LARIMER COUNTY | BOARD OF COUNTY COMMISSIONERS

P.O. Box 1190, Fort Collins, Colorado 80522-1190, 970.498.5700, Larimer.gov

Environmental and Science Advisory Board
MINUTES

Date: March 10, 2026

Time: 6:00 – 9:00 p.m.

Location: virtual only

Contact: Heidi Pruess, pruesshb@co.larimer.co.us , 970-498-7138

MEMBERS		STAFF		GUESTS
Rodger Ames	V	John Kefalas *	V	Elizabeth Relford, NFRMPO
Tasha Carr - Chair	V	Heidi Pruess ¥	V	Andrey Marsavin, CSU
Anna Cloud		Kristen Stephens	V	Jeff Collet Jr, CSU
Jeremy Cooper		Jody Shadduck-McNally	V	Howard Gebhart, AQAB
Leo Grassens - Vice Chair	V	Lea Schneider	V	Adam Schmidt, AQAB
Matthew Haag	V			Christina Swope, AQAB
Azmal Hossan				Tom Moore, RAQC
Kathryn Inman	V			Daniela Guevara, CSU
Joe Izaguirre III				Dan Welsh, AQAB
Michael Lee Jones	V			Jared Stickney, CSU
Jared McGlothlin	V			Maria Moore, AQAB
Nicole Poncelet-Johnson	V			Mark Houdashelt, AQAB
Cathelyne Powers	V			Michael Johnson, AQAB
Chris Wood	V			Selina Lujan, Fort Collins AQAB Liaison

X = present; v= present virtually; * = Commissioner Liaison; ¥ = ESAB Liaison; § = Climate and Sustainability Program; ʸ=Youth.

Call to Order: 6:00 p.m.

- **Introduction of members, staff and guests**
- **Discussion Items -** Presentation by Andrea Marsavin and Jeff Collet Jr from the Atmospheric Science Department at Colorado State University, “Ozone and precursors in Larimer County: first results from the Front Range Ozone Experiment (FROZE)”. (see attached presentation)
    - Summary and Conclusion from presentation (slide 38) included:
        - “Ozone in the Front Range results from a complex mixture of precursor emission sources, unique meteorology, and background influence

- Summer 2025 turned out to be a relatively low ozone year, due to favorable meteorology and lower background influence. 23 NAAQS exceedance days were observed
- Ozone accumulation in the foothills of Larimer Co. is associated with southeasterly transport
- Long-term trend analysis suggests that ozone production is shifting towards stronger NOx-sensitivity: continued NOx emission reductions will be essential for ozone reduction
- Conditions in Fort Collins/Larimer Co. are more NOx-sensitive than in Denver so NOx emission reductions are more effective here than in Denver
- Ongoing analysis will employ box modeling and statistical tools (PMF) to understand precursors sources and source-specific impacts on ozone production"

- Questions and Answers included:
  - What's an "average ozone number" for a "healthy city"? If 40 is our baseline and 70 is high? We have 40-60 ppb of background ozone. Yes 40 is about our baseline with health impacts beginning around 60 ppb. Polluted high ozone areas will have ozone levels at 70 ppb or higher.
  - How do temperature inversions interact with these upslope wind dynamics? Inversion is early morning or late at night when the boundary layer is low. You can still have a temperature inversion in the plains early in the morning, and a lot of these ozone precursors tend to collect there and pool there, but as the sun comes up and drives up that thermal circulation, that inversion is going to dissipate, and the upslope flow will prevail. Wintertime has the most significant inversions but
  - Could you comment on the background ozone level without any human sources, such as in Antarctica? Antarctica may have a background ozone level of 30 ppb which can be explained by the troposphere having about 10% ozone and when it mixes down into the stratosphere we see about that 30 ppb as a global average background level.
  - Does our higher elevation (above 5000 ft) and more UV contribute to the formation of Ozone? Was that included? Yes and this is one of the reasons why we struggle with a higher level of background ozone. Clean air quality days in Fort Collins are 45-47 ppb which varies from Denver metro at 51 ppb and LaSalle at 31 ppb.
  - Have you mapped dairies and other CAFO's in Weld County? Elevated emissions in Weld County are correlated to the high quantity of O&G and heavy-duty diesel trucks with local emissions mattering quite significantly. CAFOs aren't typically viewed as a large source of ozone precursors.
  - What VOC comes from wildfire smoke? Alkanes are mainly oil and gas sources. Mostly shows up in the alkenes and ethyne categories but wildfire smoke really varies based on the age of the smoke and how close you are to the fire. Fires emit all sorts of compounds but they react really quickly too. If we get long-range transport of smoke we will actually see very little enhancement of the VOCs that are shown in these graphs but we would see a lot of oxidized VOCs (like formaldehyde). Smoke episodes locally have a large impact and those from long-distance have less of an impact.

- Are you saying we have saturated NOX in the atmosphere? Or we have "undone" NOX saturation? Ozone's sensitivity to NOX has very likely changed over the past two decades due to emission reduction strategies although we have not measured a very clear declining trend in ozone. This suggests that although we have reduced NOx concentrations, we've shifted to a NOX-limited regime that may be accompanied by stronger reductions in ozone if we continue to reduce NOx emissions. The data suggest we have moved from a more VOC limited (Nox saturated) regime to/toward a more NOx-limited regime. Ozone production is most efficient at intermediate NOx/VOC ratios when you can optimally generate the proxy radicals needed to convert NO to NO2 which drives up O3 levels. Here in Fort Collins, we are likely more NOx-sensitive than we are in Denver, and the policy implication of this is that continued NOx emission reductions will likely have a stronger effect on lowering ozone here compared to Denver as well.
- We've put in many control strategies that are very expensive and ozone levels aren't changing very much. Additionally, it appears that we are only able to influence 10 ppb before we hit background levels of ozone so where can we influence policy to give us the best chance of moving the needle? Keep doing what we are doing to further reduce source emissions locally and then working regionally/ multiple states to reduce emissions.
- How was the non compliance boundary determined? 70 ppb was promulgated by EPA in 2015 and the State defined the non-attainment area via measurements collected over that standard. Following a lawsuit regarding the non-attainment boundary, Northern Weld County was added based on the sources in the area, the meteorology, and what monitoring data show, and population. The ozone standard has changed over the year, as EPA has continued to do public health studies and redefine what constitutes an exceedance of ozone. So, as you mentioned, in 2015, it was established as 70 parts per billion. Previous to that, in 2008, it was 75 parts per billion.
- Possible considerations for future discussions included: population growth, vehicle miles traveled increases, Need to discourage car transport on hot days? Need to put a "lid" on dairy sludge? Expand the non-attainment area?
- Is it more influential to limit VOC or NOx? That's a question we are looking to answer and the answer may well vary spatially across the non-attainment area. NOX reductions do appear to have more influence on ozone. Smoke influence may be having more influence as well as VOC to NOx ratio.
- Do you think you have sufficient data from 2025 to do a good job with source "type" apportionment, or do you think this type of monitoring over additional ozone seasons would be beneficial?
- https://raqc.egnyte.com/dl/8GDyBCppWhmf/RAQC_Control_Strategy_Blueprint_Board_endorsed_Nov_2025.pdf_
- If any of your organizations would be interested in partnering/collaborating with the NFRMPO on the upcoming ozone conference, you can reach me at erelford@nfrmpo.org. We will be doing a call for abstracts, and on March 18th you will be able to get more information on our website www.nfrmpo.org.

- **Announcements**
    - Environmental Stewardship Awards : ESAB members reviewed the current award description and nomination form. Suggested expansion and clarification of the award criteria and evaluation process were discussed.
        - The deadline for nominations will be on March 27, 2026.
    - The ESAB has 6 openings accepting applications at this time. Visit https://www.larimer.gov/boards/environmental-and-science-advisory-board
- **Agenda Topics for Future Meetings** – The April meeting will be a working group session.
- **Adjourn** – The meeting adjourned at 7:40 PM.

Ozone and precursors in Larimer County: first results from the **Front Range OZone Éxperiment (FROZÉ)**

Larimer County ESAB meeting
March 10, 2026

Andrey Marsavin[1], Amy Sullivan[1], Jared Stickney[1], Yong Zhou[1], Jihee Ban[1], Daniela Guevara[1], Brandon McGuire[1], Matthew Davis[1], Emily Fischer[1], Jeff Collett[1], Barkley Sive[2], Wade Permar[3], Emily Cope[3], Damien Ketcherside[3], Lu Hu[3], Erick Mattson[4], Alicia Frazier[4], Tom Moore[5]

[1]Department of Atmospheric Science, Colorado State University
[2]Air Resources Division, National Park Service
[3]Department of Chemistry and Biochemistry, University of Montana
[4]Colorado Department of Public Health and Environment
[5]Denver Metro/Northern Front Range Regional Air Quality Council

COLORADO STATE UNIVERSITY

RAQC Regional Air Quality Council

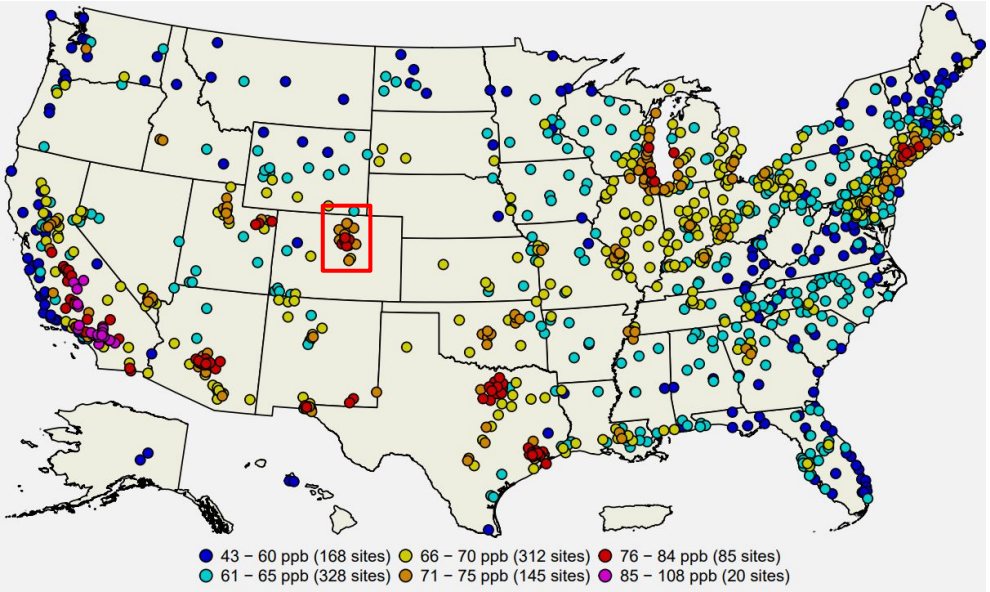
LARIMER COUNTY

UNIVERSITY OF MONTANA

COLORADO Department of Public Health & Environment

Front Range ozone levels rank among the highest in the U.S

2022-2024 O_3 design values:



The O_3 NAAQS is exceeded if the three-year average of the annual 4th highest max. daily 8-h average (MDA8) is over **70** parts per billion by volume (ppbv)

Figure: US EPA

Nonattainment areas for the 2008 EPA O_3 National Ambient Air Quality Standard (NAAQS):

EXTREME
Los Angeles-South Coast Air Basin, CA
Riverside County (Coachella Valley), CA; San Joaquin Valley, CA

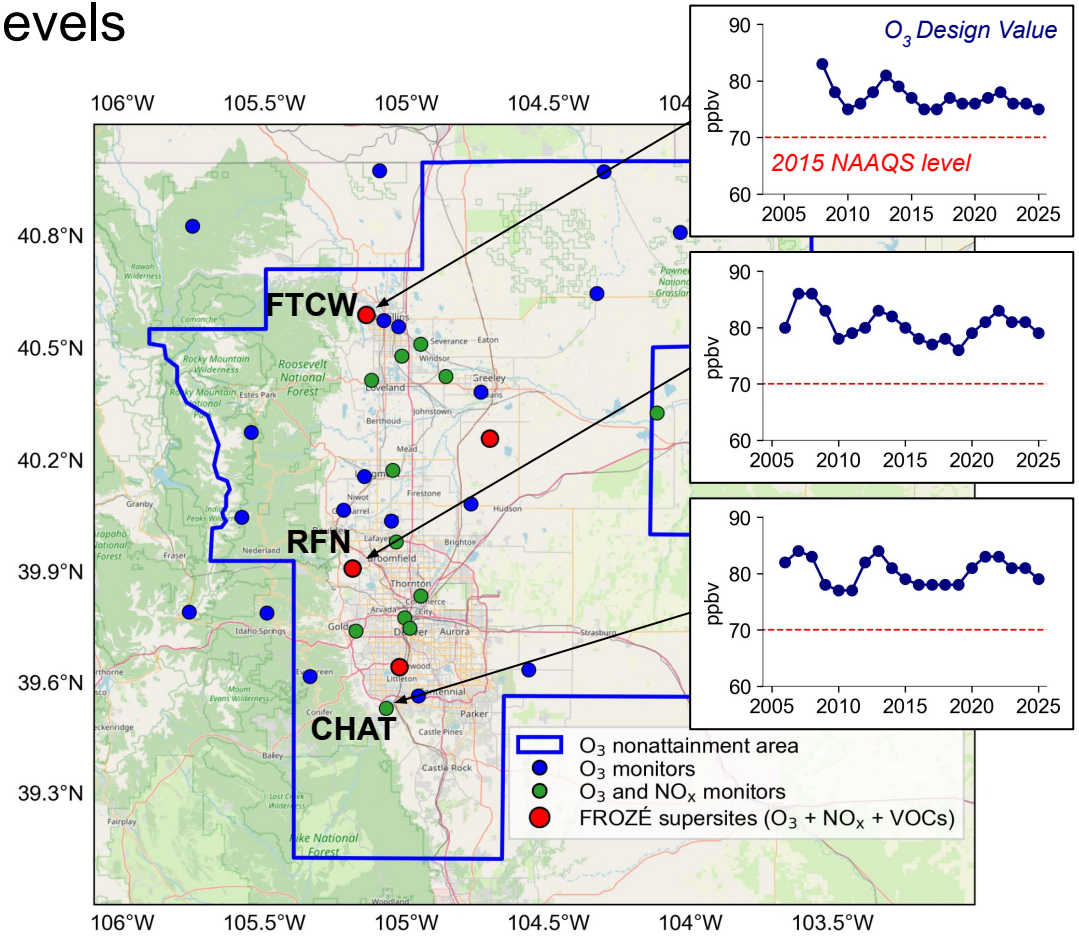
SEVERE
Dallas-Fort Worth, TX
Denver-Boulder-Greeley-Ft. Collins-Loveland, CO
Houston-Galveston-Brazoria, TX; Kern County (Eastern Kern), CA
Los Angeles-San Bernardino Counties (West Mojave Desert), CA
Morongo Band of Mission Indians, CA; New York-N. New Jersey-Long Island, NY-NJ-CT; Sacramento Metro, CA; San Diego County, CA

SERIOUS
Greater Connecticut, CT; Nevada County (Western part), CA
Ventura County, CA

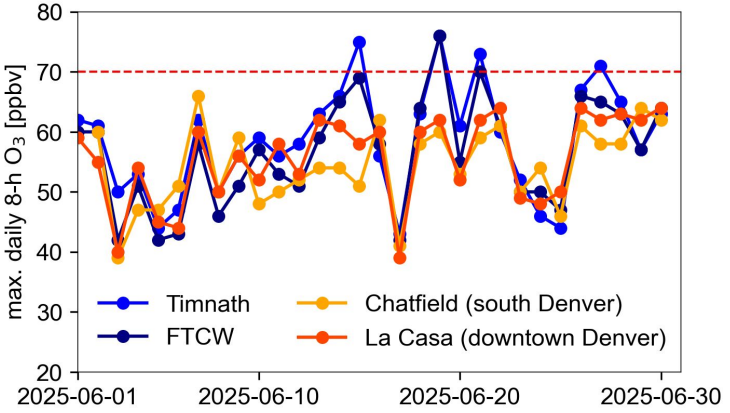
MODERATE
Baltimore, MD; Imperial County, CA; Mariposa County, CA
Pechanga Band of Luiseno Mission Indians of the Pechanga Reservation, CA; Phoenix-Mesa, AZ

MARGINAL
Allentown-Bethlehem-Easton, PA; Calaveras County, CA
Chico (Butte County), CA; Dukes County, MA; Jamestown, NY;
Lancaster, PA; Philadelphia-Wilmington-Atlantic City, PA-NJ-MD-DE
Pittsburgh-Beaver Valley, PA; Reading, PA; San Francisco Bay Area, CA; San Luis Obispo (Eastern San Luis Obispo), CA; Seaford, DE
Tuscan Buttes, CA; Upper Green River Basin Area, WY

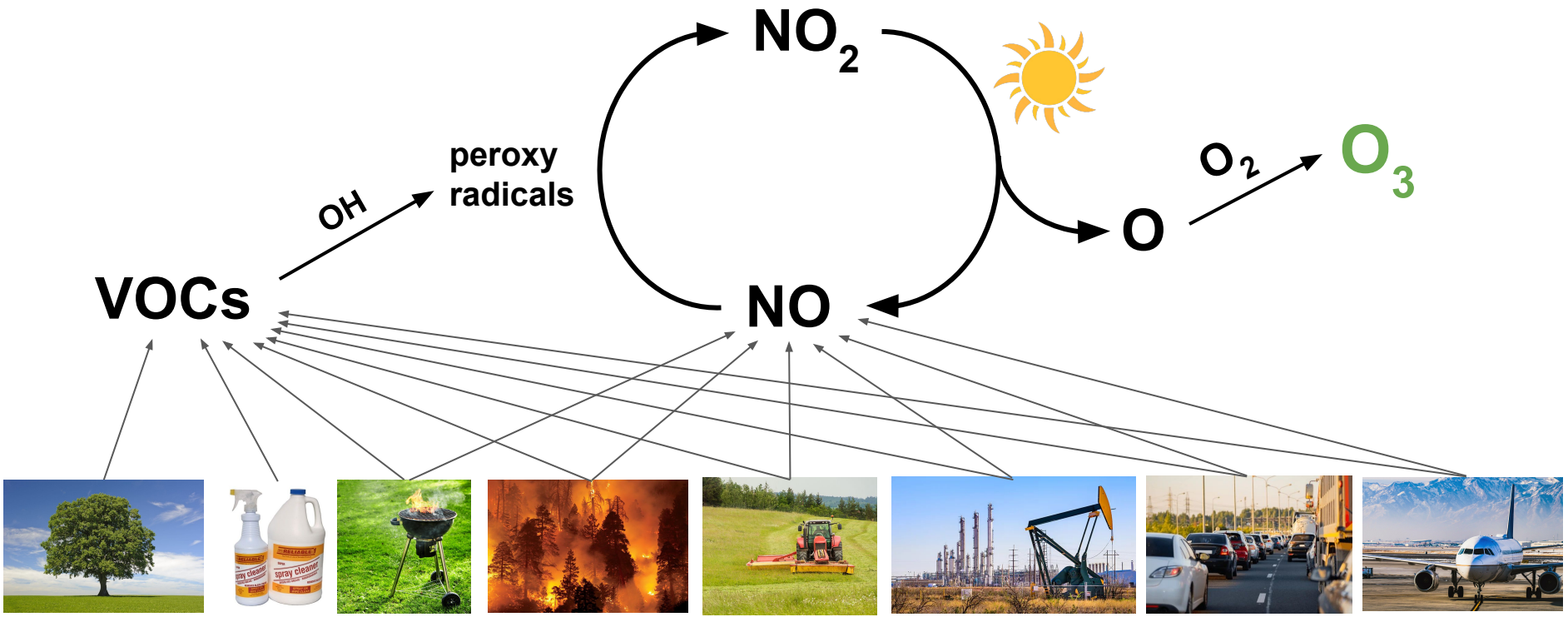
Monitoring sites across the Front Range consistently record high ozone levels



- How different are conditions in Larimer county compared to other high-ozone sites in the Denver Metro Area?

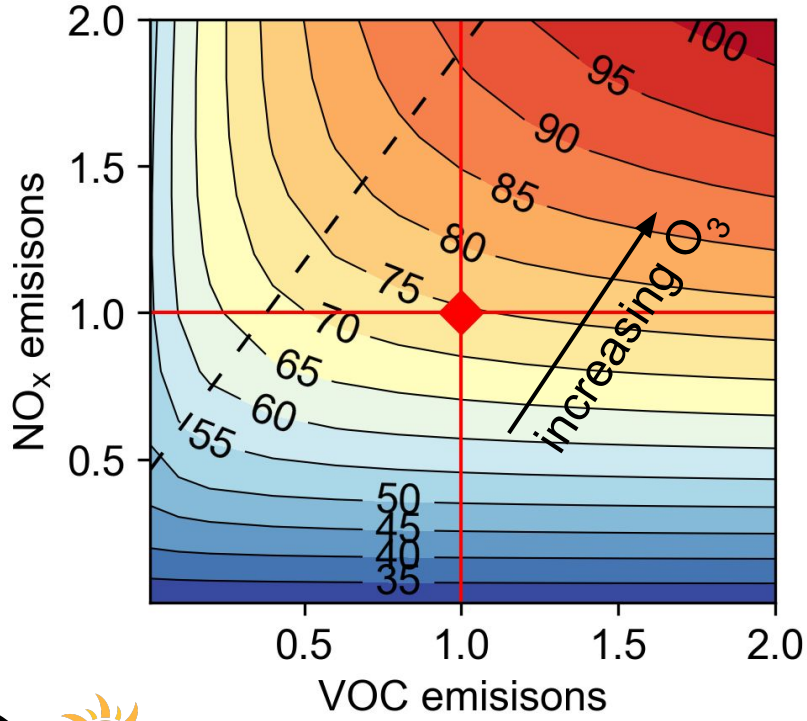


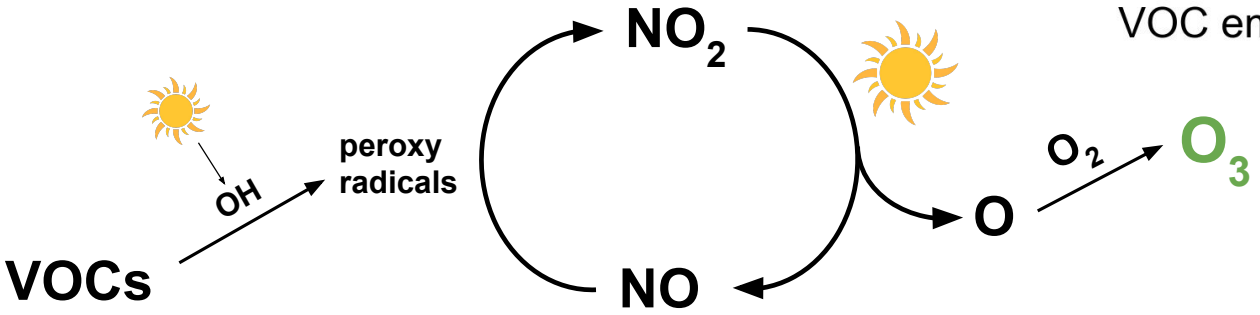
How does ground-level ozone form?



O_3 accumulation depends on:

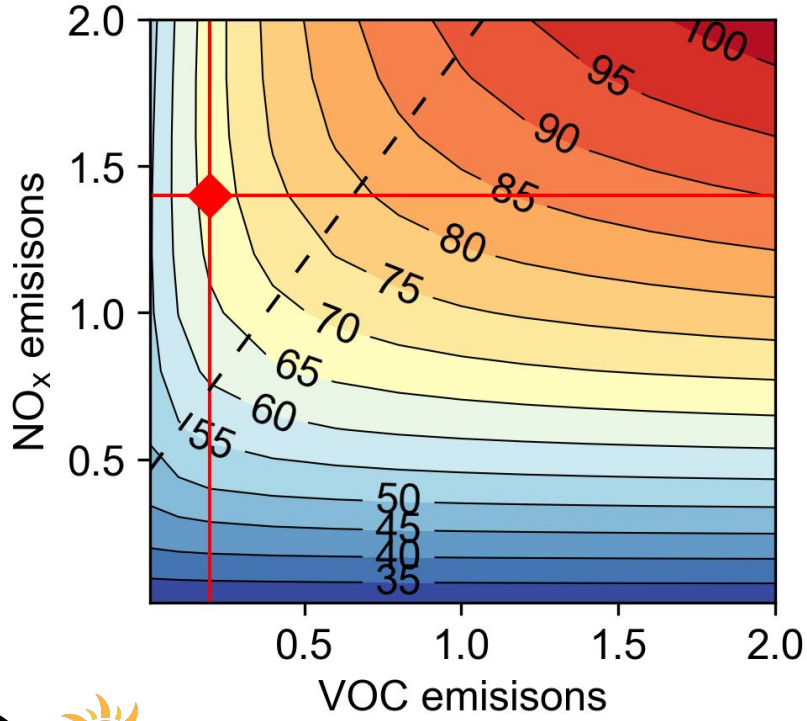
- Solar radiation
- Temperature
- Wind speed and mixed layer height
- **Amount of NO_x and VOCs**
  - NO_x-limited regime:
    - high VOC/NO_x
    - If NO_x emissions increase, O_3 increases

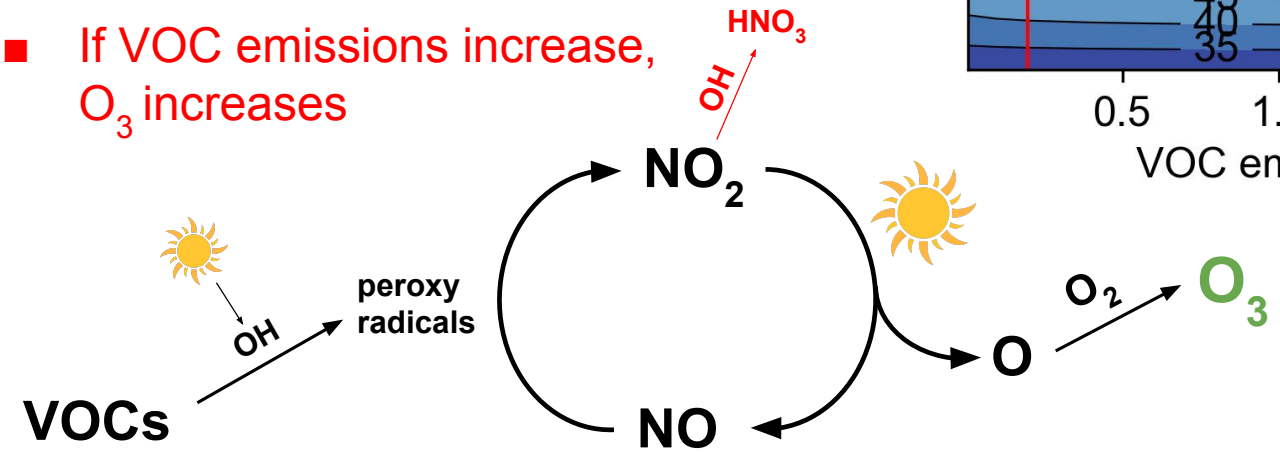




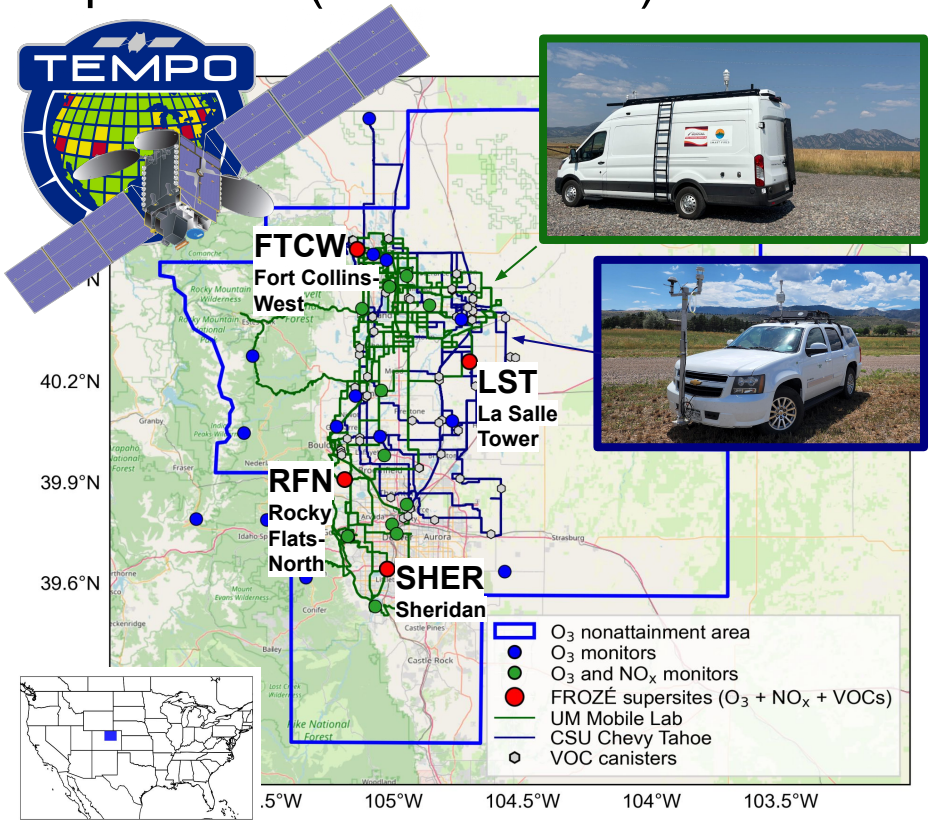
O_3 accumulation depends on:

- Solar radiation
- Temperature
- Wind speed and mixed layer height
- **Amount of NO_x and VOCs**
  - NO_x-saturated (VOC-limited):
    - low VOC/NO_x
    - If VOC emissions increase, O_3 increases





Measurement of ozone precursors during the Front Range OZone Éxperiment (FROZÉ 2025)



- June-August 2025
- Four stationary supersites with O_3, NO_x and on-line VOC measurements
- Mobile measurements
  - **U. Montana Mobile Laboratory**
    - O_3, NO_x, CO, CO_2, methane, VOCs (PTR-ToF-MS)
  - **CSU Chevy Tahoe "Plume Tracker"**
    - O_3, NO_2, CO_2, methane, ethane
- **TEMPO** satellite NO_2 and HCHO
  - 7 special operation days

TEMPO special operations: 10-min scans during FROZÉ

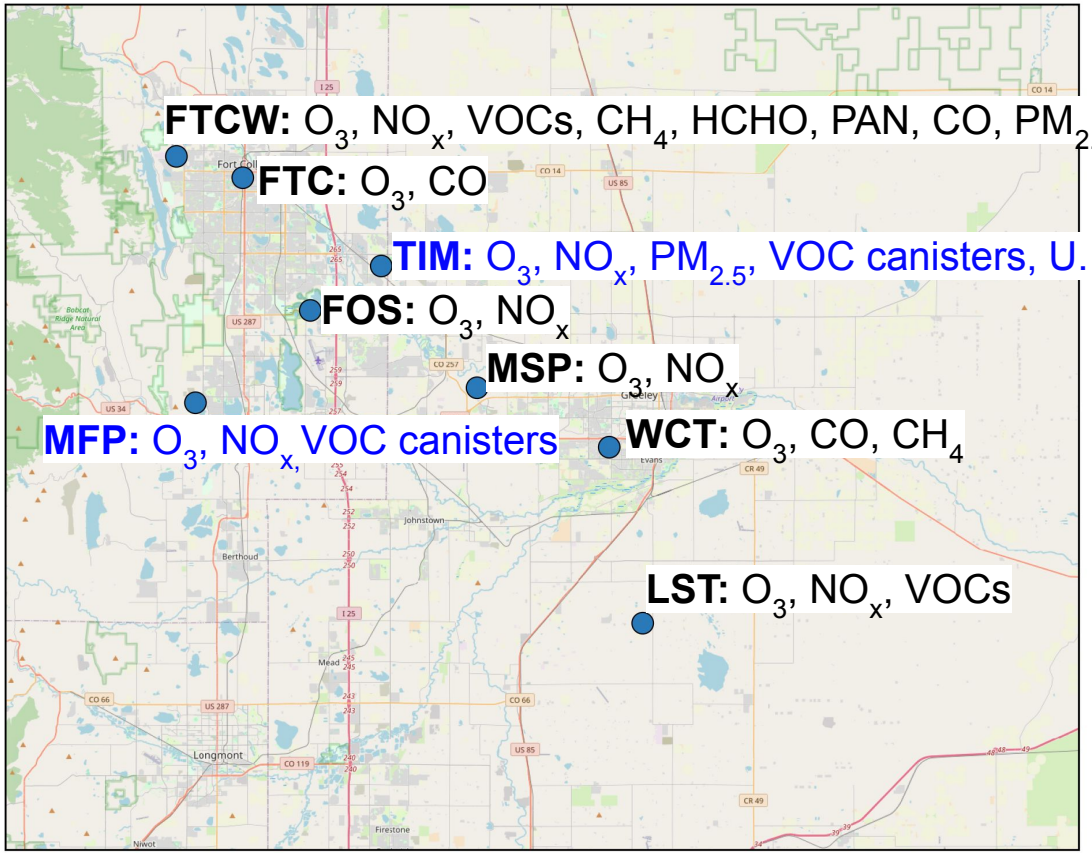
nominal operations July 9, 2025

special operations August 12, 2025

increasing NO_2 →

maps created with:
https://tempo.si.edu/data_for_public.html

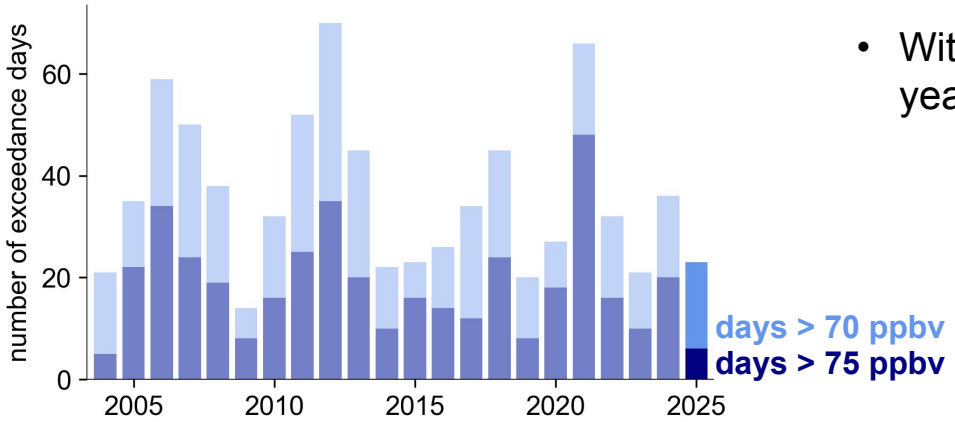
Additional monitoring across Larimer and Weld Counties



Additional Larimer Co. VOC sampling
1-h canister samples collected at **MFP** and **TIM** between 12:00-13:00 MST on select days between July-August 2025

LARIMER COUNTY

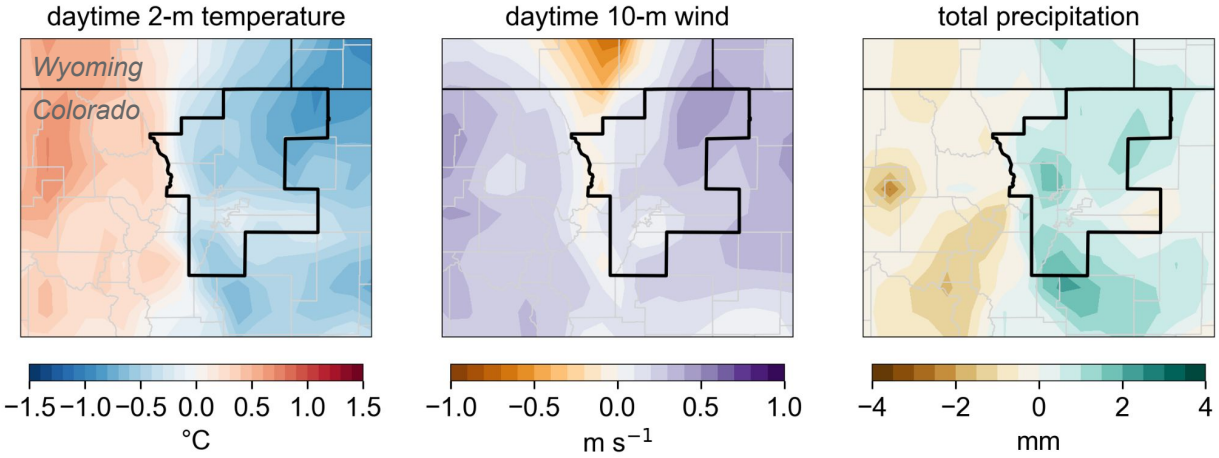
How did 2025 compare to earlier years?



- With 23 exceedances, 2025 was a relatively low-O_3 year for the Front Range

Lower-than-usual ozone in 2025 driven by favorable meteorology

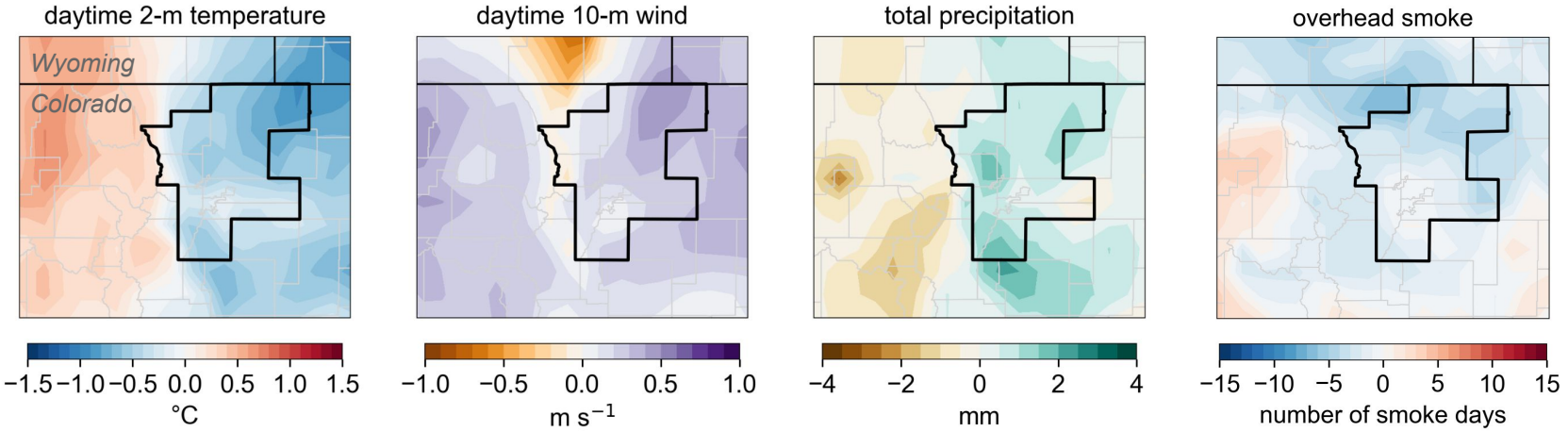
June-August 2025 departure from 2019-2025 mean:



meteorological reanalysis data from ERA5

Relatively low smoke influence in 2025 helped keep ozone levels lower

June-August 2025 departure from 2019-2025 mean:

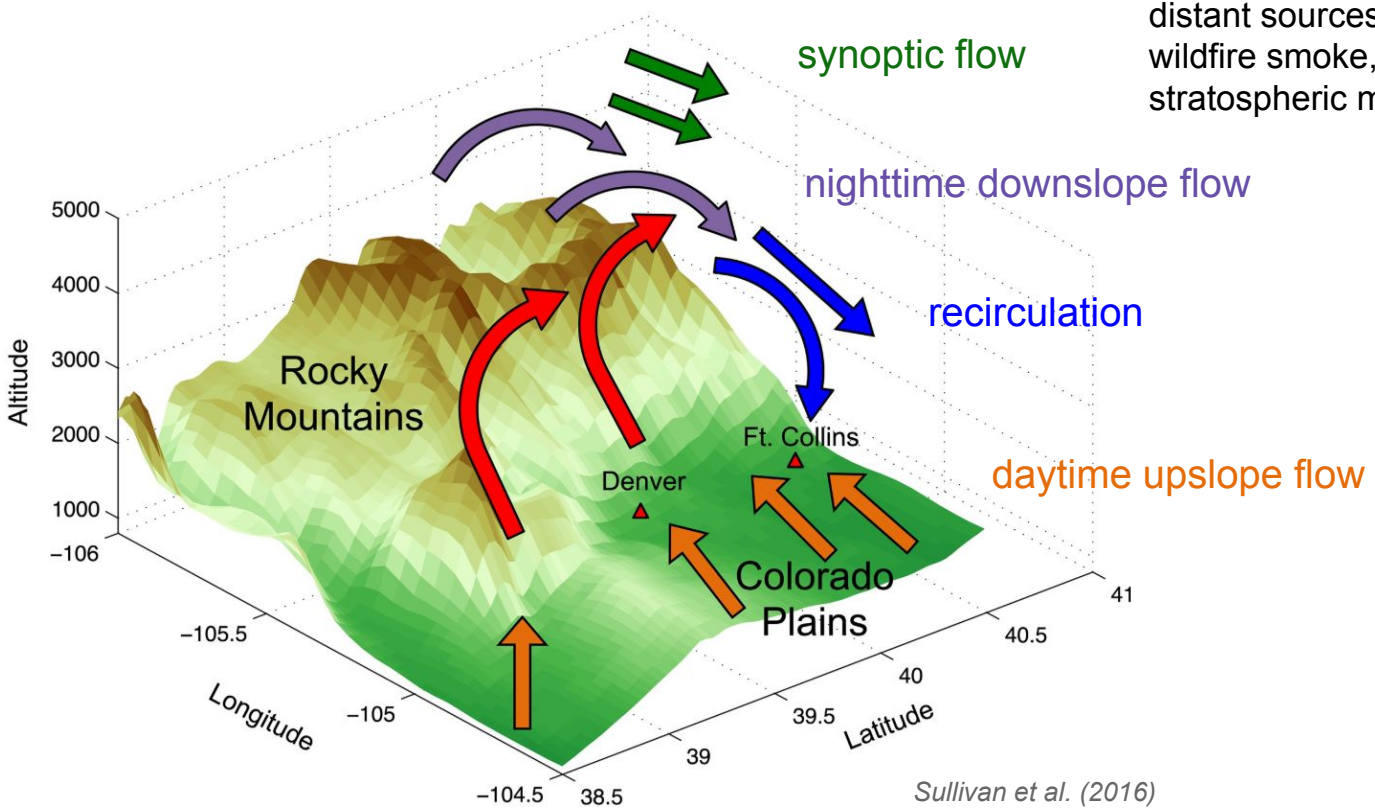


meteorological reanalysis data from ERA5

NOAA Hazard Mapping System (HMS) medium and heavy smoke days

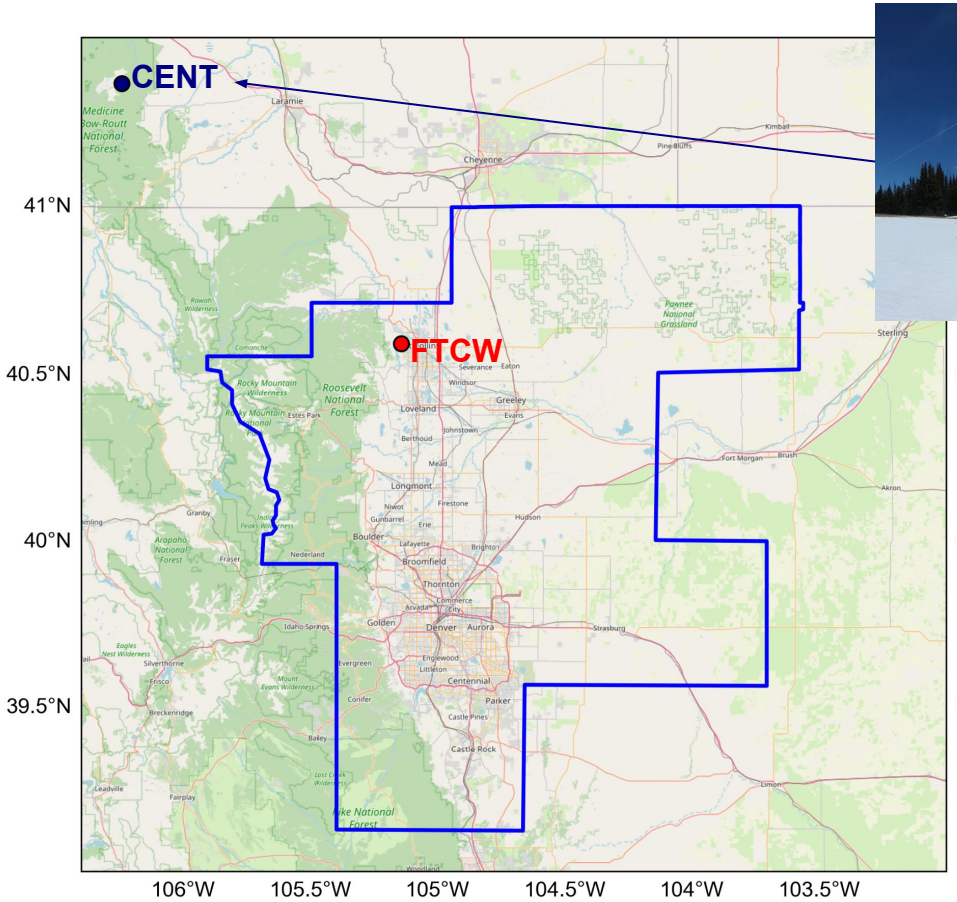
Dynamics of ozone formation in the Front Range

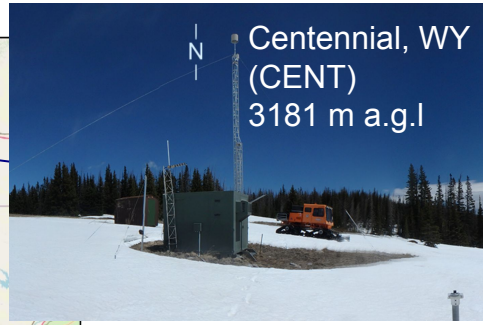
contains 40-60 ppbv “background” O_3 from distant sources, including West Coast cities, wildfire smoke, transpacific transport, stratospheric mixing

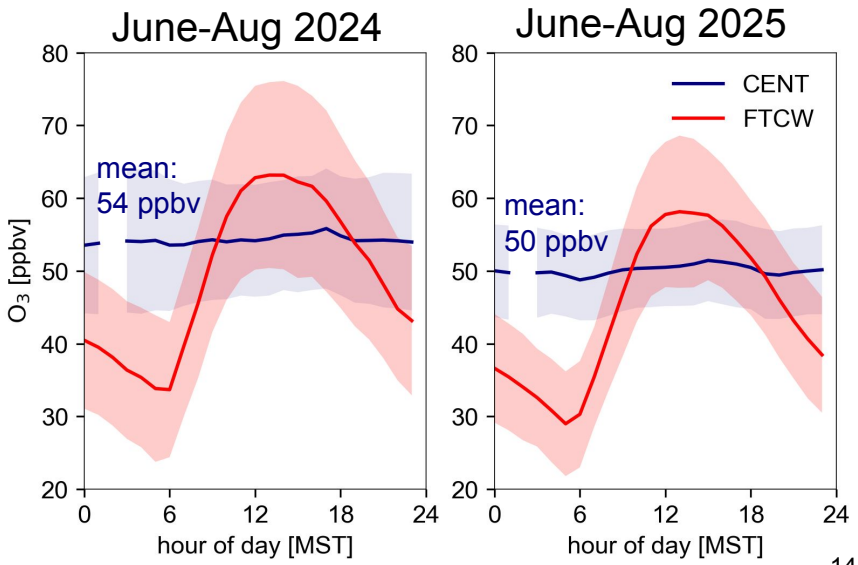


Sullivan et al. (2016)

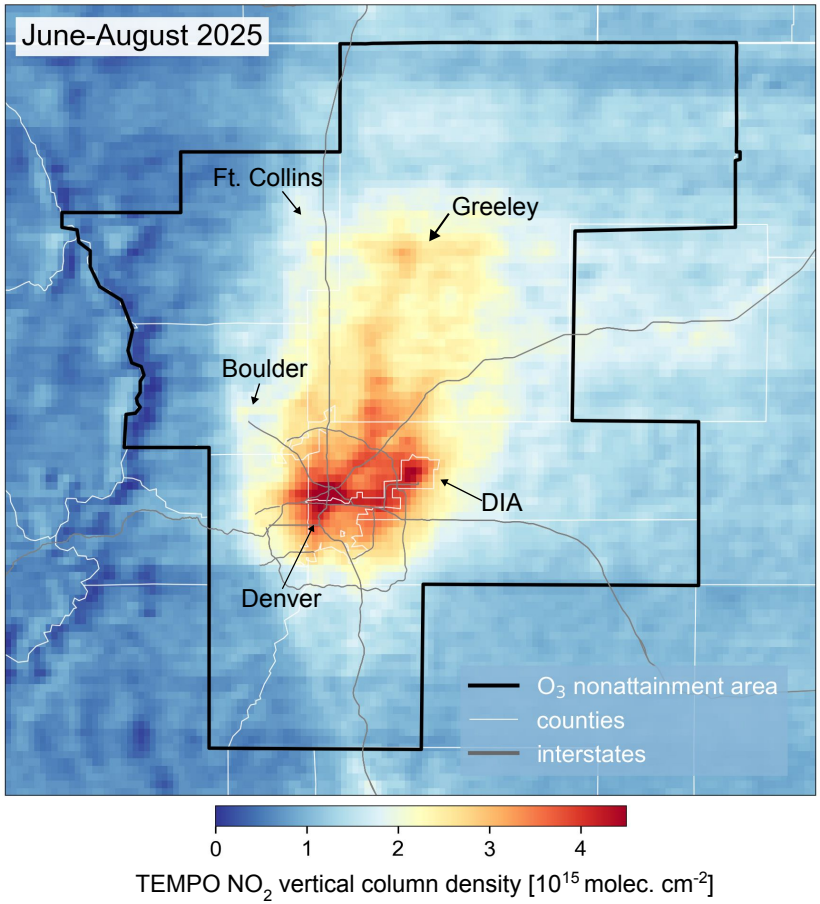
Background ozone in 2025 was also lower compared to previous years



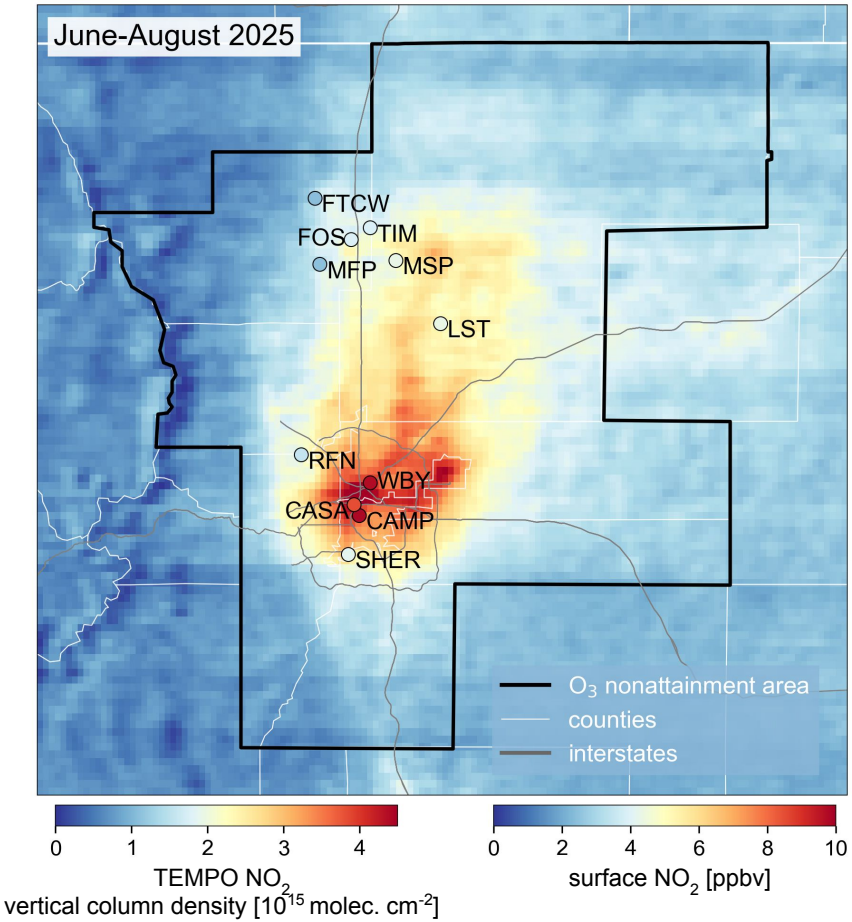


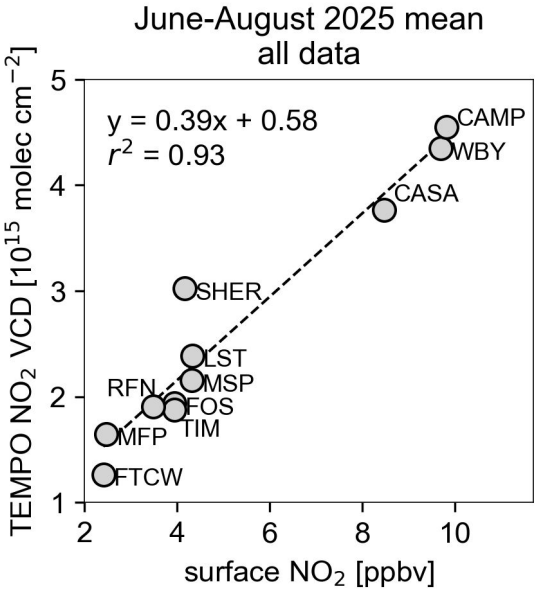


Distribution of ozone precursors across the Front Range: insights from TEMPO

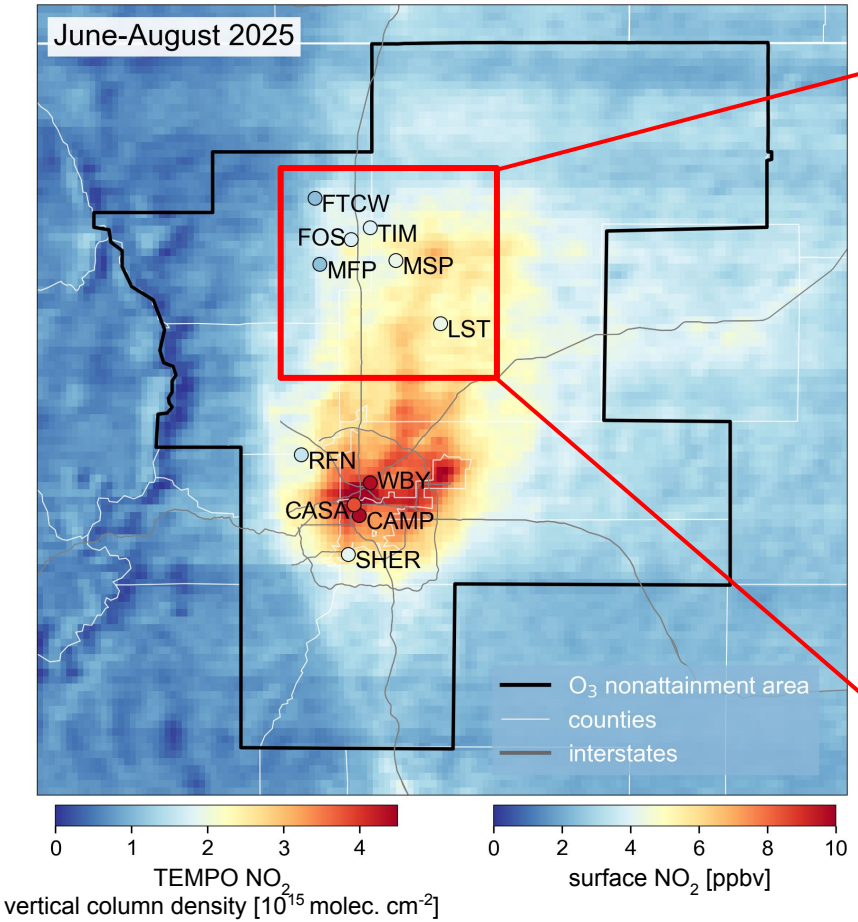


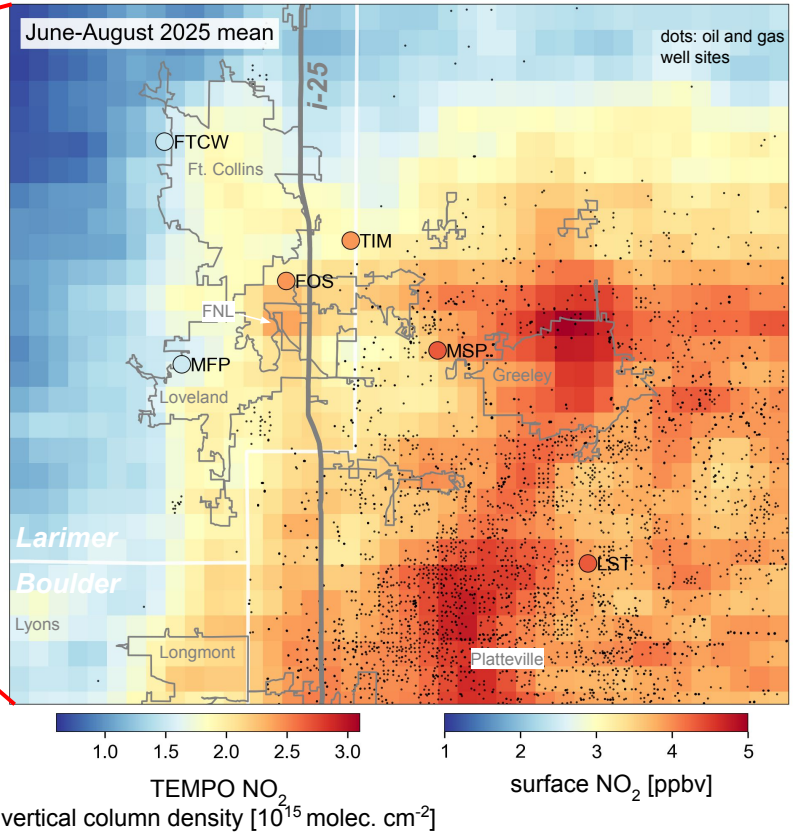
TEMPO NO_2 spatial pattern strongly agrees with surface monitoring sites



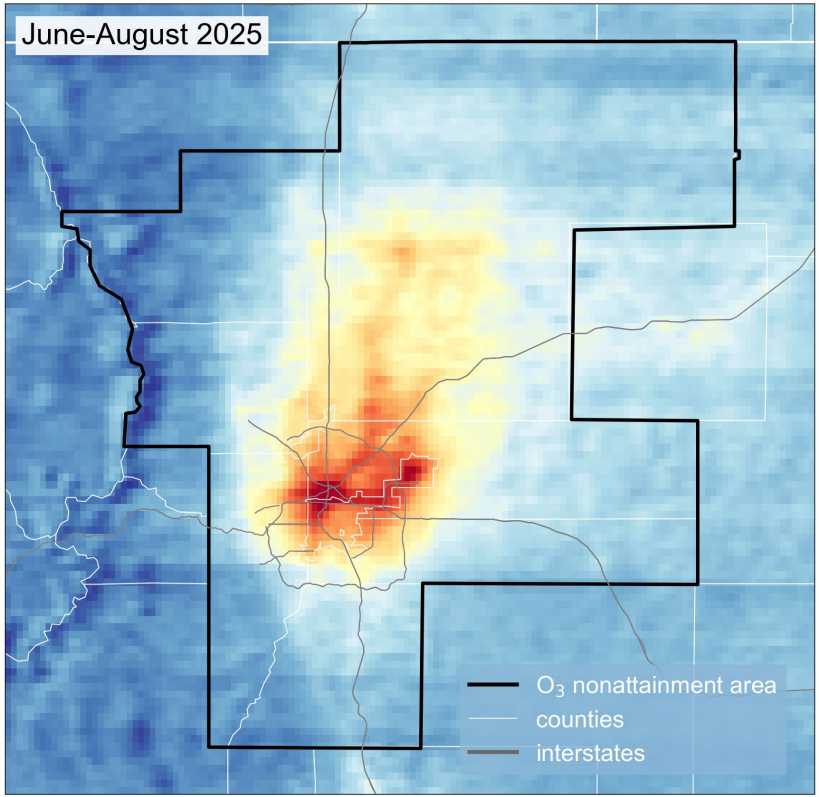


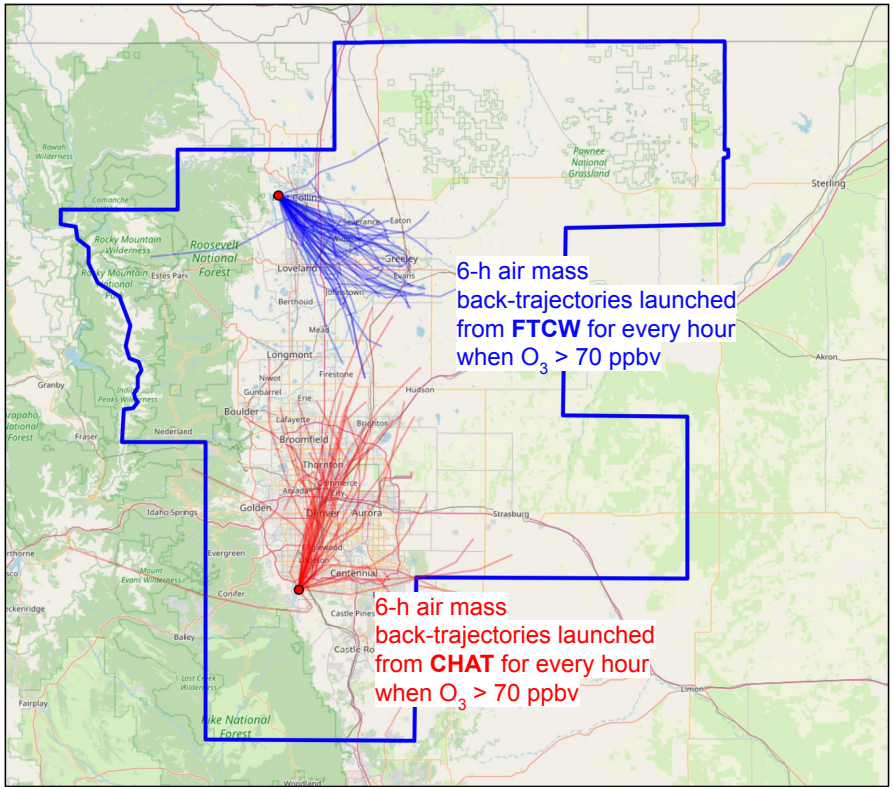
Larimer/Weld counties: strong NO_2 gradient





High ozone “footprints” vary across monitoring sites





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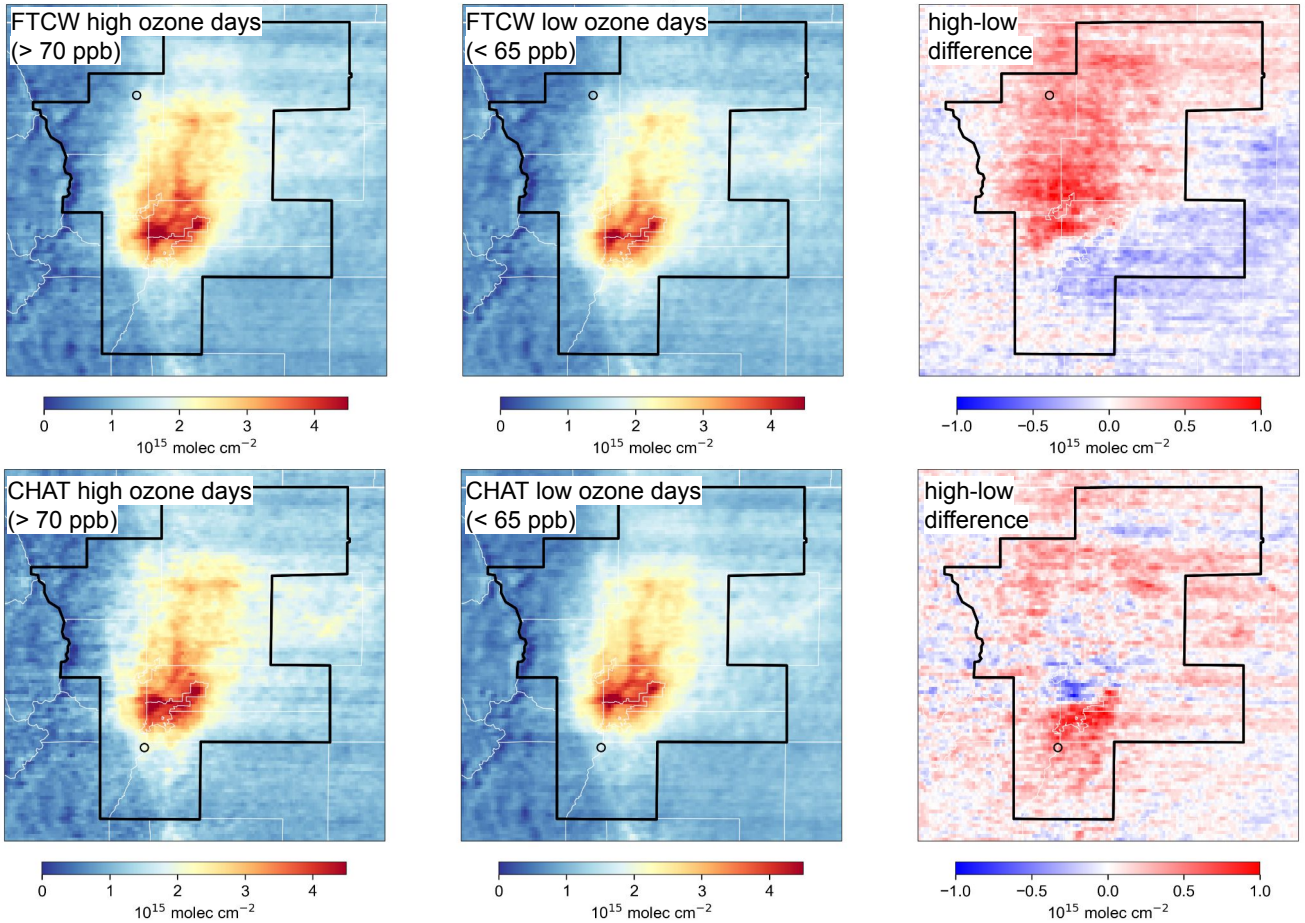
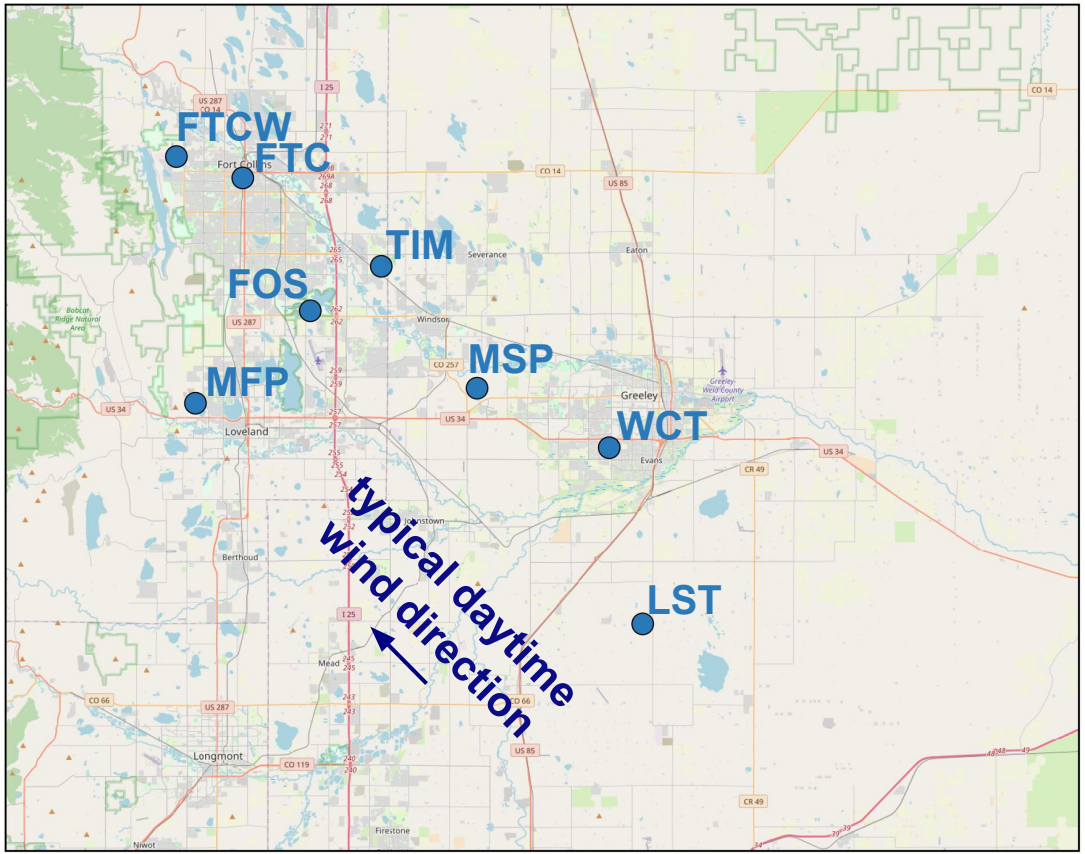
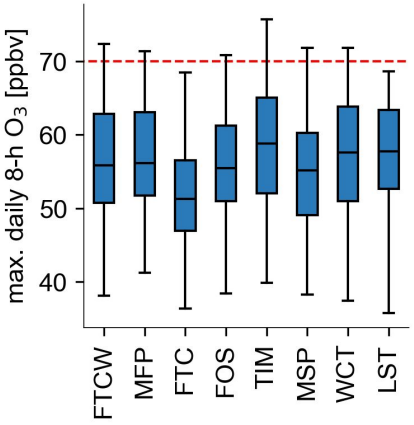
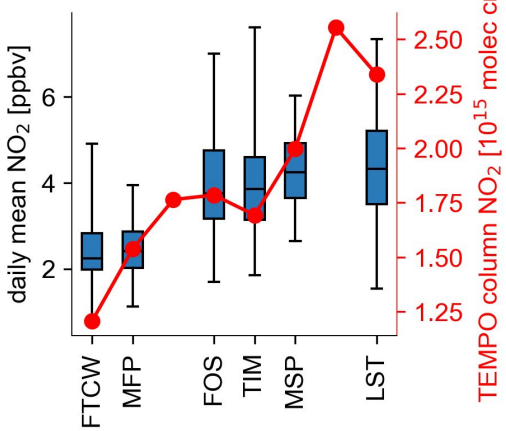


- O_3 production in the northern part of the nonattainment area is more strongly driven by local emissions rather than transport from Denver
- Enhanced NO_2 on high O_3 days can be explained by a combination of higher emissions and lower wind speeds favoring pollutant accumulation

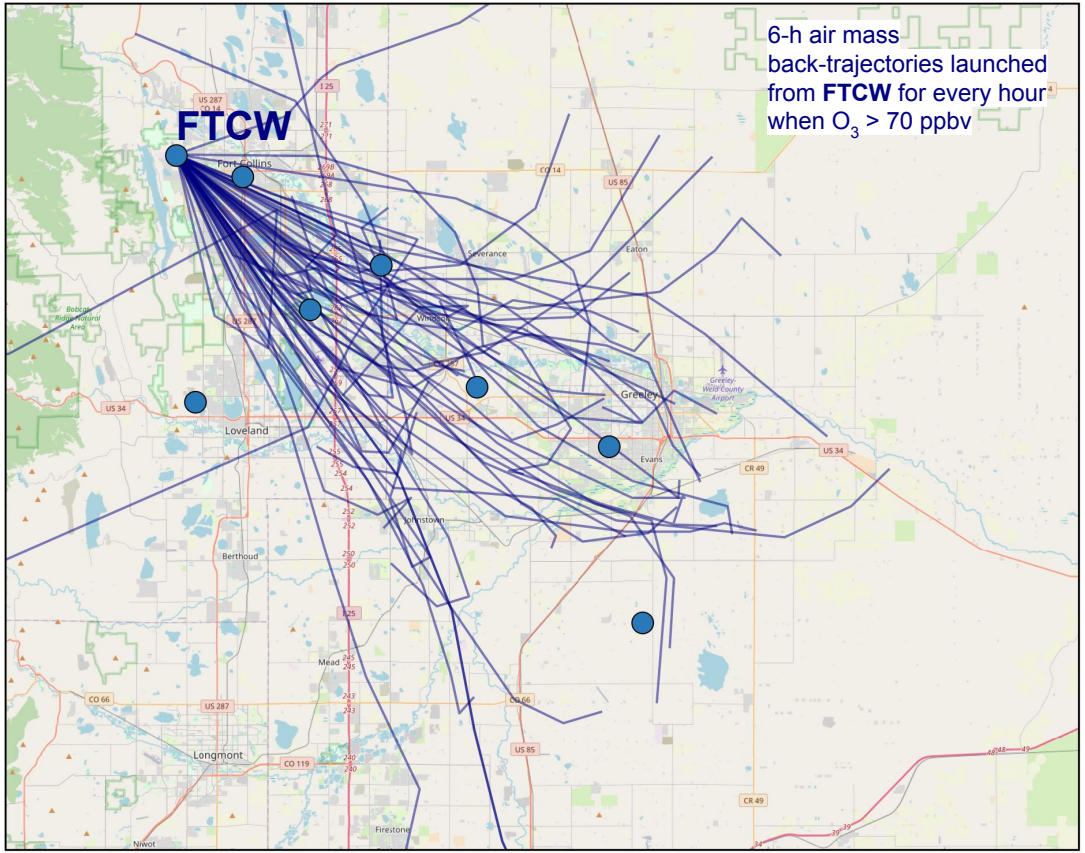
Larimer and Weld counties: following ozone production with upslope flow

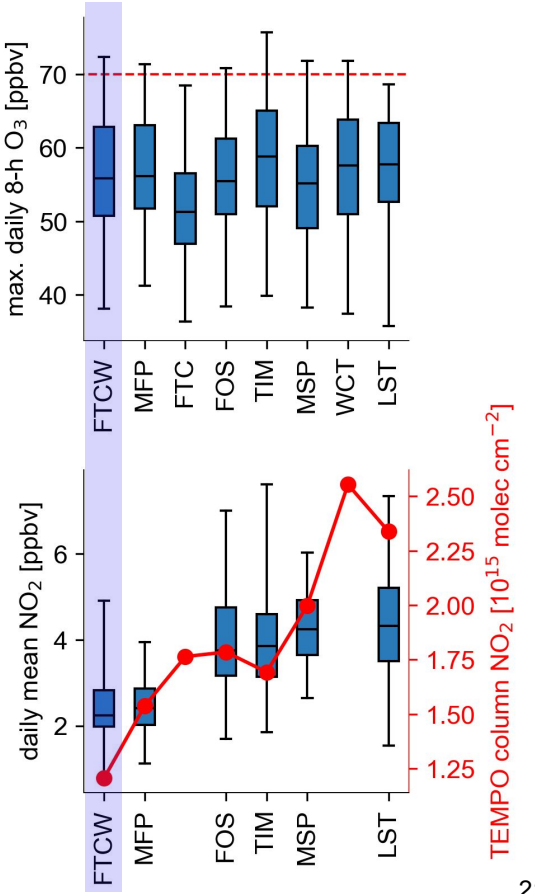




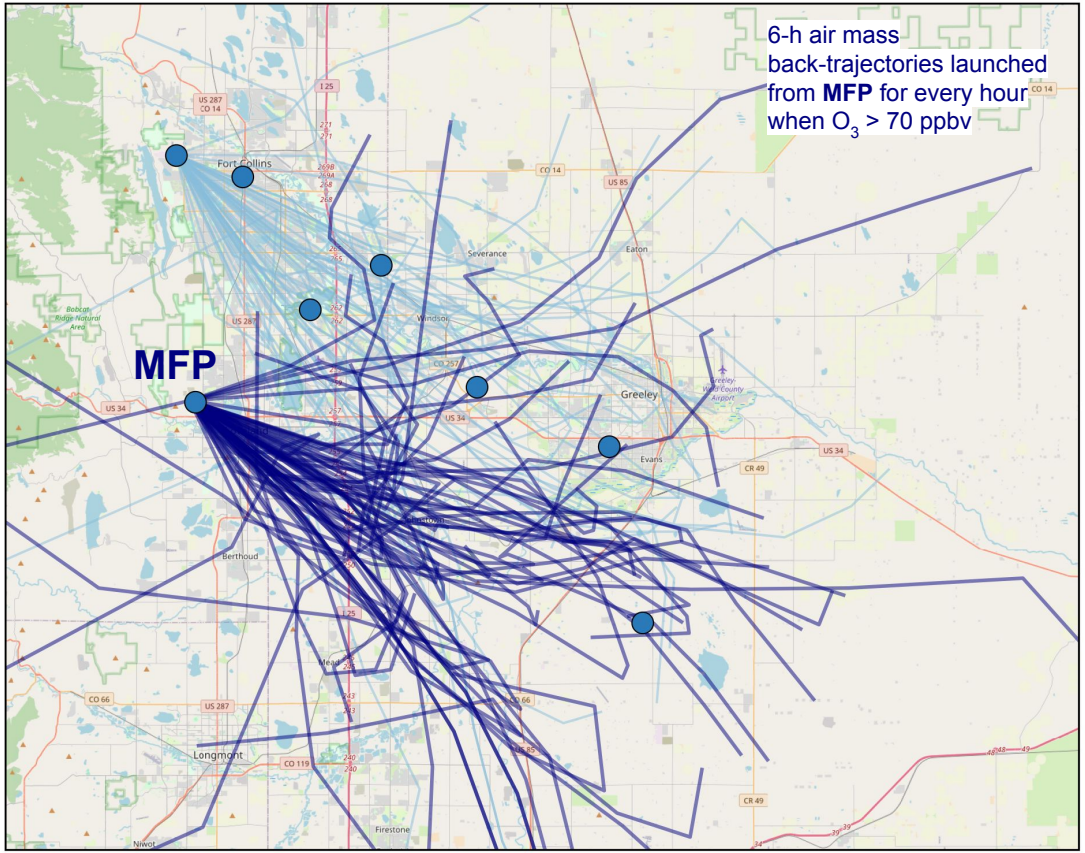


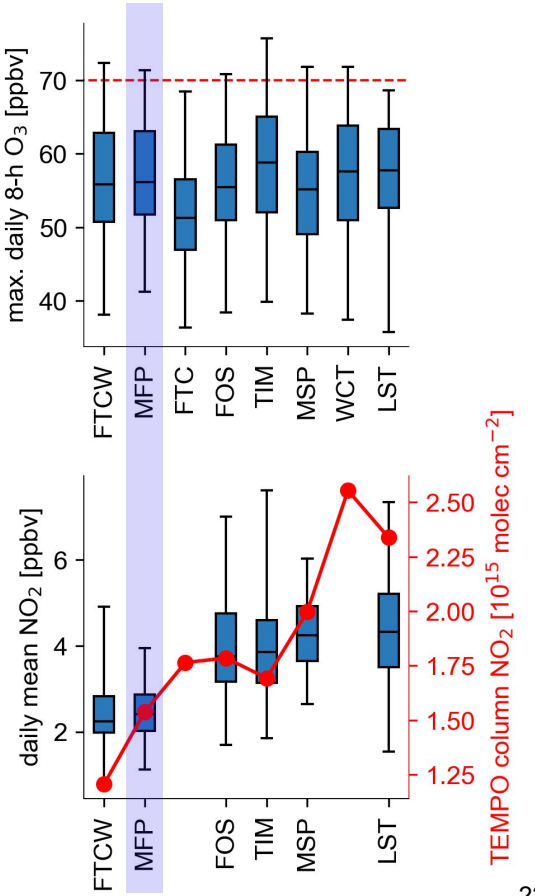
Larimer and Weld counties: following ozone production with upslope flow



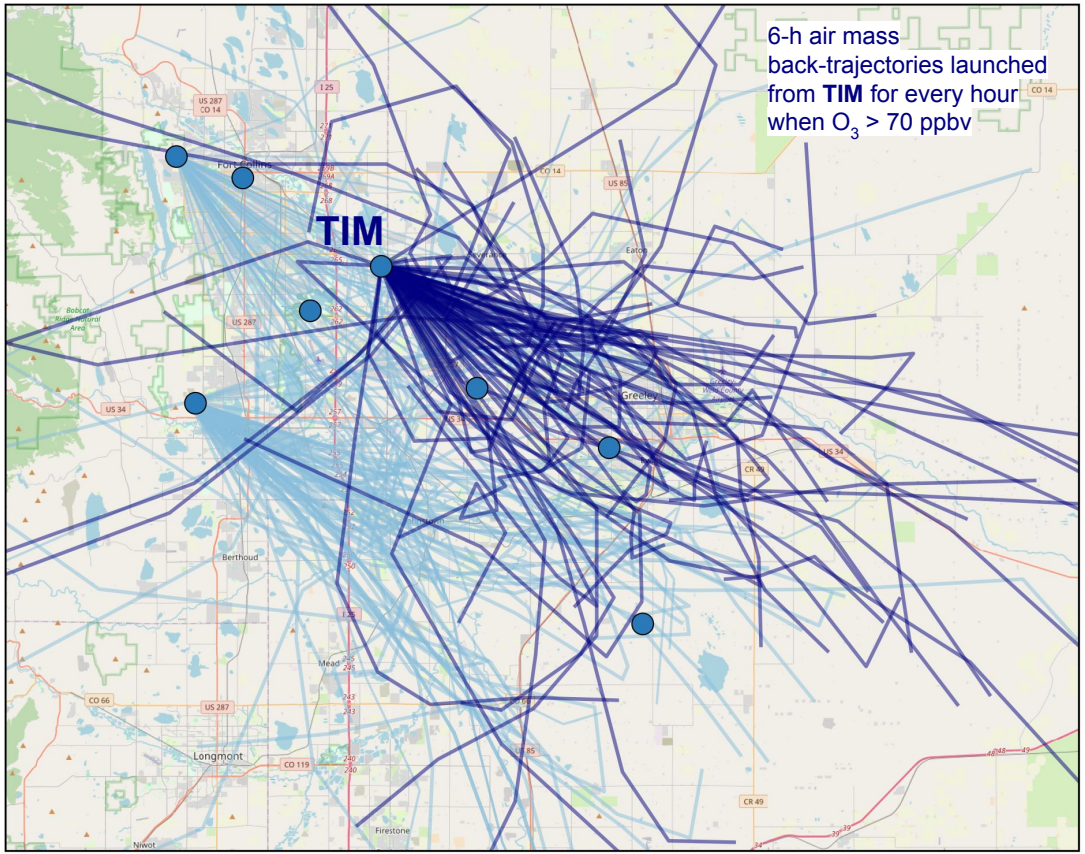


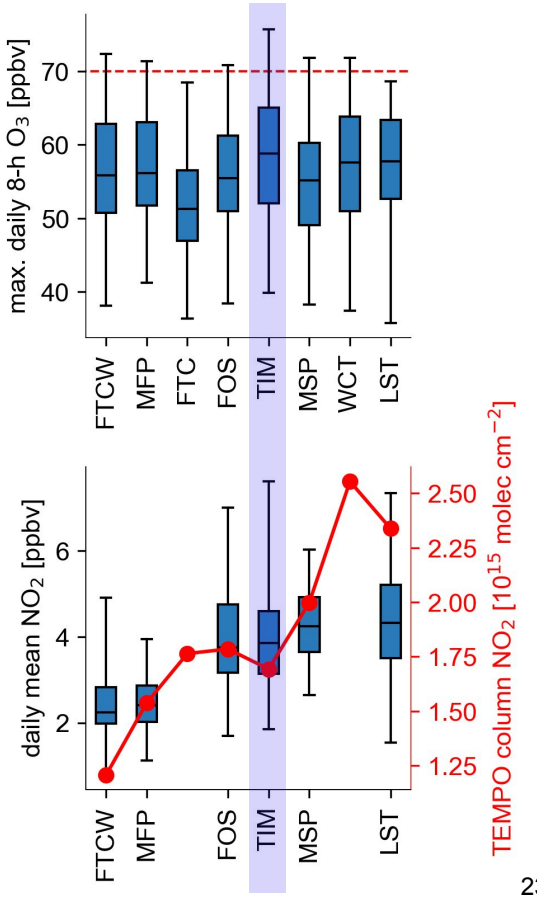
Larimer and Weld counties: following ozone production with upslope flow



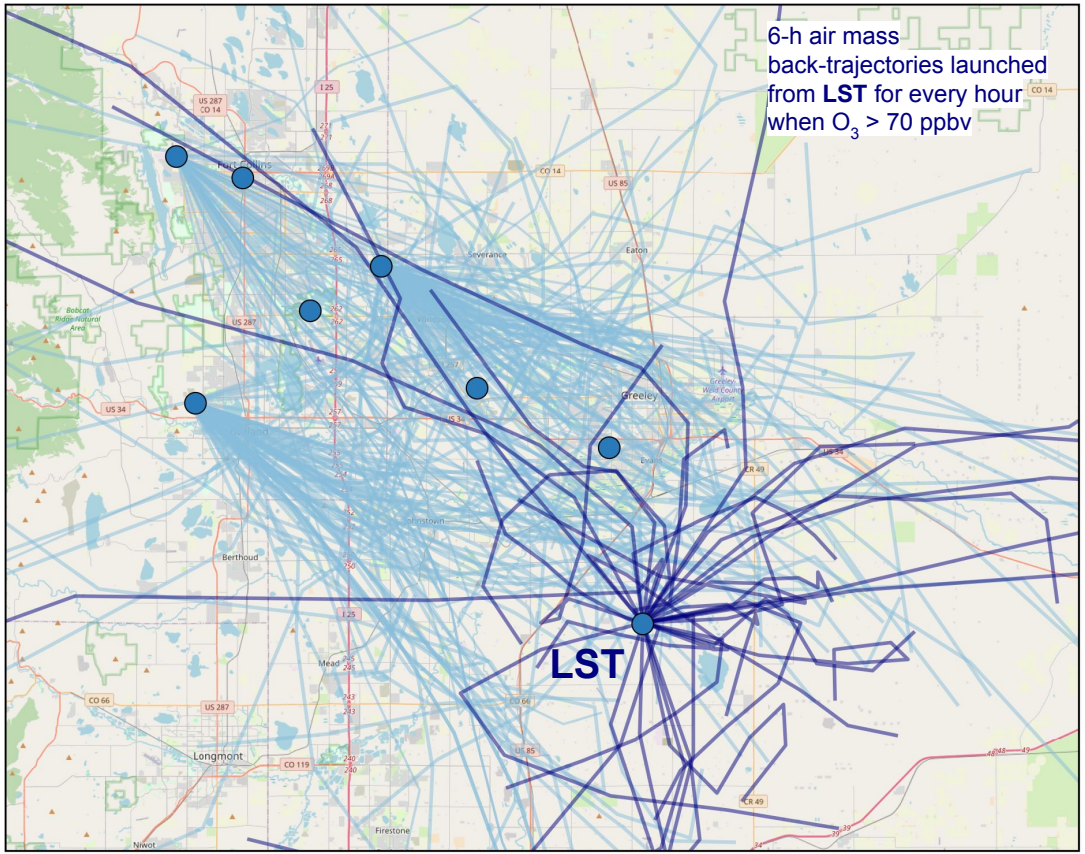


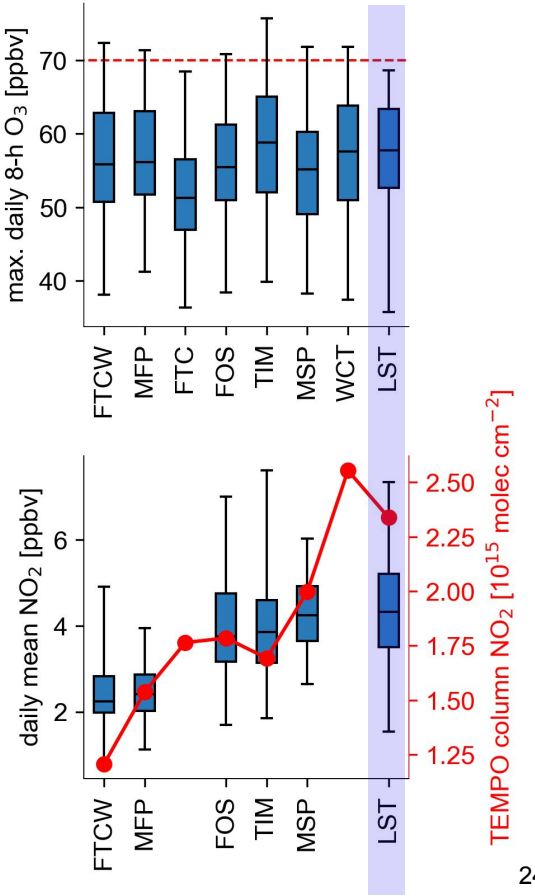
Larimer and Weld counties: following ozone production with upslope flow





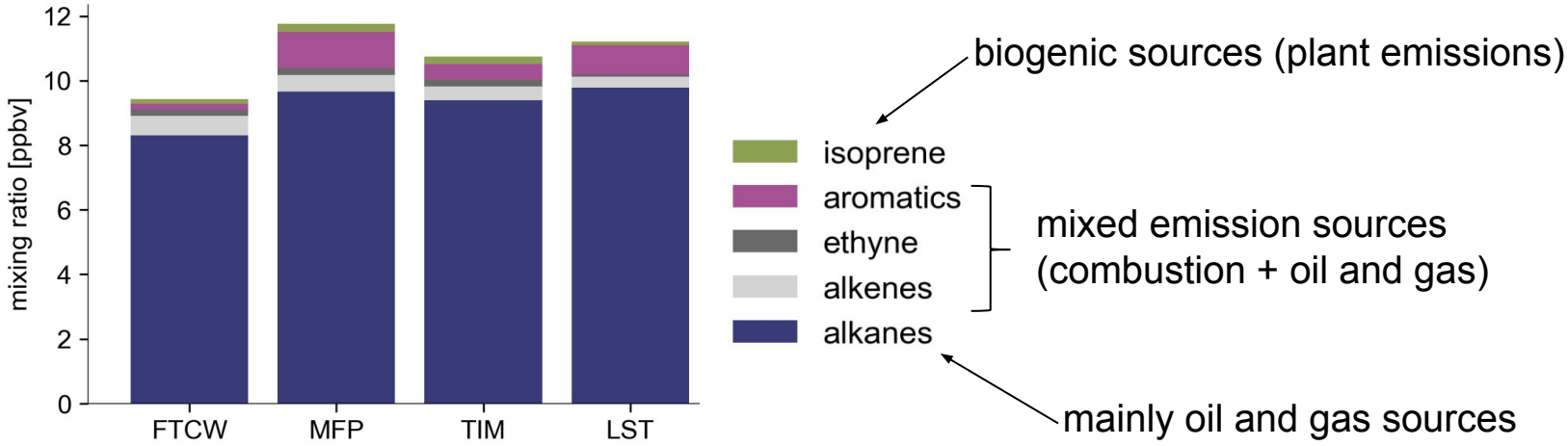
Larimer and Weld counties: following ozone production with upslope flow





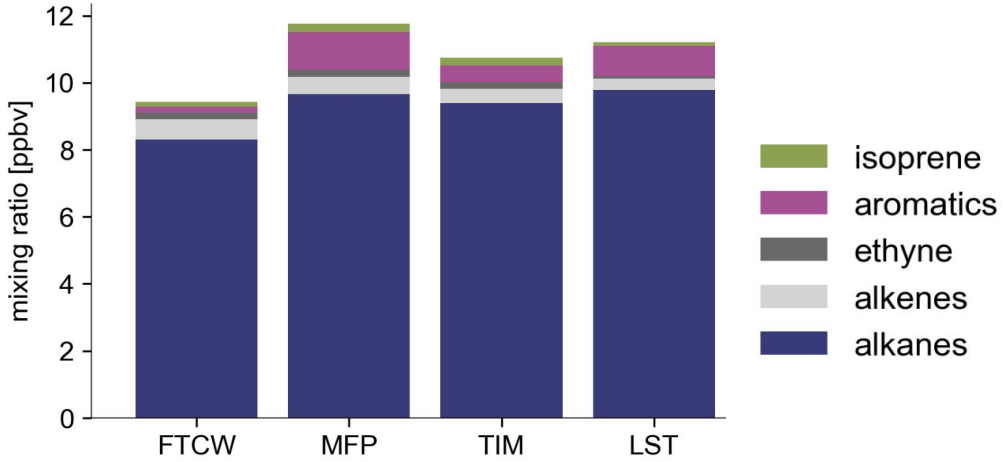
VOC measurements reveal influences from different emission sources

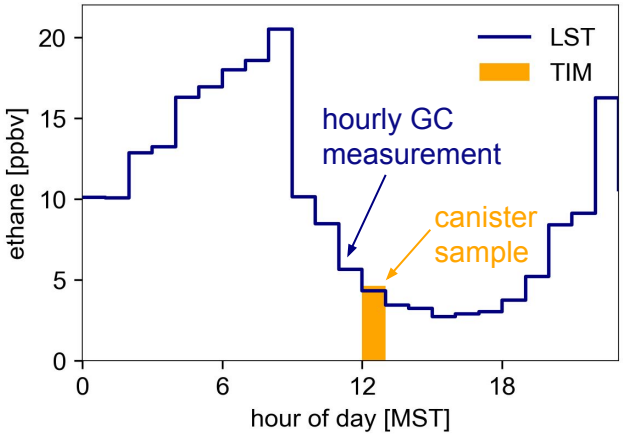
12:00-13:00 MST averages on canister sample days

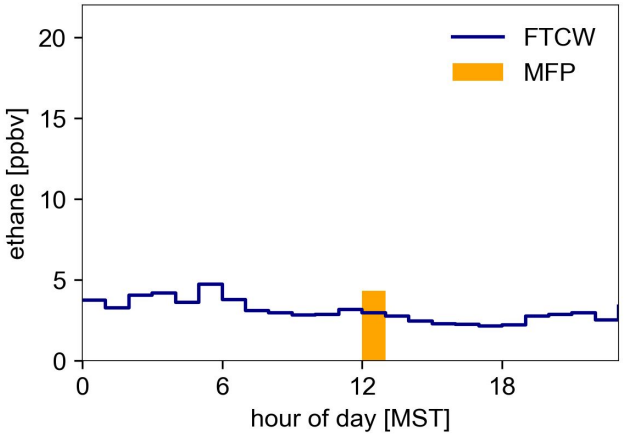


Mid-day canisters don’t capture the highest concentrations but coincide with peak ozone production periods

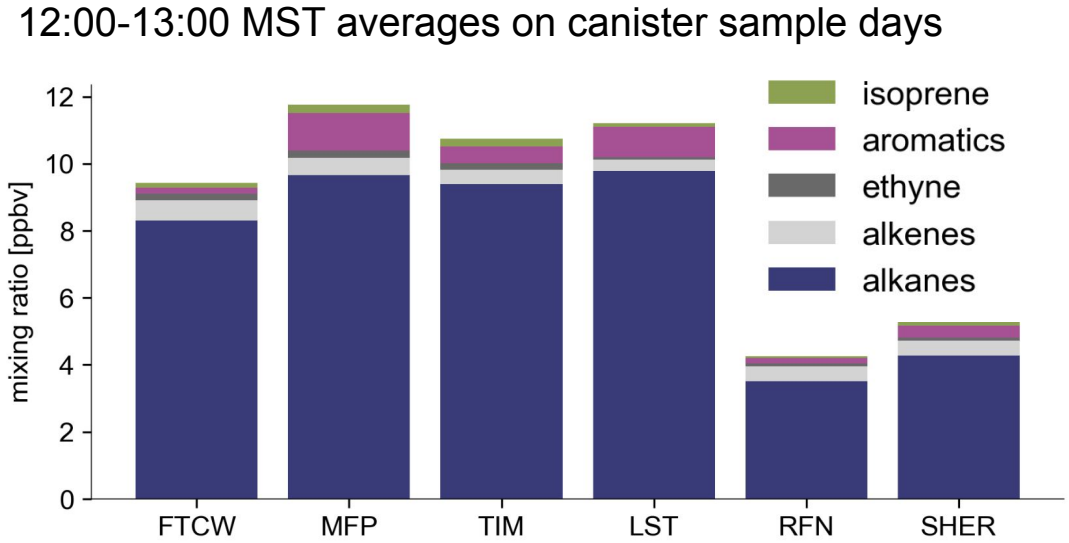
12:00-13:00 MST averages on canister sample days

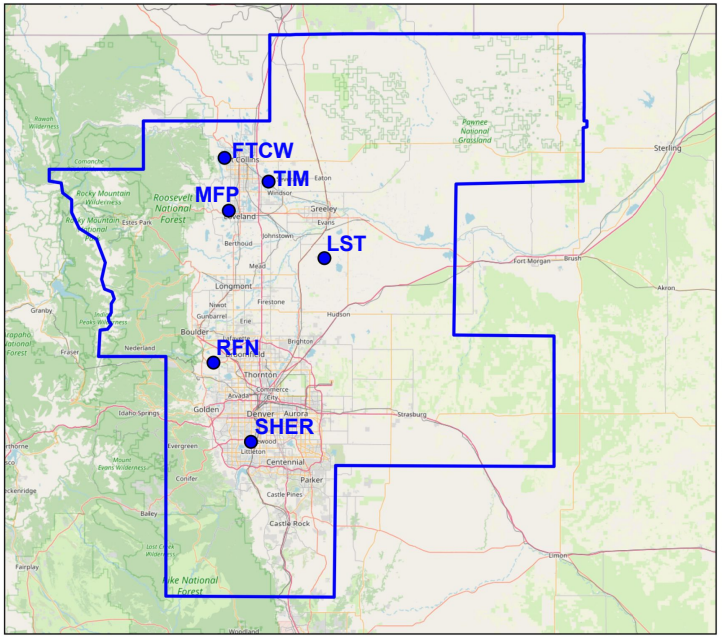




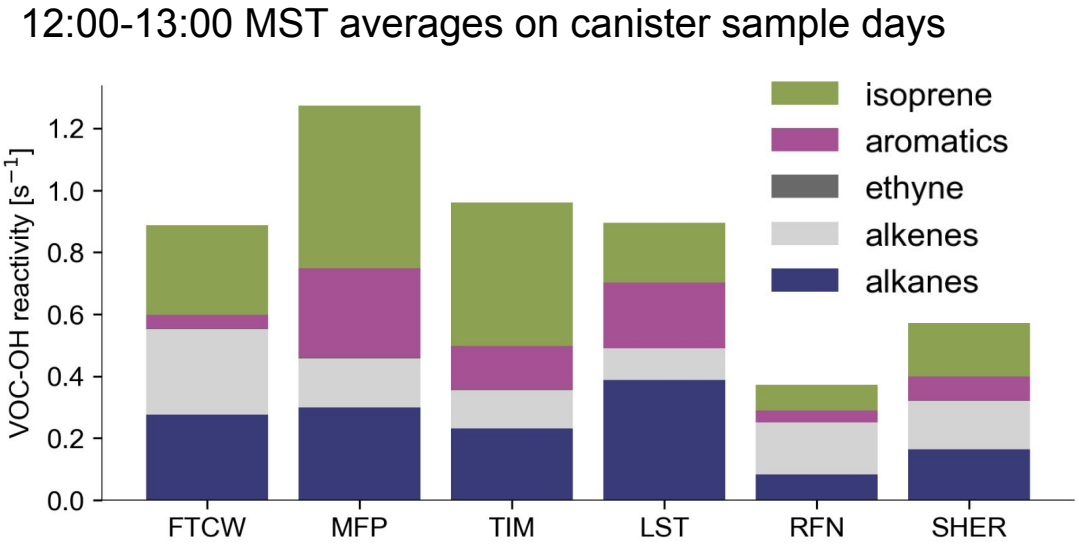


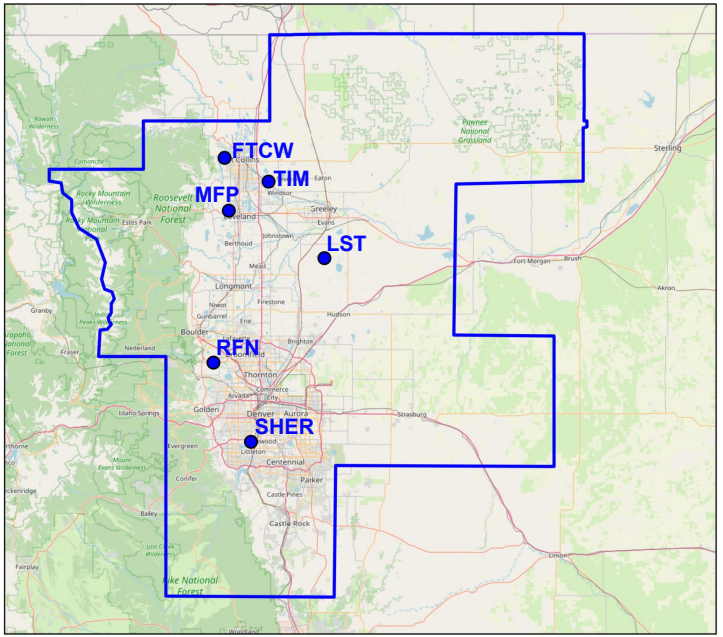
Northern VOC sites have larger contributions from alkanes compared to the Denver Metro Area



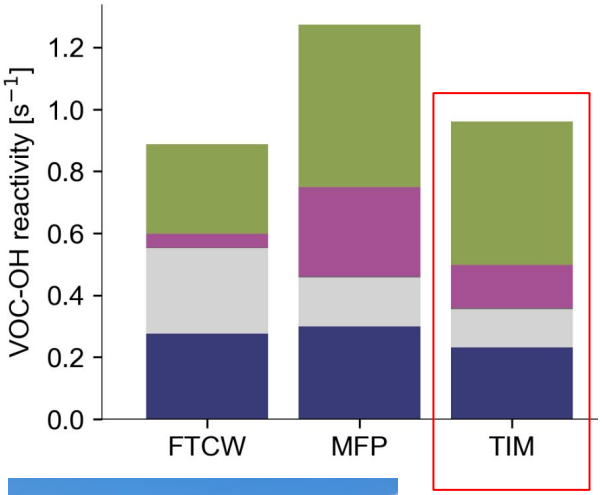


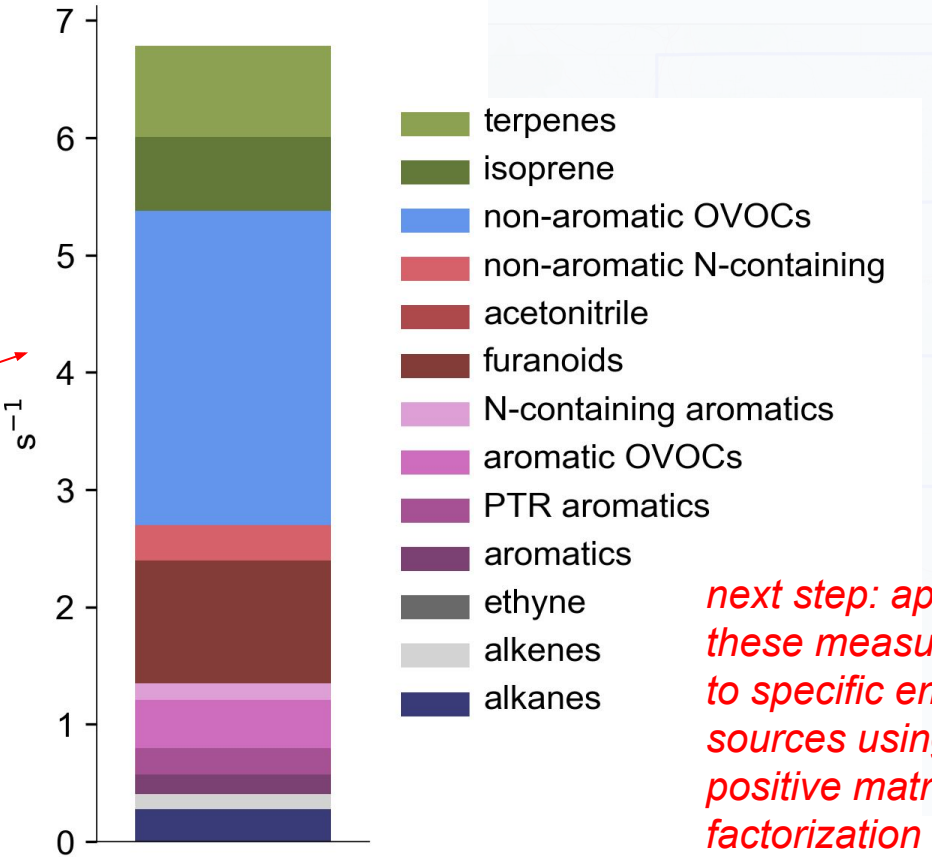
OH-reactivity identifies compounds most important for ozone formation





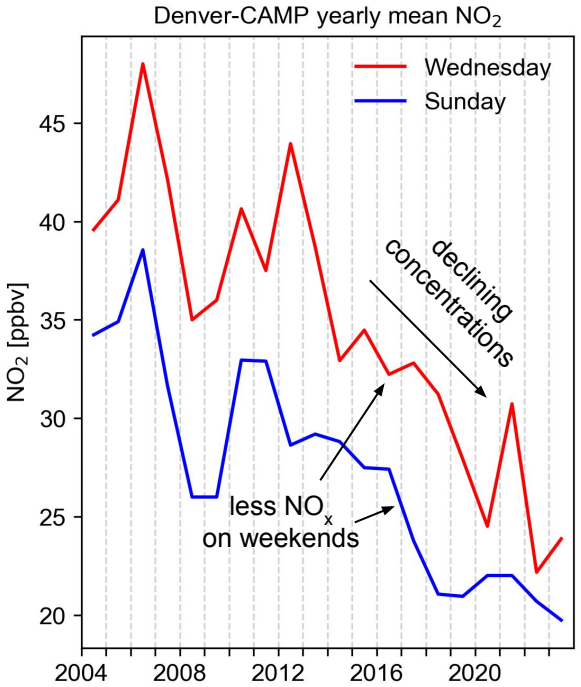
U. Montana PTR-ToF-MS measured a much larger suite of VOCs, many of which (especially oxygenated VOCs) are important for ozone

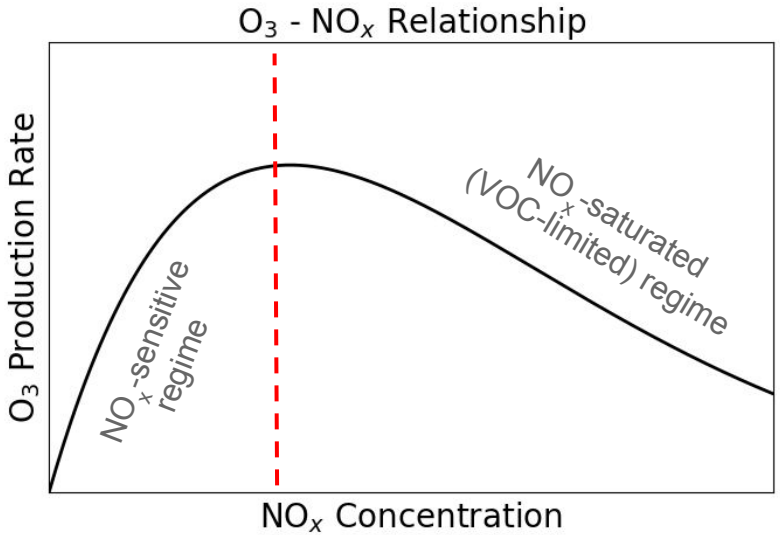




next step: apportion these measurements to specific emission sources using positive matrix factorization (PMF)

Long-term perspective: how has ozone responded to NO_x emission declines?





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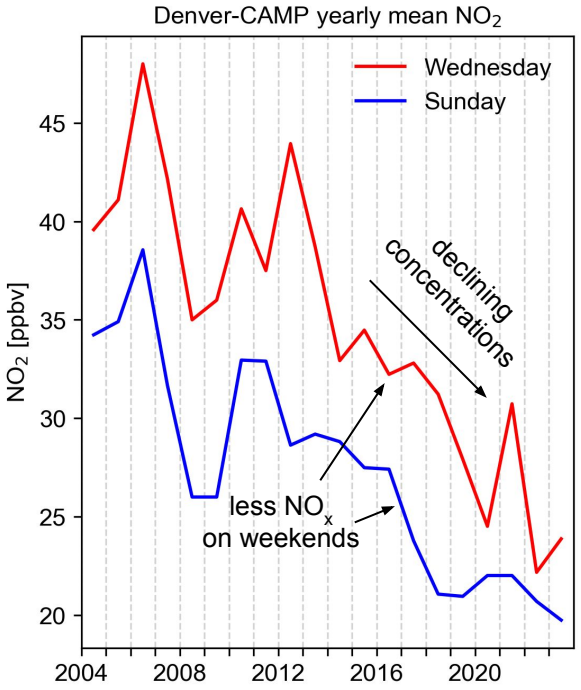
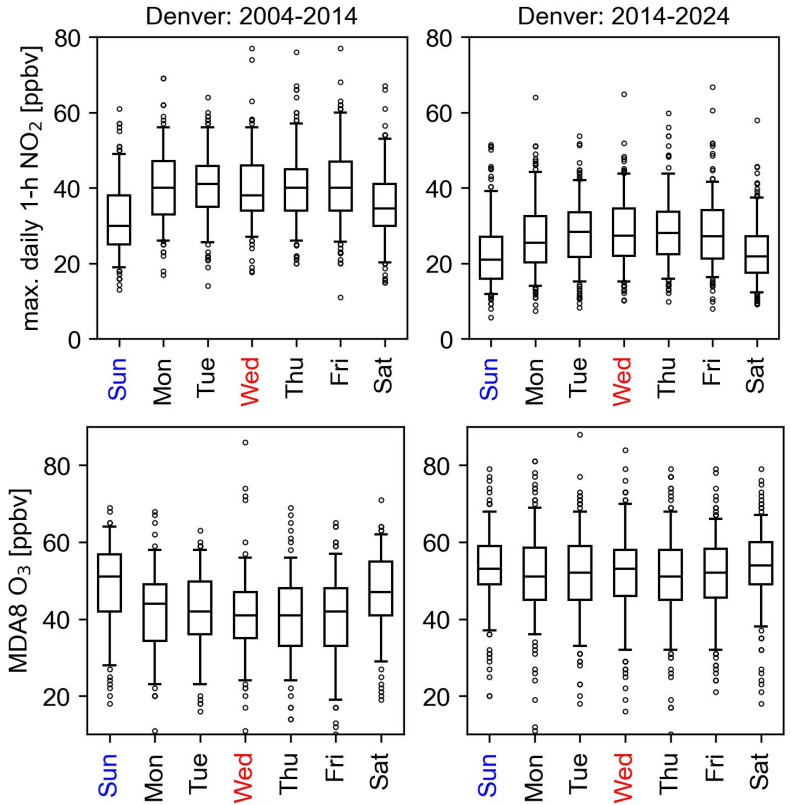


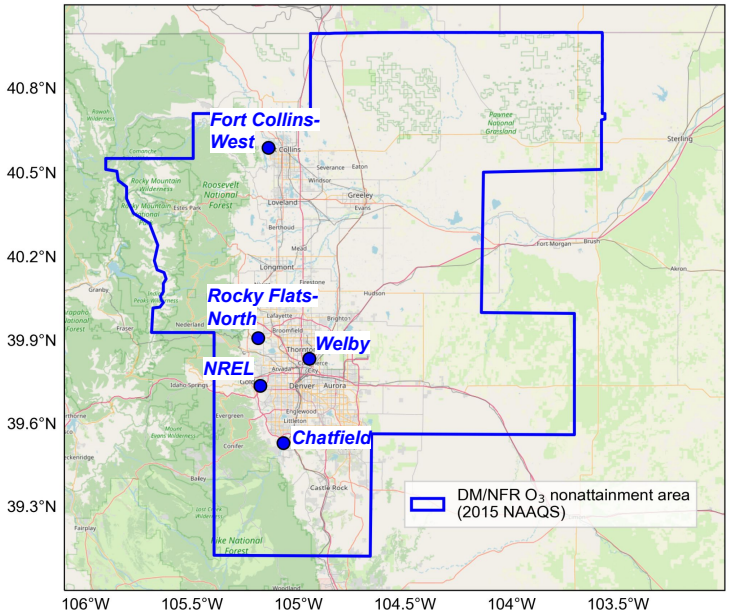


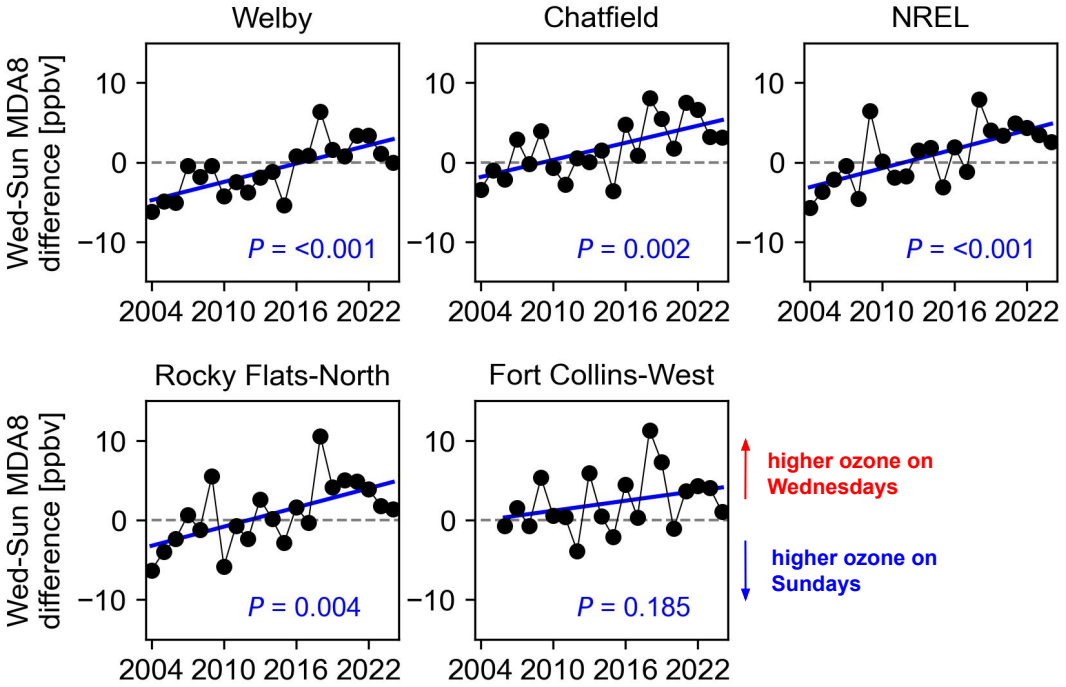
NO_2 weekly cycles reflect changes in vehicle emissions

Assuming constant VOC reactivity, higher ozone on weekends = NO_x-suppressed ozone production

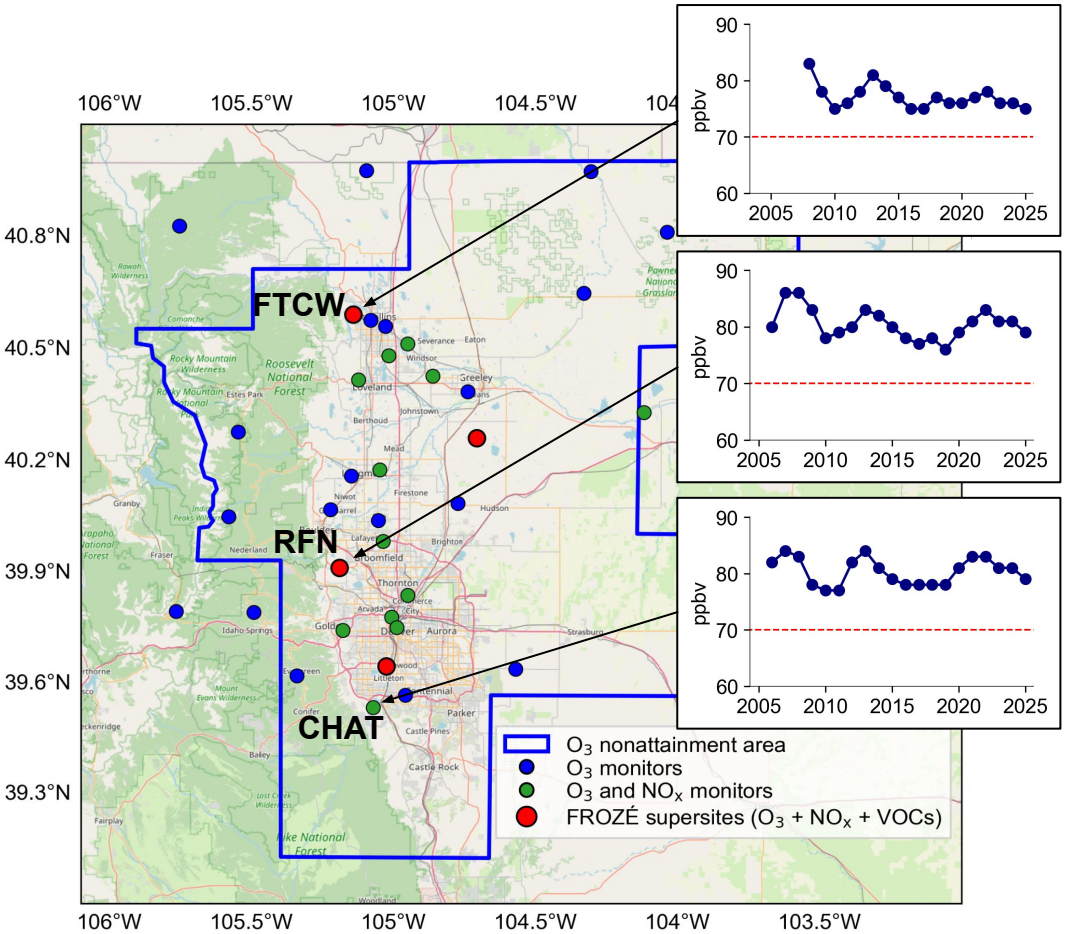
Higher ozone on weekdays = NO_x-sensitive ozone production

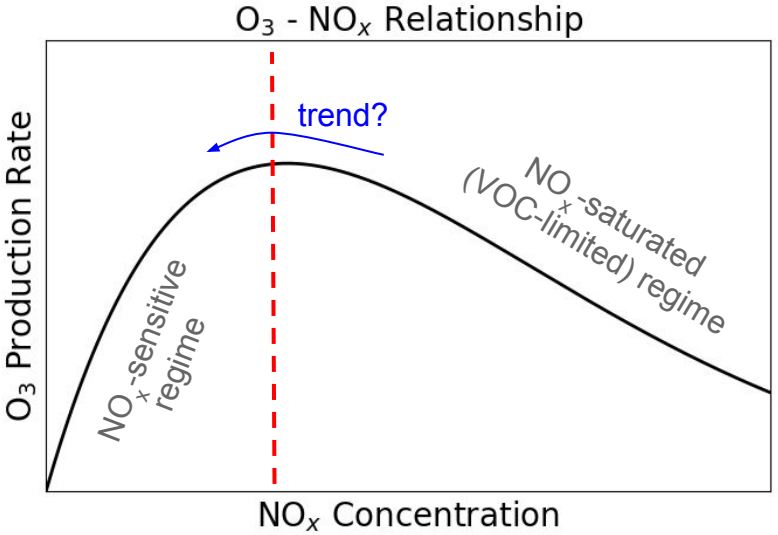
Ozone production is becoming more sensitive to NO_x over time



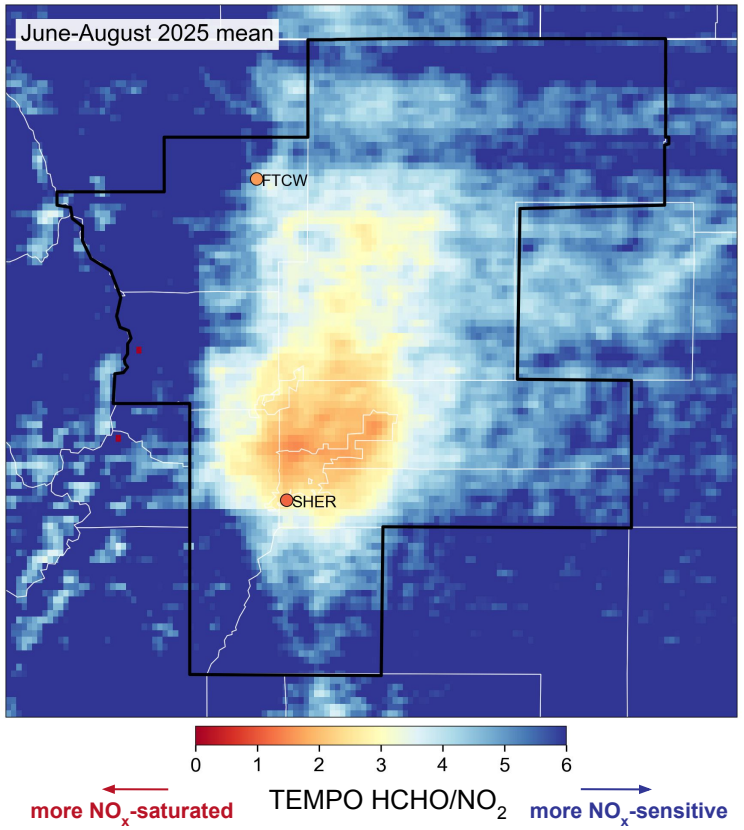


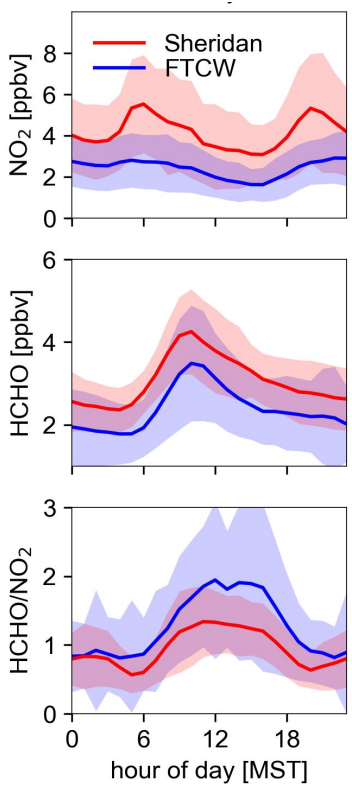
Continued NO_x emission reductions are expected to lower future ozone





Summer 2025 formaldehyde (HCHO) and NO_2 observations indicate stronger NO_x-sensitivity in Fort Collins vs. Denver





$HCHO/NO_2$ as indicator of O_3 production sensitivity:

- higher values → more NO_x-sensitive
- lower values → more NO_x-saturated (VOC sensitive)

Ozone production in Fort Collins is very likely more sensitive to NO_x compared to Denver

- NO_x emissions reductions will have a larger ozone-reducing impact in Fort Collins

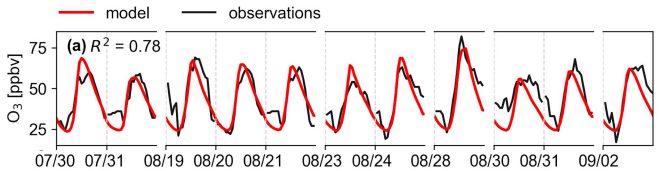
Modeling ozone production will help us further understanding sensitivity differences

Observationally-constrained box-modeling will quantify specific impacts of precursor changes on ozone production

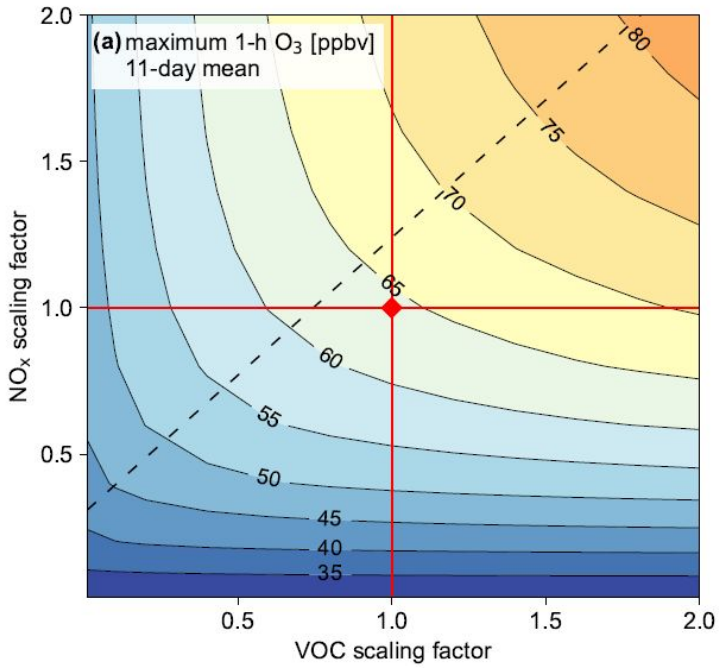
F0AM box modeling:

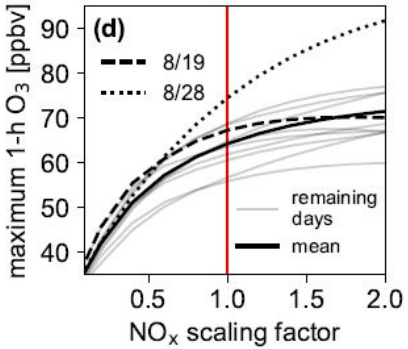
- Location and date specific
- Constrained by VOC and NO_x observations – not subject to emission inventory uncertainties
- re-run with scaled NO_x and VOC inputs to examine sensitivity

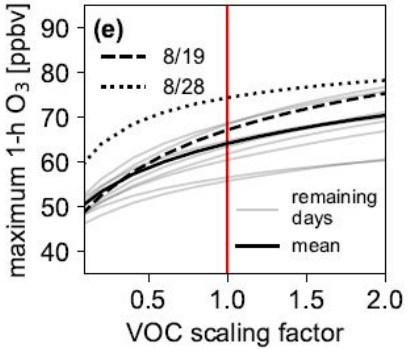
Example from Carlsbad Caverns National Park, summer 2019:



Example from Carlsbad Caverns National Park, summer 2019:



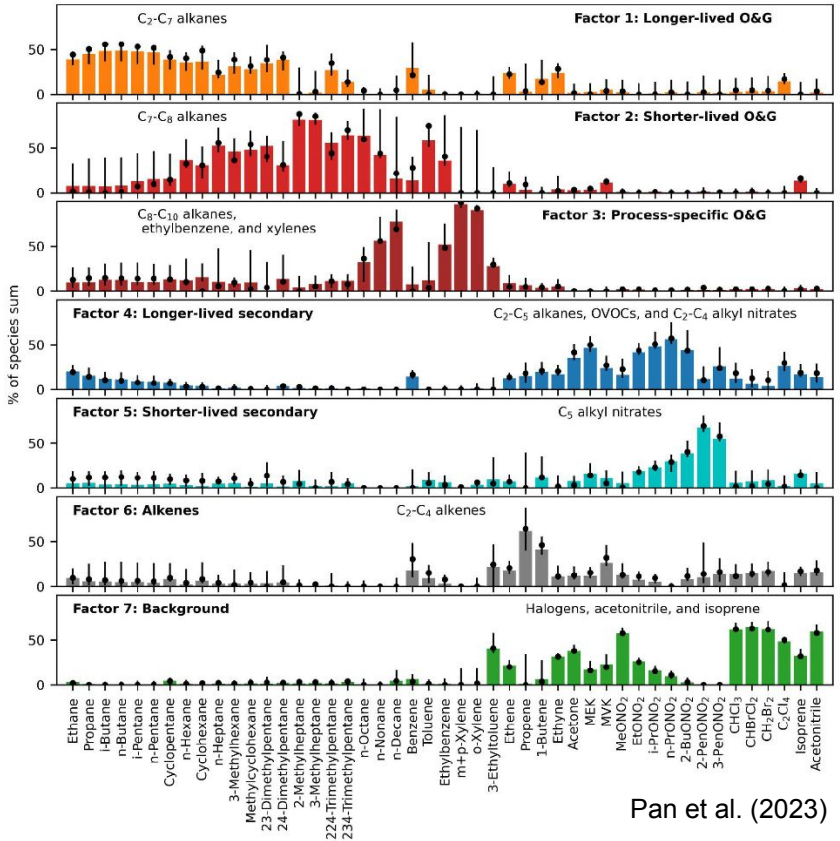




Marsavin et al. (2024)

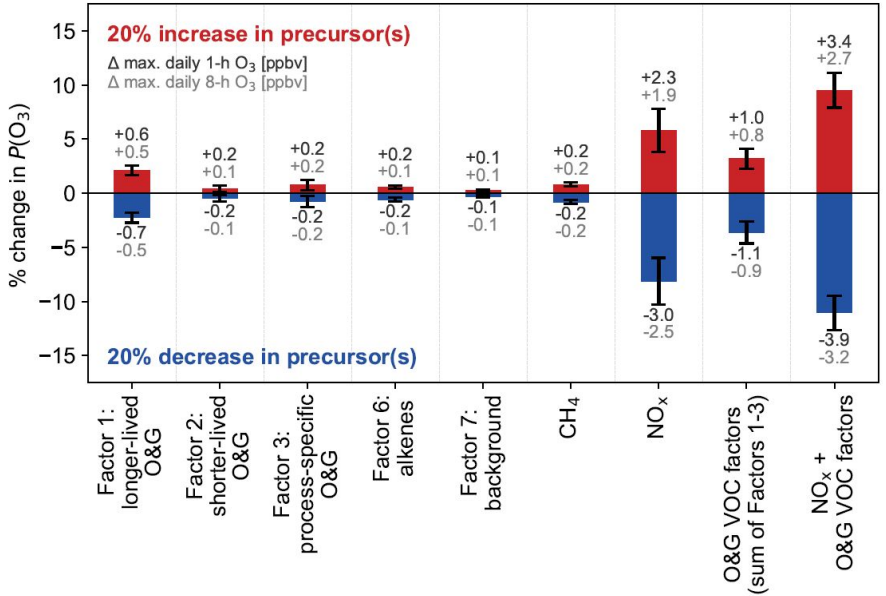
Positive matrix factorization (PMF) will be used to apportion VOC observations to specific sources

examples from Carlsbad Caverns National Park, summer 2019:



Pan et al. (2023)

Box model results: how does ozone production respond to changes in NO_x and specific VOC sources?



Marsavin et al. (2024)

Full project timeline

Activity	2025				2026				2027			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Field campaign preparation	■	■										
Field campaign		■	■									
Finalize and post campaign data				■	■	■						
Analysis of mobile observations						■	■					
PMF VOC Source Attribution						■	■					
Assess O_3 NO_x-VOC Sensitivity with obs						■	■					
F0AM photochemical box modeling							■	■				
Assess O_3 NO_x-VOC Sensitivity with TEMPO								■	■			
PGM performance testing and improvement									■	■	■	■
Journal article preparation and submissions							■	■	■	■	■	■
Final report preparation and submission											■	■

Summary and conclusions

- Ozone in the Front Range results from a **complex mixture of precursor emission sources**, unique meteorology, and background influence
- Summer 2025 turned out to be a relatively low ozone year, due to favorable meteorology and lower background influence. *23 NAAQS exceedance days were observed*
- Ozone accumulation in the foothills of Larimer Co. is associated with **southeasterly transport**
- Long-term trend analysis suggests that ozone production is shifting towards **stronger NO_x-sensitivity**: continued NO_x emission reductions will be essential for ozone reduction
- Conditions in Fort Collins/Larimer Co. are more NO_x-sensitive than in Denver
- Ongoing analysis will employ box modeling and statistical tools (PMF) to understand precursors sources and **source-specific impacts** on ozone production

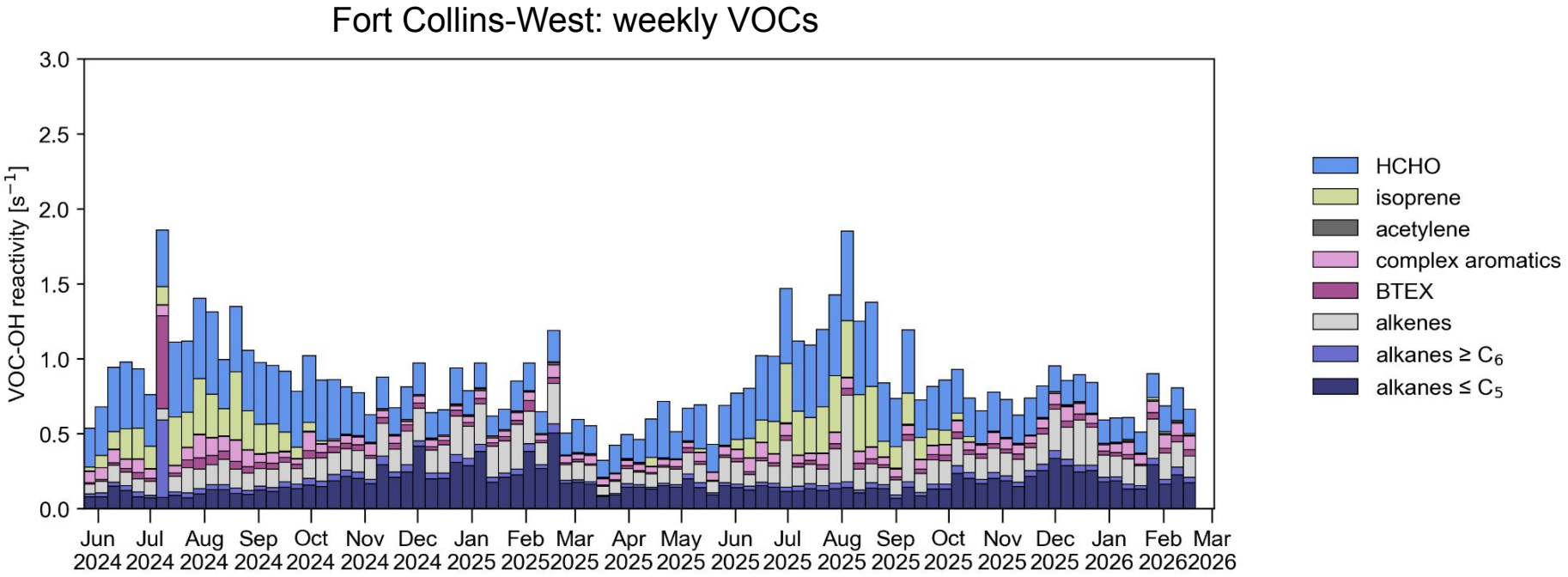
Thank you!

Andrey Marsavin, PhD student: marsavin@rams.colostate.edu
Dr. Jeff Collett, Professor: jeffrey.collett@colostate.edu

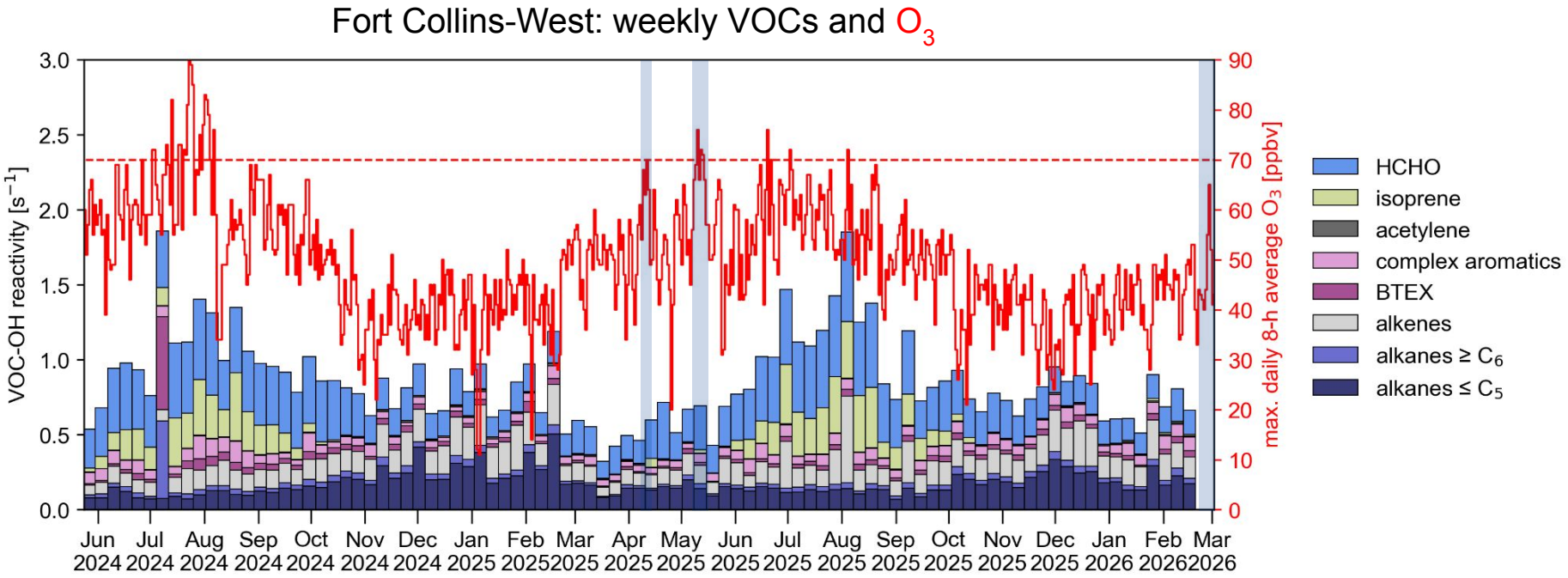
This research is supported by the Colorado Air Quality Enterprise

extra slides

Concentrations of most primary VOCs are higher in the winter, but OH-reactivity peaks in the summer when considering biogenic emissions and photochemical products (i.e, HCHO)



Ozone peaks in the summer but off-season events are possible

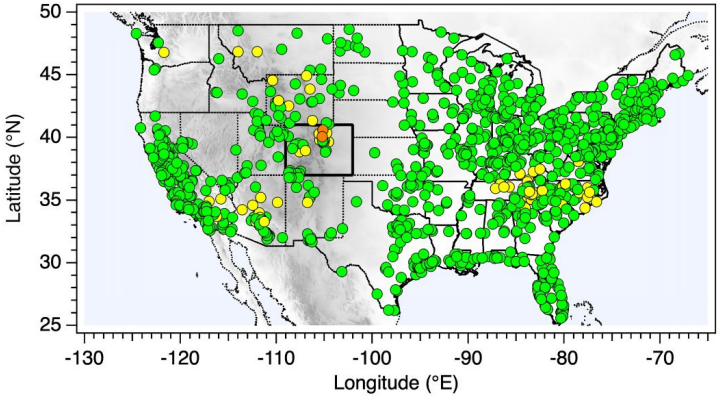


Ozone peaks in the summer but off-season events are possible

An Unusual Winter Ozone Event in Colorado

Andrew O. Langford[1], Kenneth C. Aikin[1,2], Raul J. Alvarez II[1], Sunil Baidar[1,2], W. Alan Brewer[1], Steven S. Brown[1], Matthew M. Coggon[1,2], Patrick D. Cullis[2,3], Jessica B. Gilman[1], Georgios I. Gkatzelis[1,2,4], Detlev Helmig[5], Bryan J. Johnson[3], K. Emma Knowland[6,7], Rajesh Kumar[8], Aaron D. Lamplugh[1,2,9], Brandi J. McCarty[1,2], Ann M. Middlebrook[1], Gabriele Pfister[10], Jeff Peischl[1,2,3], Irina Petropavlovskikh[2,3], Pamela S. Rickly[1,2,9], Michael A. Robinson[1,2], Andrew W. Rollins[1], Scott P. Sandberg[1], Christoph J. Senff[1,2], and Carsten Warneke[1]

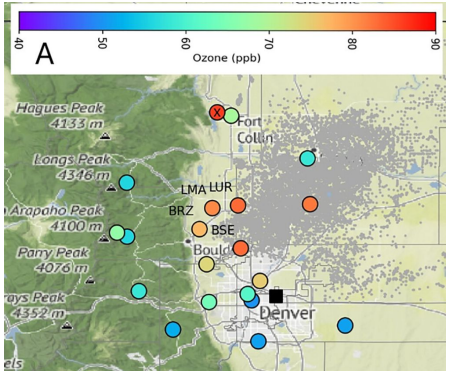
April 17. 2020



Late Winter Ozone and PM 2.5 NAAQS Exceedance in the Northern Colorado Front Range in Relation to Oil and Natural Gas Emissions

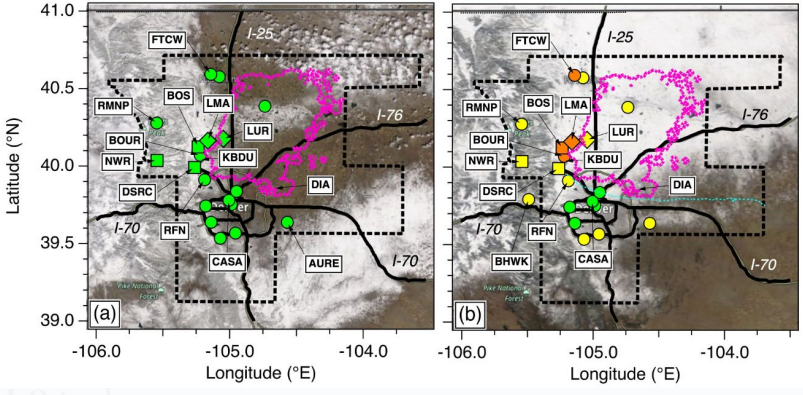
D. Caputi[1,2], D. Helmig[1], L. S. Darby[1,3], G. Greenberg[1,4], J. Hueber[1], S. Simoncic[1,5], and J. Ortega[1]

March 20, 2021

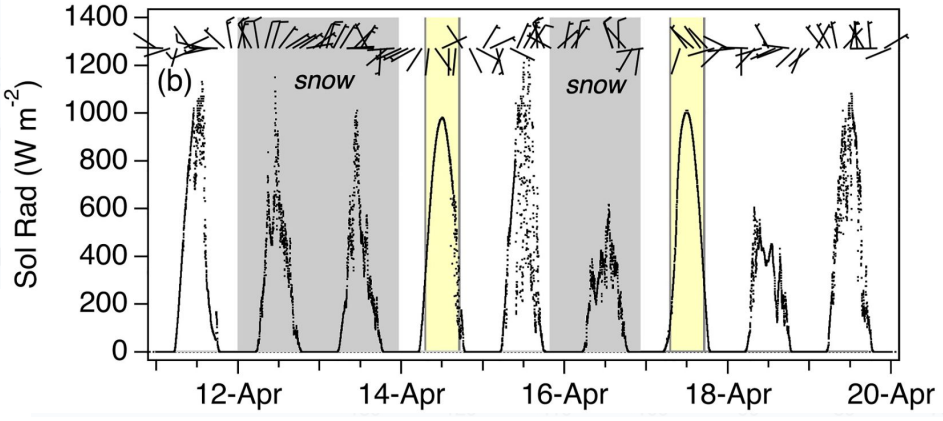


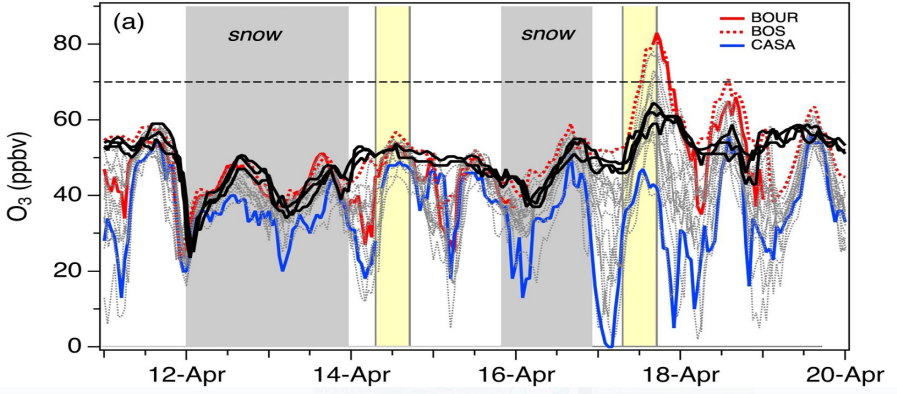
Ingredients for wintertime ozone production

- Sunny skies following snow cover leads to increase photochemistry
- Statically stable boundary layer (inversion) traps pollutants near the surface and allows ozone to build up



- Winter ozone events are more to be associated with **NO_x-saturated (VOC-limited)** conditions





Langford et al., 2025