitor Site, 3 pm MDT on June 15, 2021

Area of Influence/Residence Time Analysis



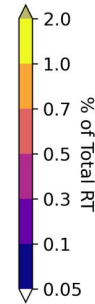
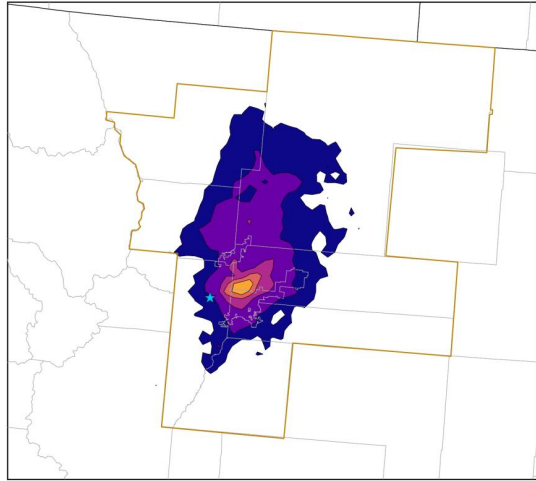
NREL - 2016-2022 - 163 days \geq 70 ppb - All height Residence Time



Residence time is calculated as the percent of the total residence time across all trajectories in each grid cell

Weighted Emissions Potential (WEP)

NREL - 2016-2022 - 163 days \geq 70 ppb - All height
Residence Time

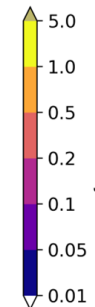
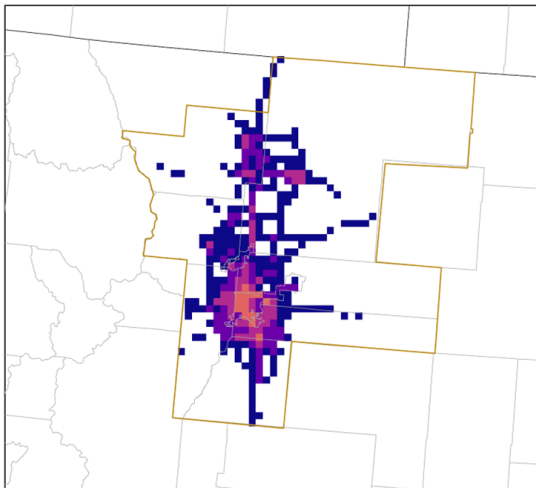


RT

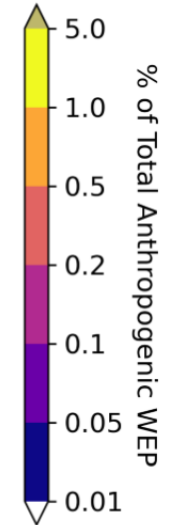
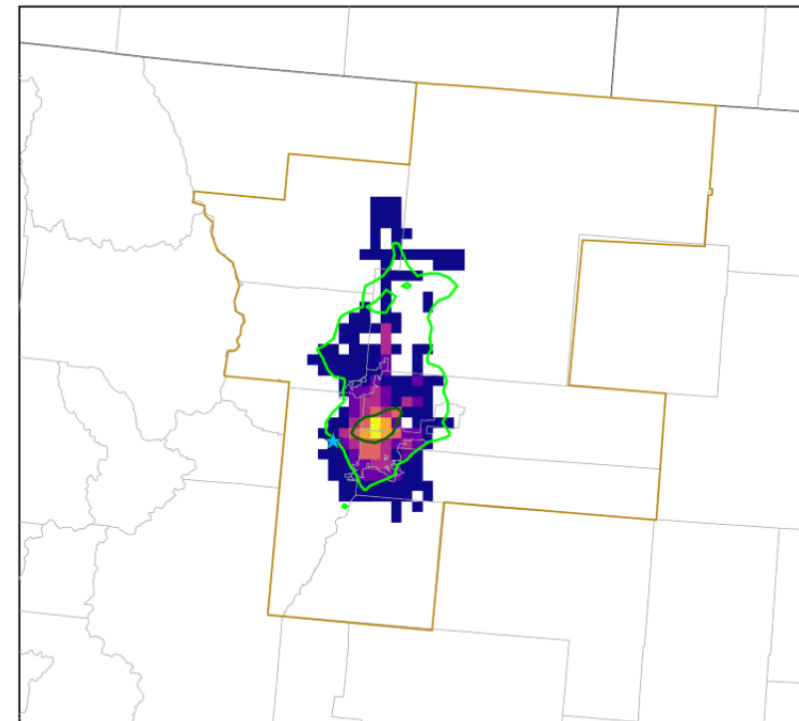
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Emissions

Denver NAA 2026 Episode NOx Emissions
On-road Mobile



NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
On-road Mobile - NOx

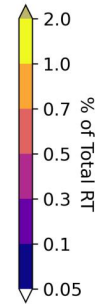
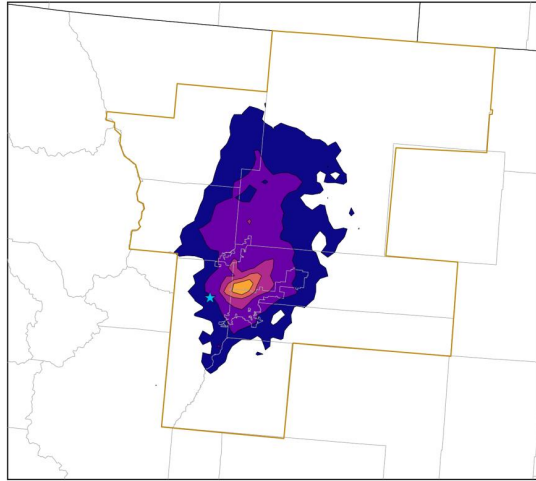


Contour indicates AOI with Residence Time $>$ 0.5%
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WEP is the product of RT and 2026 VOC or NOx emissions and is presented as a percent of the total anthropogenic WEP across all grid cells. The contours identify where RT $>$ 0.5% and 0.1%.

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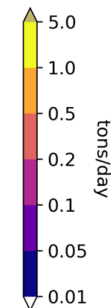
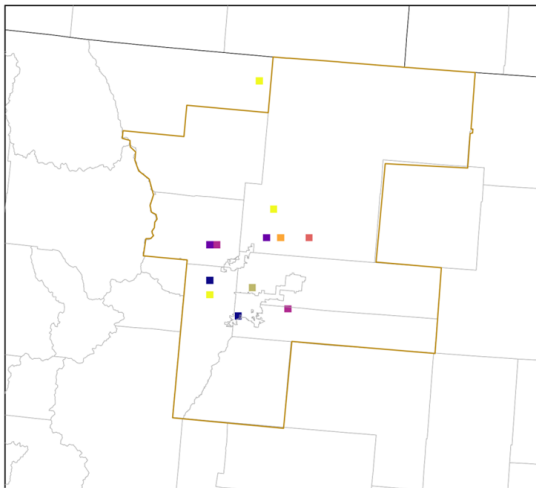


RT

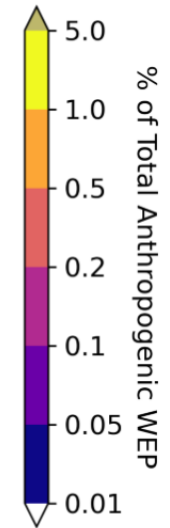
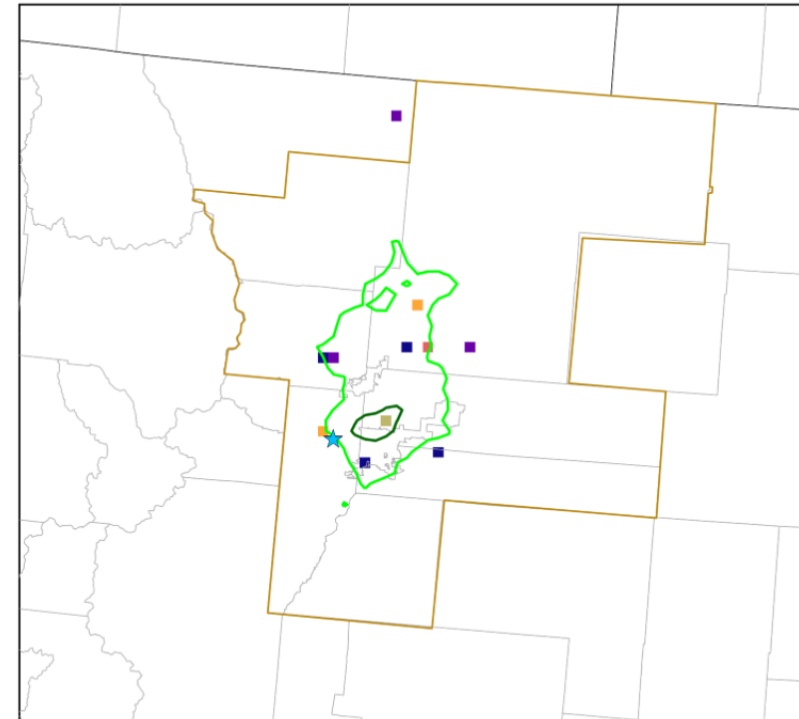
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Emissions

Denver NAA 2026 Episode NOx Emissions
EGU Point



NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
EGU Point - NOx

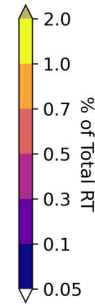
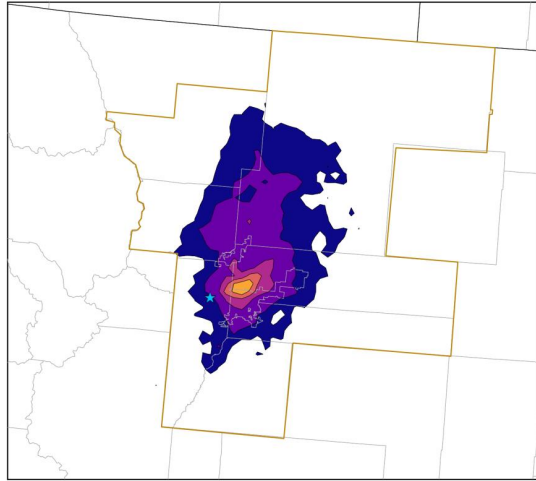


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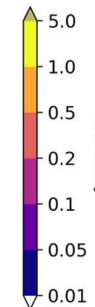
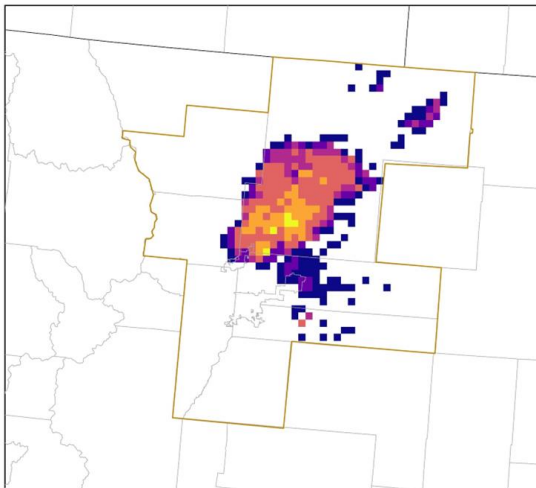


RT

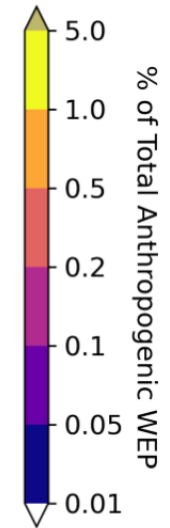
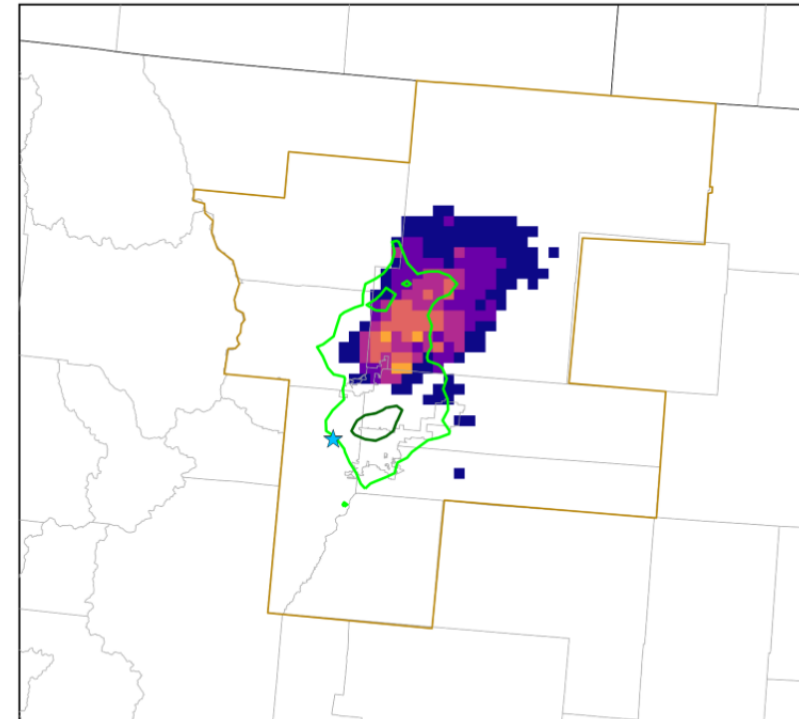
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Emissions

Denver NAA 2026 Episode VOC Emissions
O&G Area



NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
O&G Area - VOC



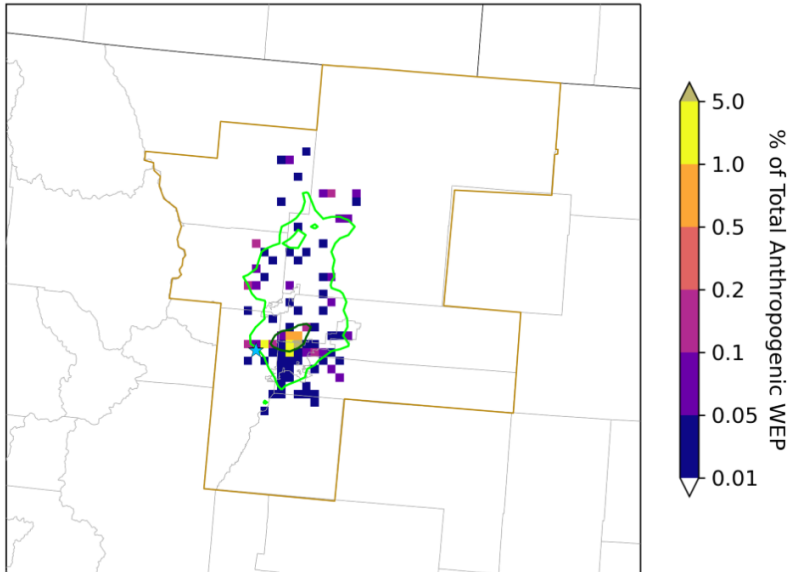
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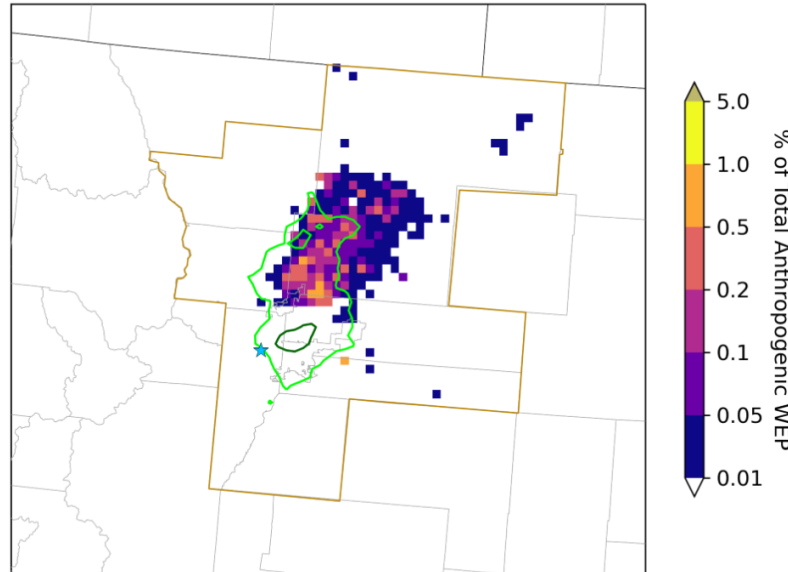
- WEP plots are normalized by total anthropogenic WEP and so percent contributions of different source sectors in the NAA can be directly compared

NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Non-EGU Point - NO_x



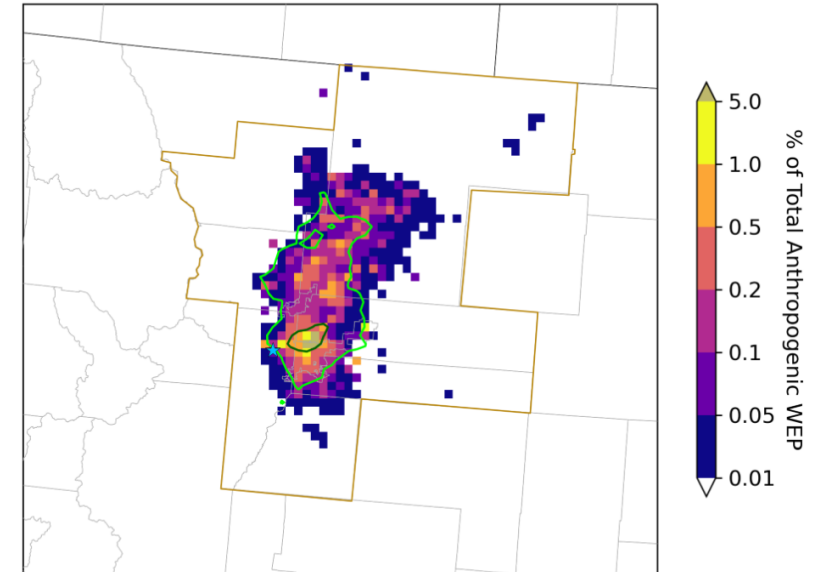
Contour indicates AOI with Residence Time > 0.5%
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NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NO_x



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NREL - 2016-2022 - 163 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total Anthro - NO_x

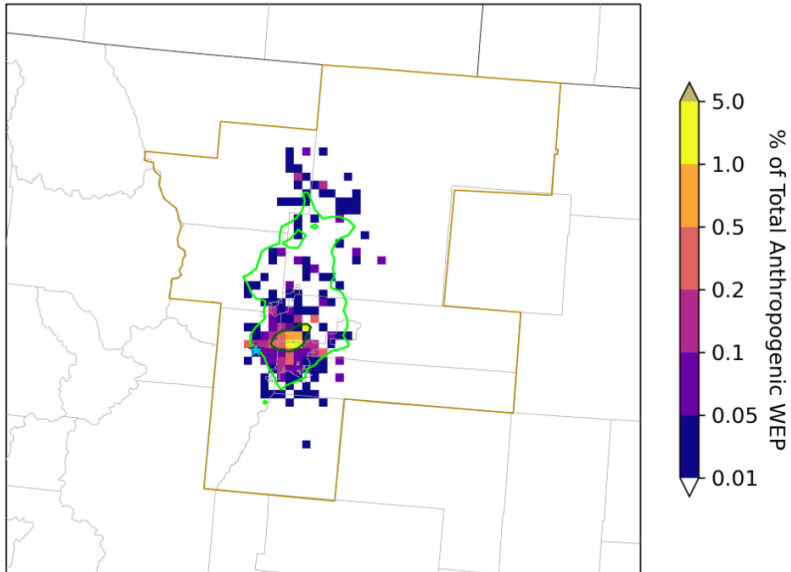


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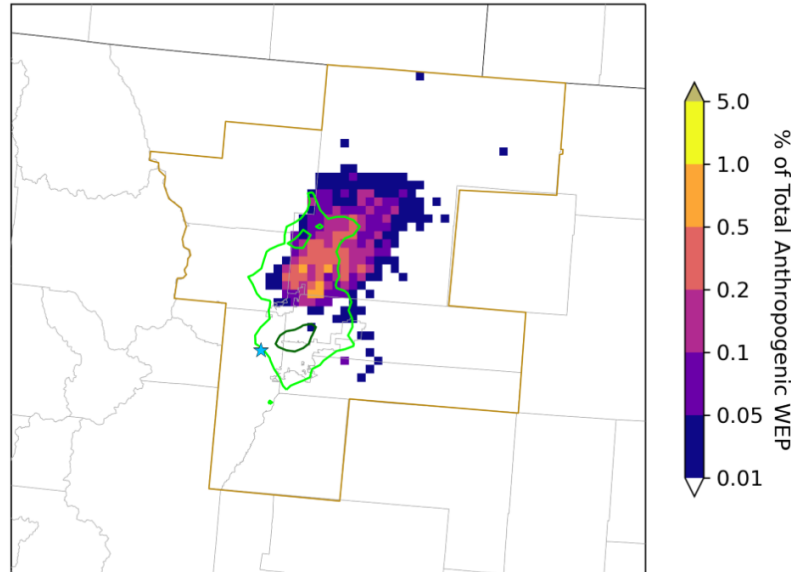
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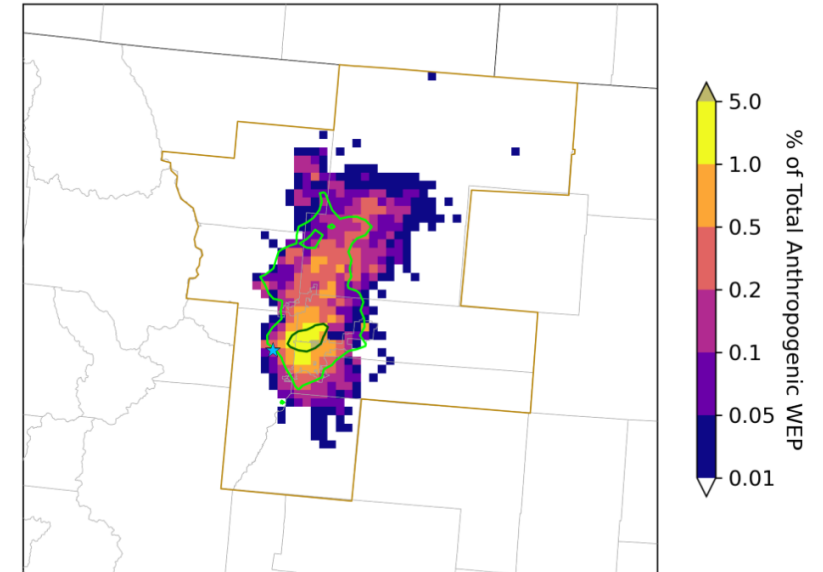
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Total O&G - VOC



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Total Anthro - VOC

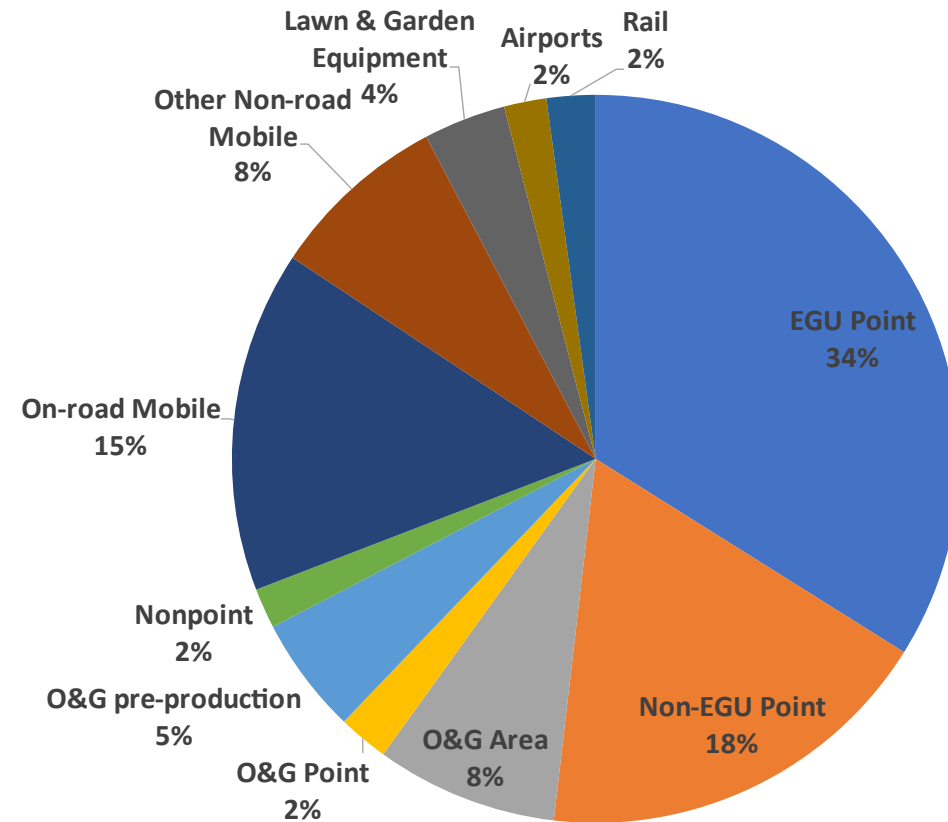


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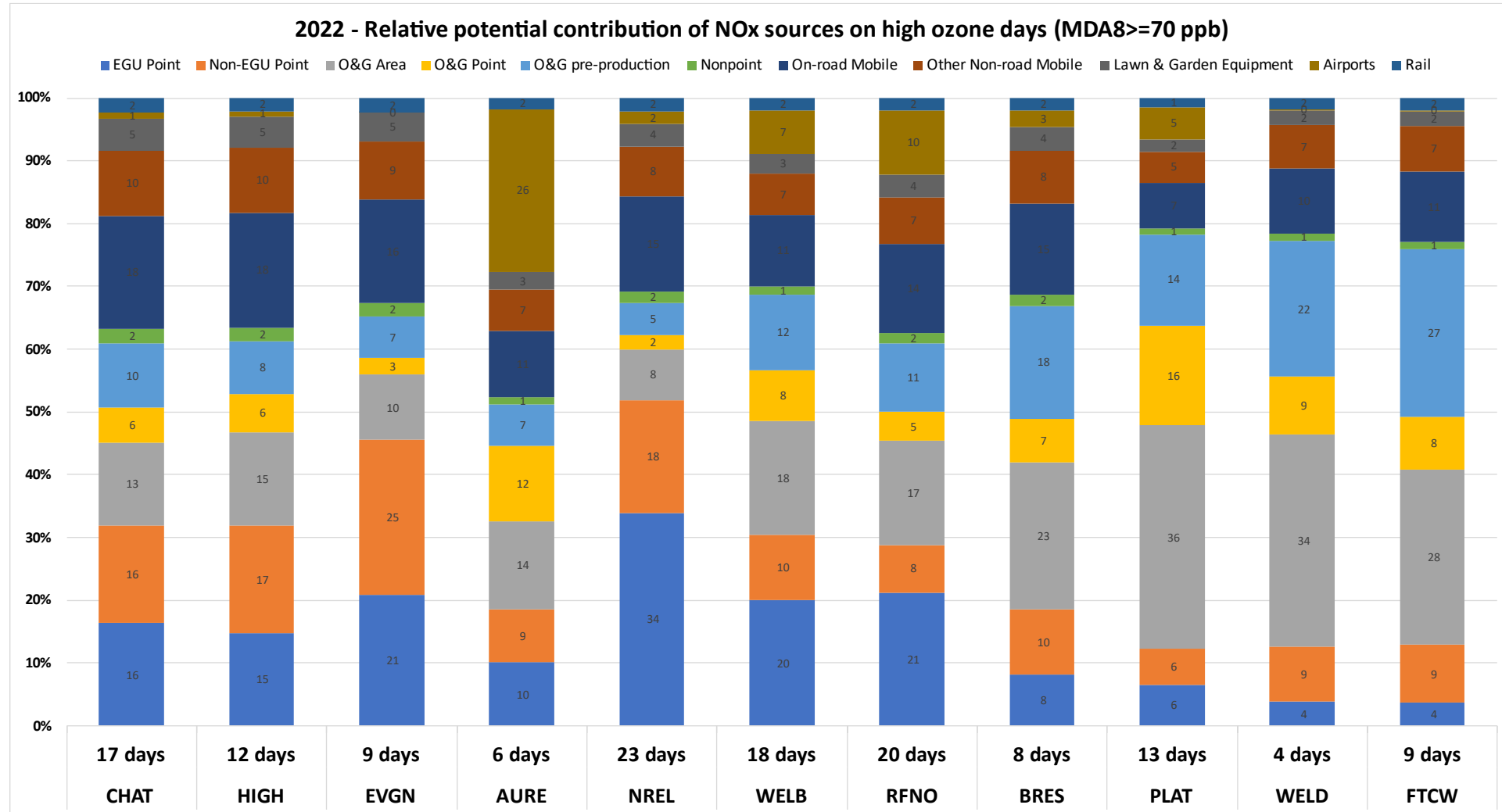
Potential Source Contribution (PSC) Analysis

- Potential source contributions are estimated summing the WEP for each source sector/region across the analysis domain
- It shows the potential contribution of each source sector relative to the total anthropogenic contribution
- WEP and PSC are estimated for the 2026 OTB base case emissions
- An evaluation of potential control scenarios will also be performed to assess potential impacts of strategies once they are more clearly defined

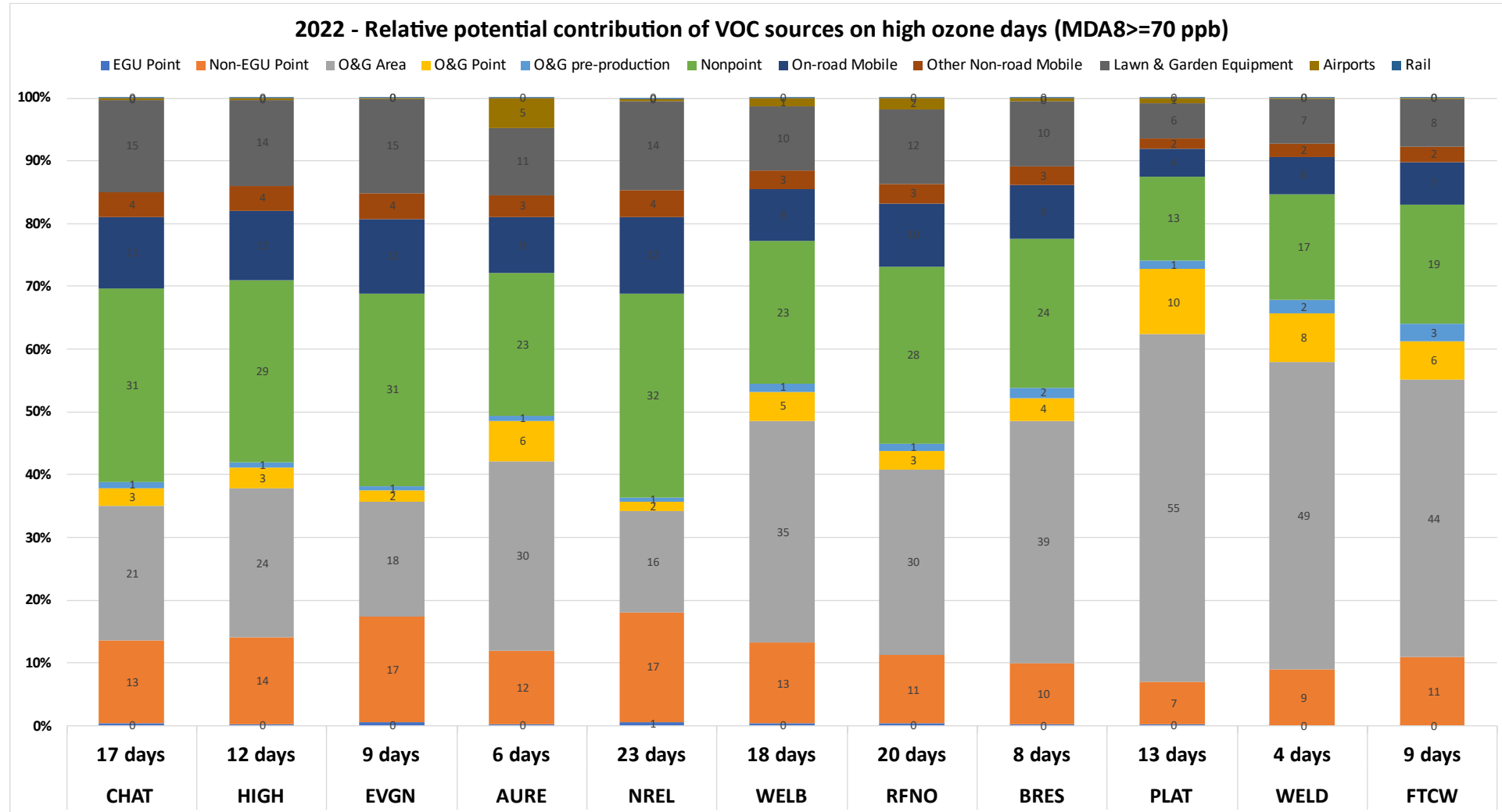
2022 NREL - Relative potential contribution of NO_x sources on high ozone days (MDA8 ≥ 70 ppb) - 23 days



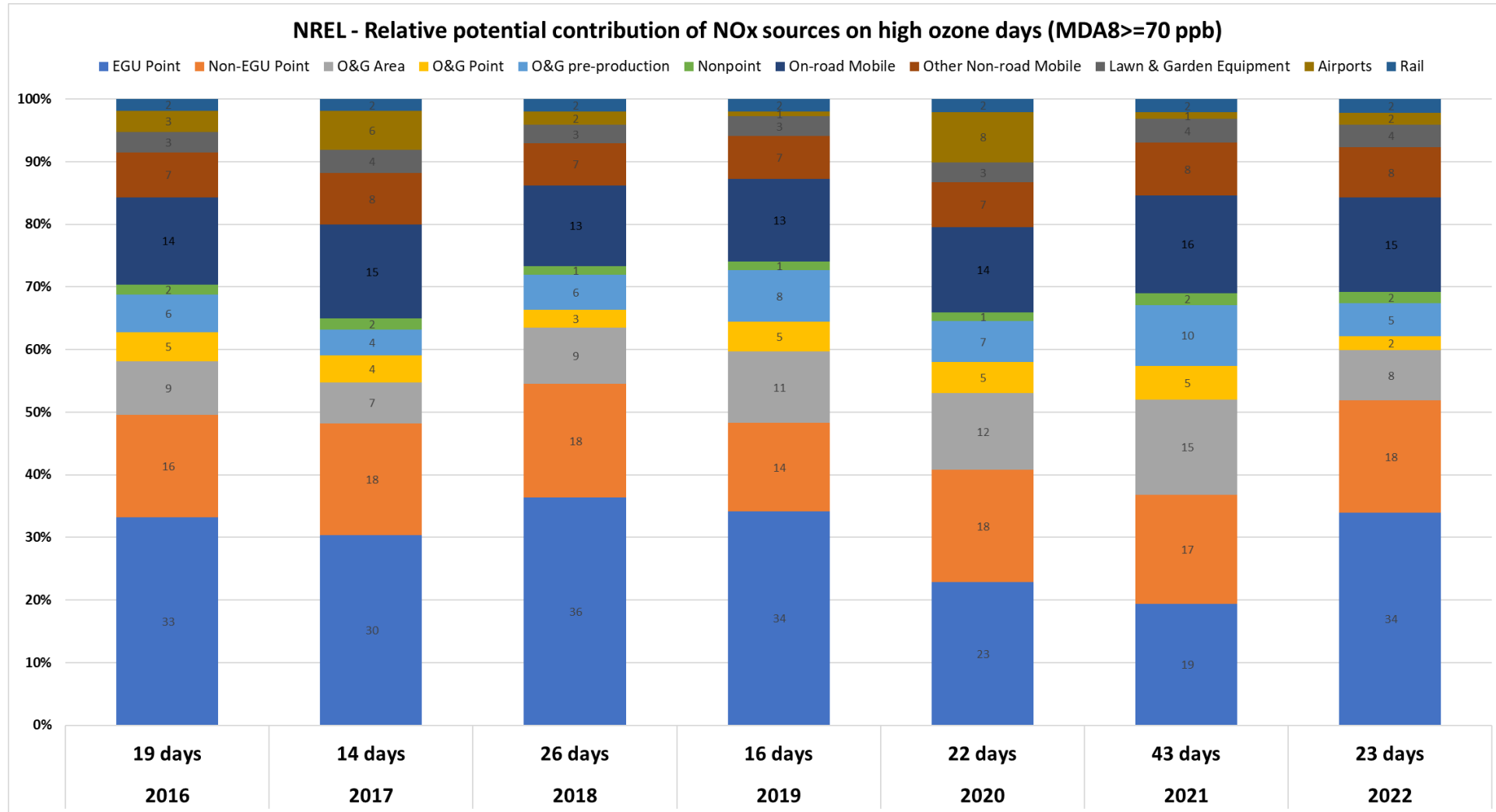
PSC 2022 Initial Results: Variation Across Sites - NOx



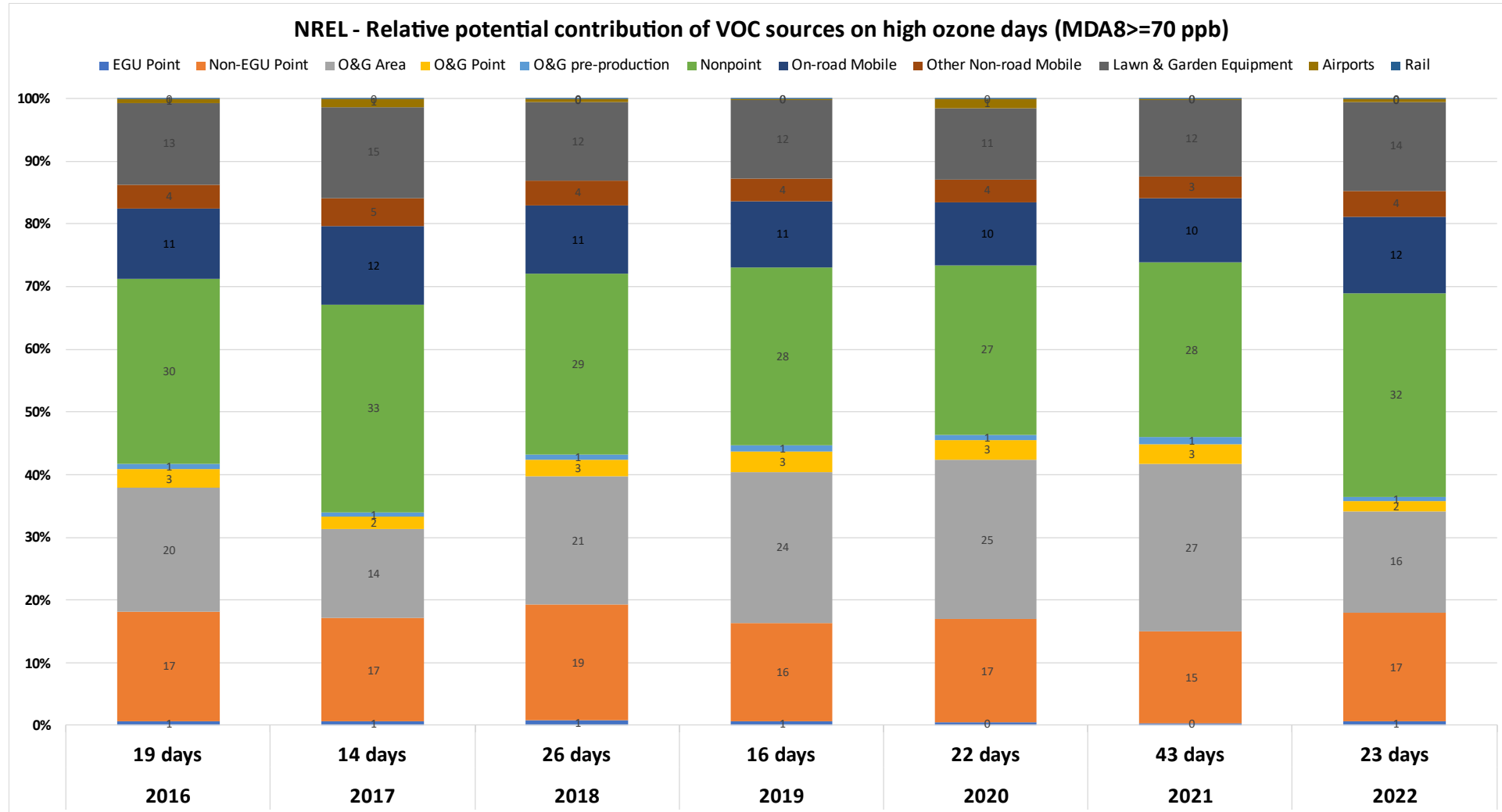
PSC 2022 Initial Results: Variation Across Sites - VOC



PSC NREL Initial Results: Variation Across Years - NOx

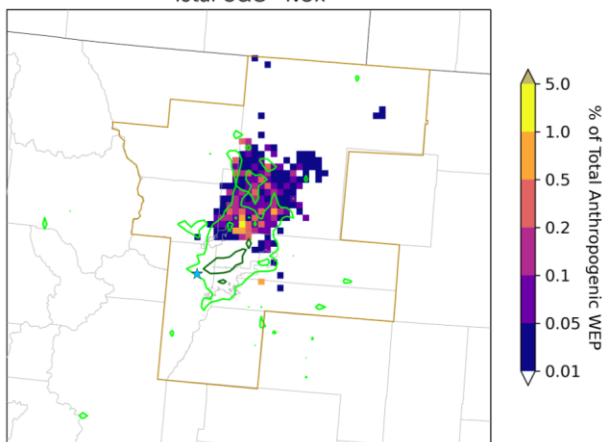


PSC NREL Initial Results: Variation Across Years - VOC



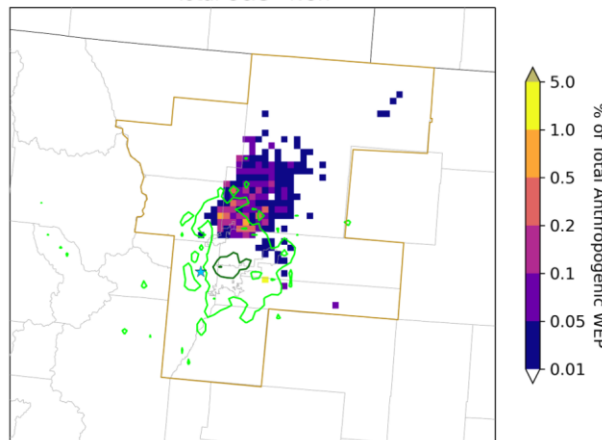
WEP NREL Total O&G NOx: Variation Across Years

NREL - 2016 - 19 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NOx



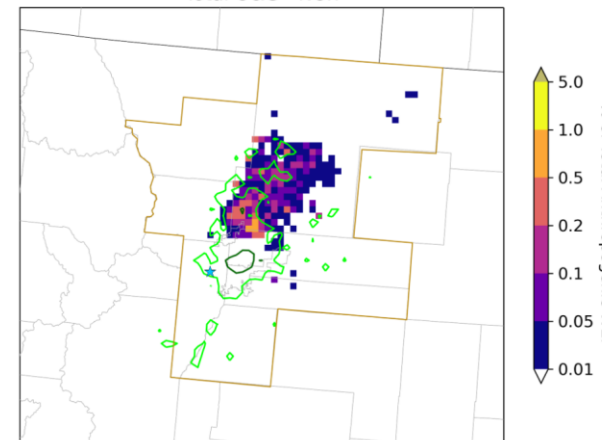
Contour indicates AOI with Residence Time > 0.5%
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NREL - 2017 - 14 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NOx



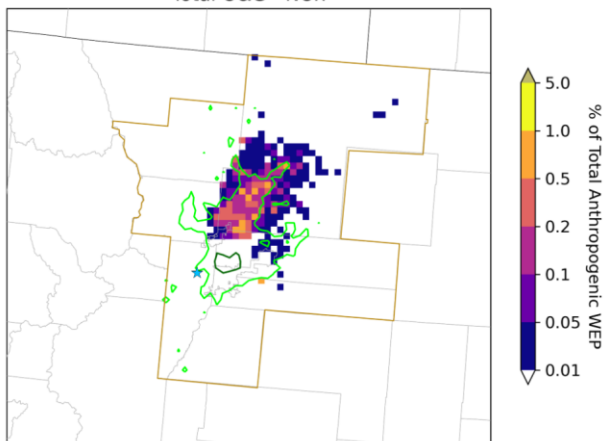
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NREL - 2018 - 26 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NOx



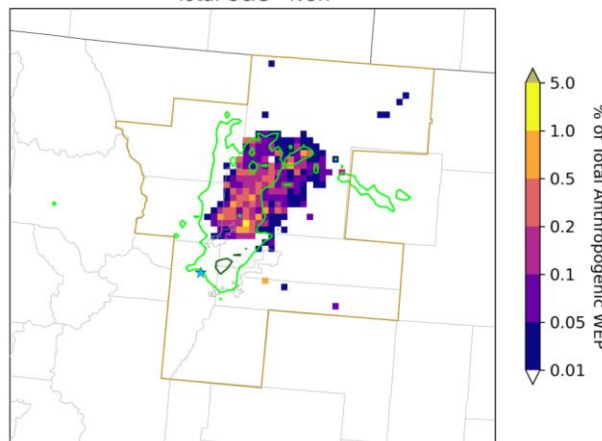
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NREL - 2020 - 22 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NOx



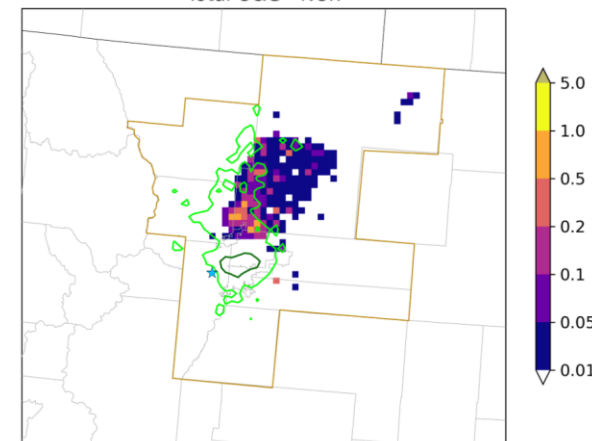
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NREL - 2021 - 43 days \geq 70 ppb - All heights
CWRT Weighted Emissions Potential
Total O&G - NOx



Contour indicates AOI with MDA8 Concentration Weighted Residence Time > 0.5%
Contour indicates AOI with MDA8 Concentration Weighted Residence Time > 0.1%

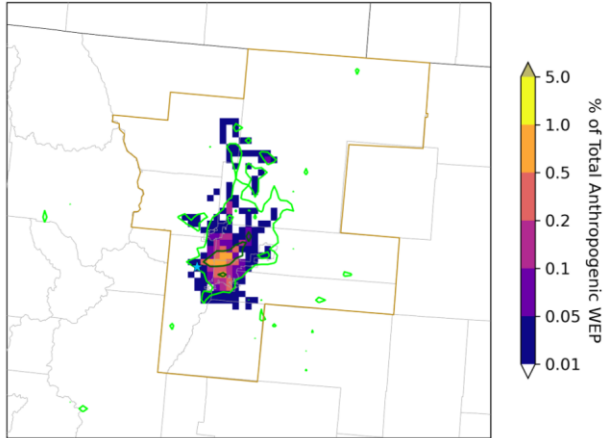
NREL - 2022 - 23 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
Total O&G - NOx



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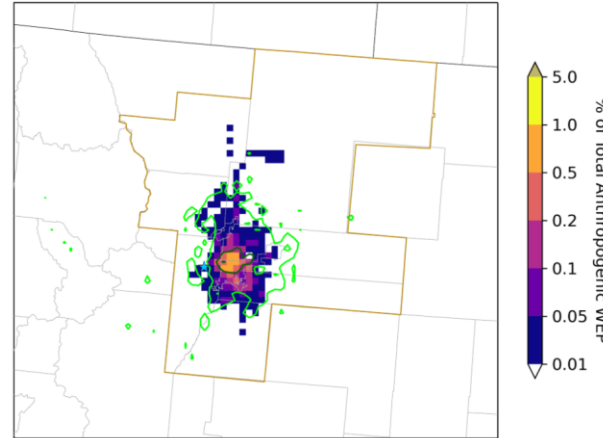
WEP NREL On-Road Mobile NOx: Variation Across Years

NREL - 2016 - 19 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
On-road Mobile - NOx



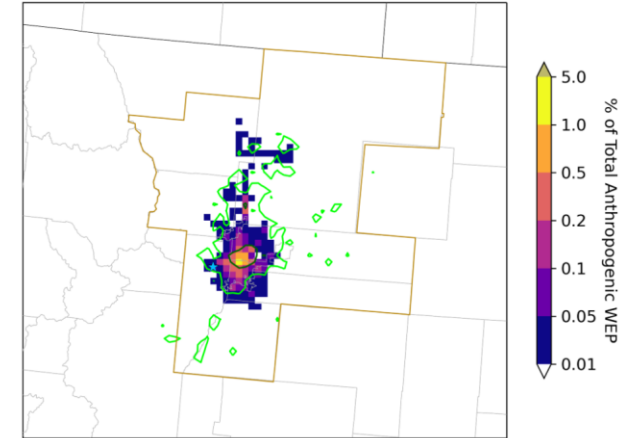
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NREL - 2017 - 14 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
On-road Mobile - NOx



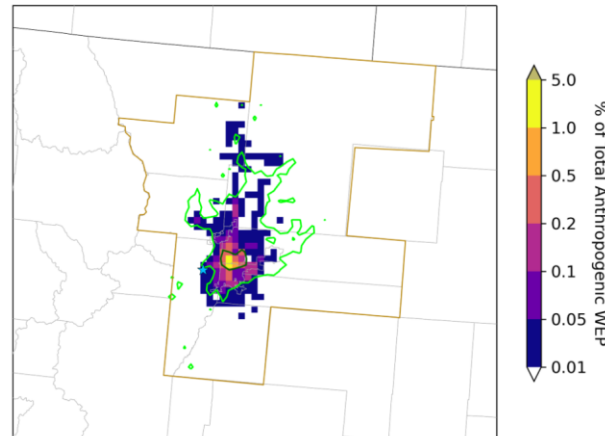
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NREL - 2018 - 26 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
On-road Mobile - NOx



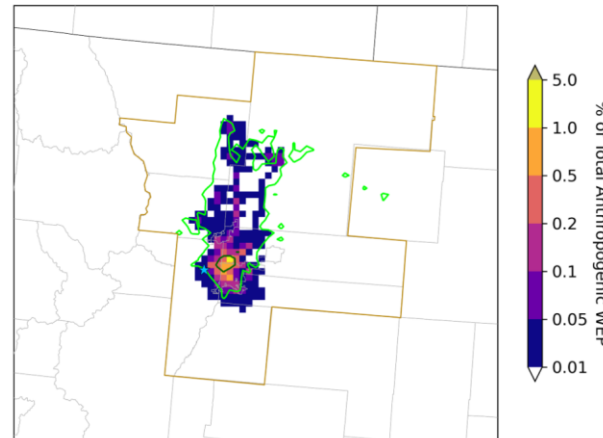
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On-road Mobile - NOx



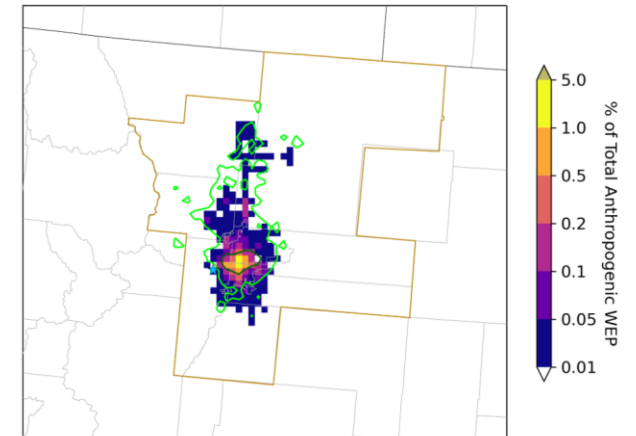
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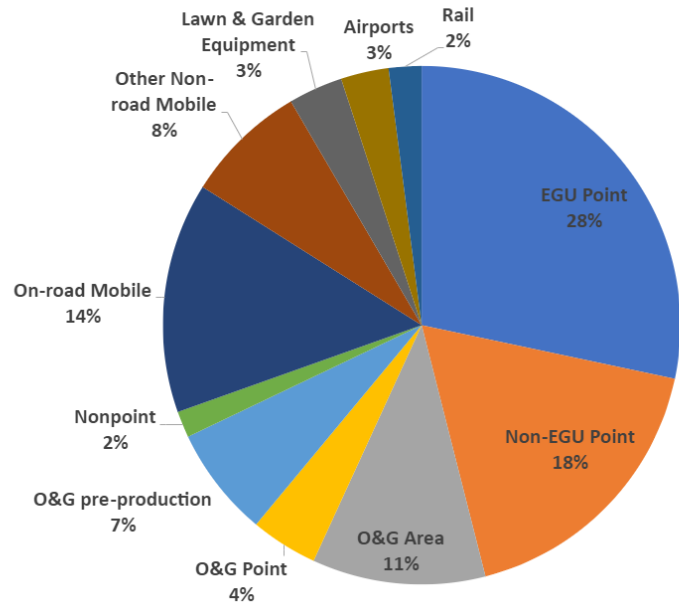
NREL - 2022 - 23 days \geq 70 ppb - All heights
RT Weighted Emissions Potential
On-road Mobile - NOx



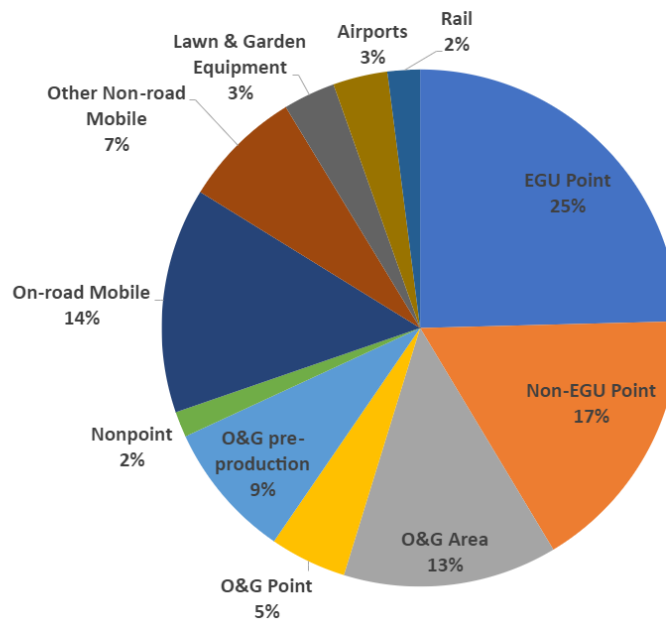
Contour indicates AOI with Residence Time > 0.5%
Contour indicates AOI with Residence Time > 0.1%

PSC NREL NOx: Variation MDA8 Ozone (71, 76 and 80 ppb)

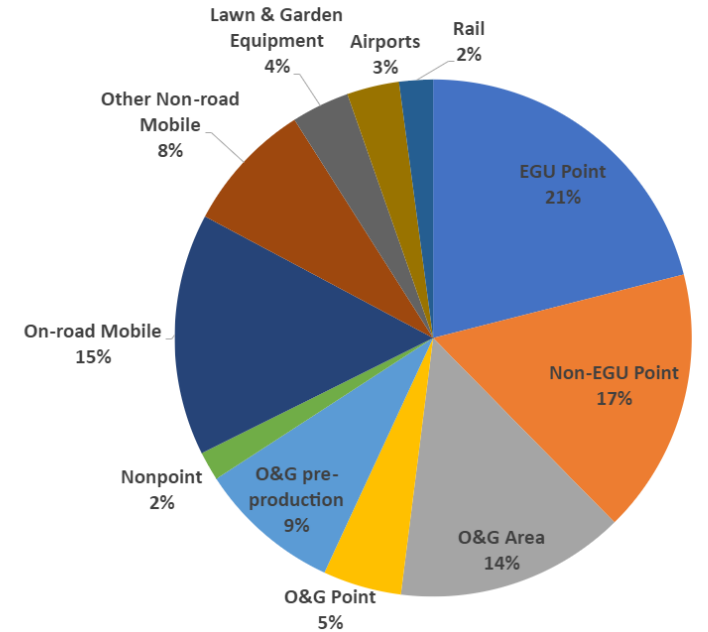
NREL - Relative potential contribution of NOx sources on high ozone days (MDA8 >= 71 ppb) - 150 days



NREL - Relative potential contribution of NOx sources on high ozone days (MDA8 >= 76 ppb) - 74 days



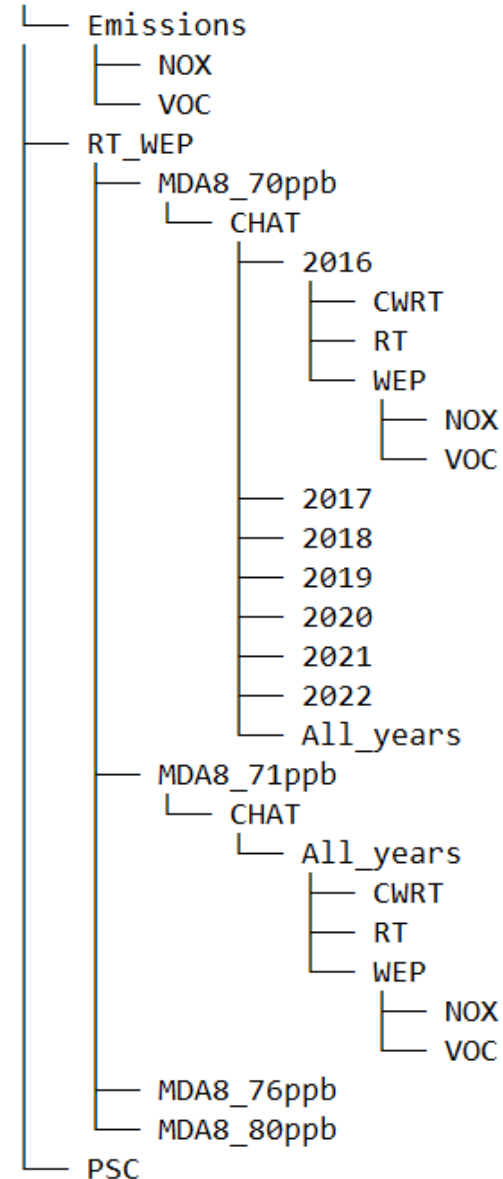
NREL - Relative potential contribution of NOx sources on high ozone days (MDA8 >= 80 ppb) - 42 days



Summary of Deliverables

- Website with methodology descriptions and results
- Maps of emissions, residence time and weighted emissions potential
- Pie charts and tables from the potential source contribution analysis
- Excel dashboards that will allow for subsequent analysis
- Shapefiles of residence time and WEP results

Example of directory tree



Number of products

- 28 emissions maps
- 436 RT plots
- 436 CWRT plots
- 2834 RT-WEP plots
- 2834 CWRT-WEP plots
- 4 PSC spreadsheets

Next Steps and Schedule

- Continue analysis for different MDA8 thresholds and without days flagged for wildfire smoke
- Evaluate potential control scenarios to assess potential impacts of strategies once they are more clearly defined
 - Evaluate 2026 NO_x/VOC control strategy effectiveness for reducing NO_x and VOC emissions that are transported to monitors arriving at times of observed high ozone in 2016-2022
- Present to EPA Emission Inventory Conference (September 28)
- Present to the A&WMA Rocky Mountain Section Meeting (November 2)
- Publish results on website (draft version in November)