NMED CAMx 2022v2 12/4 km

CAMx 2022v2 12/4 km Base Case Simulation

Model Performance Evaluation and Sensitivity Tests

April 9, 2026

RAMBOLL

Bright ideas.
Sustainable change.

Content

- Preliminary assessment of Phase 2 CAMx 2022v2 12/4 km base case model performance

Phase	Modeling Platform	Identifier (short name)
Phase 2	2022v2 12/4 km with 4 km met & emissions	NMED_4km2022v2
Phase 1	2022v1 12/4 km with flexinest emissions	NMED_4kmflxNest
Phase 1	2022v1 12 km EPA Platform	12US2_4kmNMED

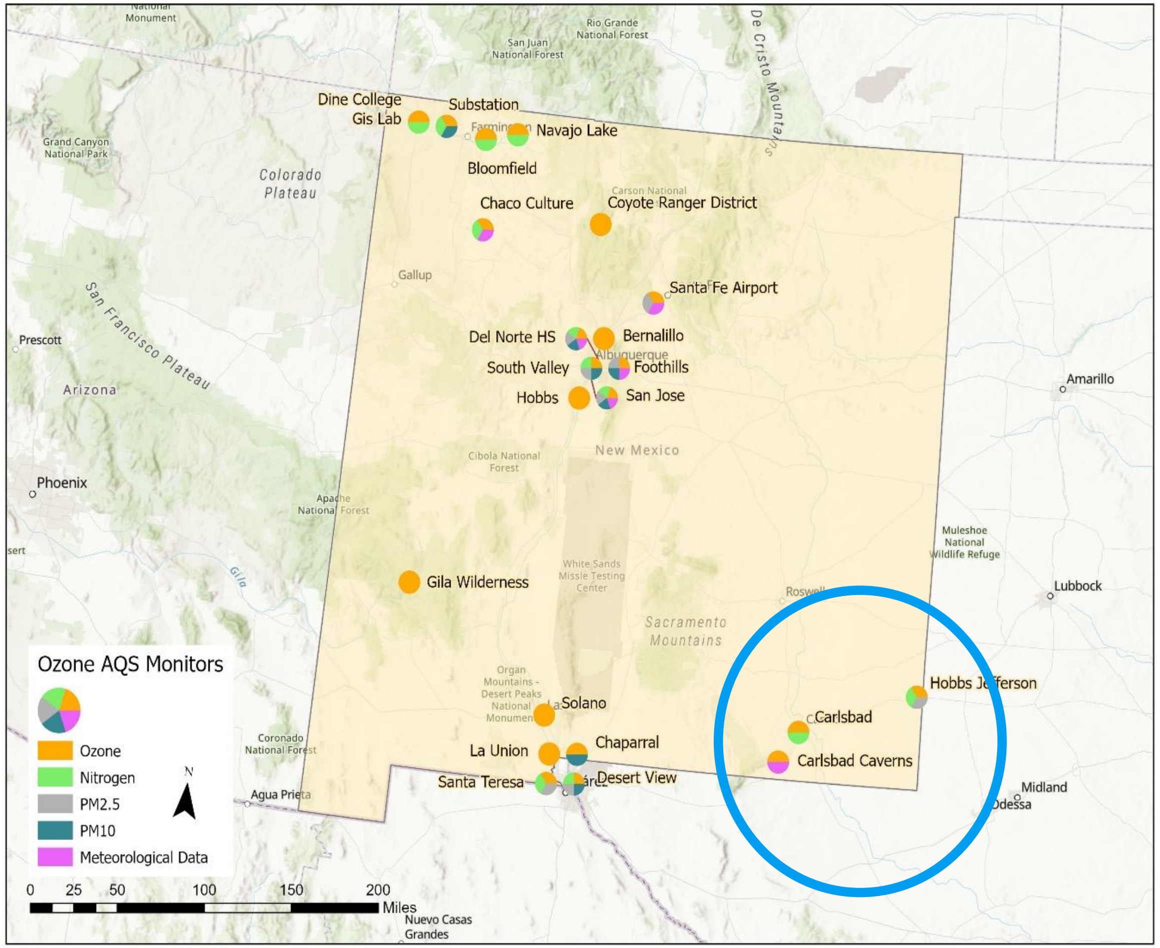
- Evaluation using AQS ozone and NO_X measurements in Permian Basin
- Evaluation using 2021 CarCavAQS and 2023 HEI Loving, NM field study VOC and NO_X data
- Relationship between ozone and temperature
- TROPOMI Satellite NO_2 and HCHO comparisons
- Selection of 20-day period for 2022 Sensitivity tests
- Initial CAMx 2022v2 12/4 km sensitivity tests
  - Vertical Mixing Sensitivities
  - Permian Basin O&G Emissions Sensitivities
- Next Steps:
  - Task E: Local Source Ozone Source Apportionment Modeling
  - Task F: State and International Ozone Source Apportionment Modeling

Base Case Ozone Evaluation

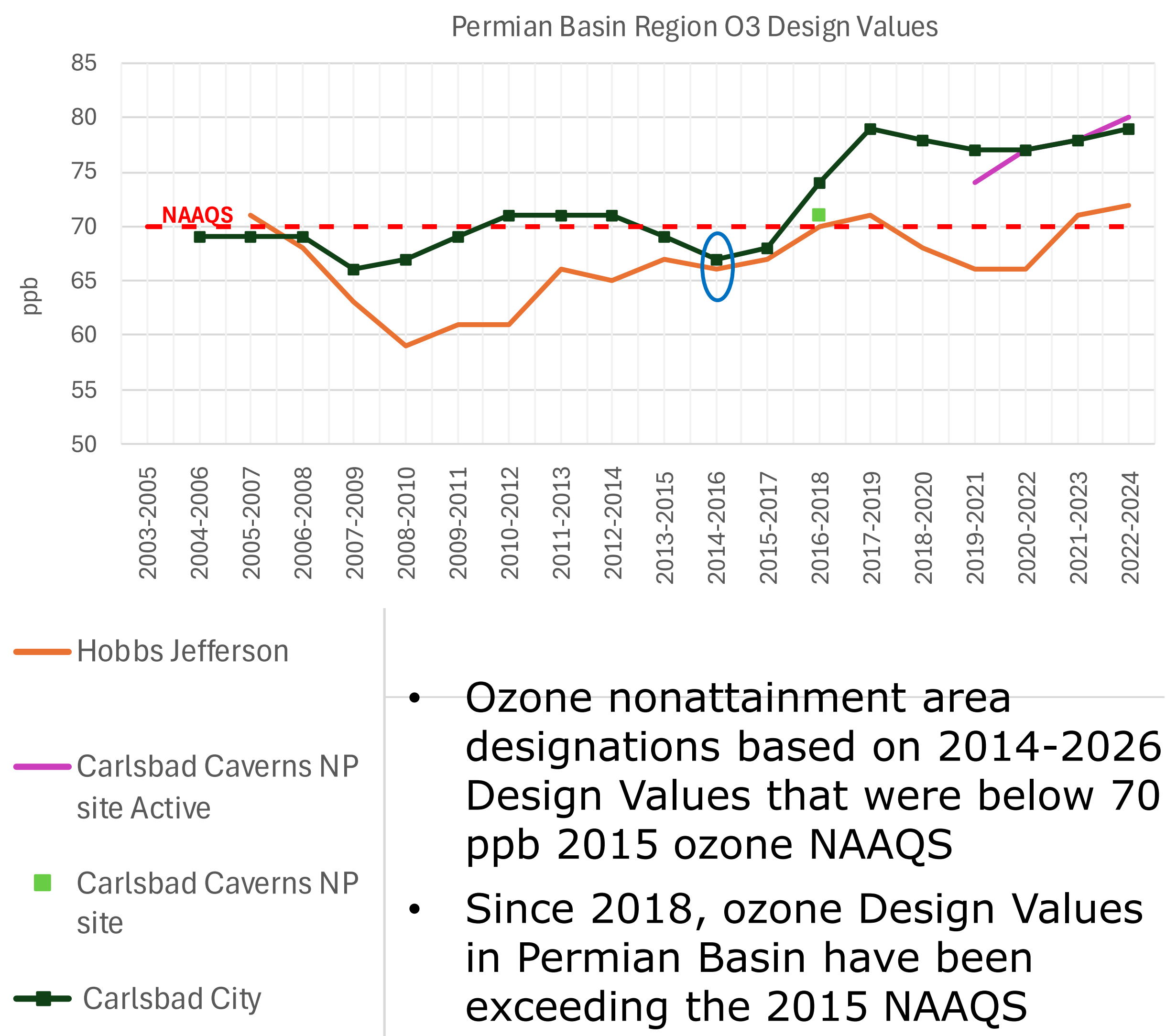
Phase I (4 km 2022v1 Flexinest) vs. Phase II (4 km 2022v2)

Phase II: May – September 2022 (5 months)

Preliminary MPE focus on Ozone and NOx in NM Permian



Site ID	County	Location
350150010	Eddy	Carlsbad Caverns
350151005	Eddy	Carlsbad (City)
350250008	Lea	Hobbs Jefferson



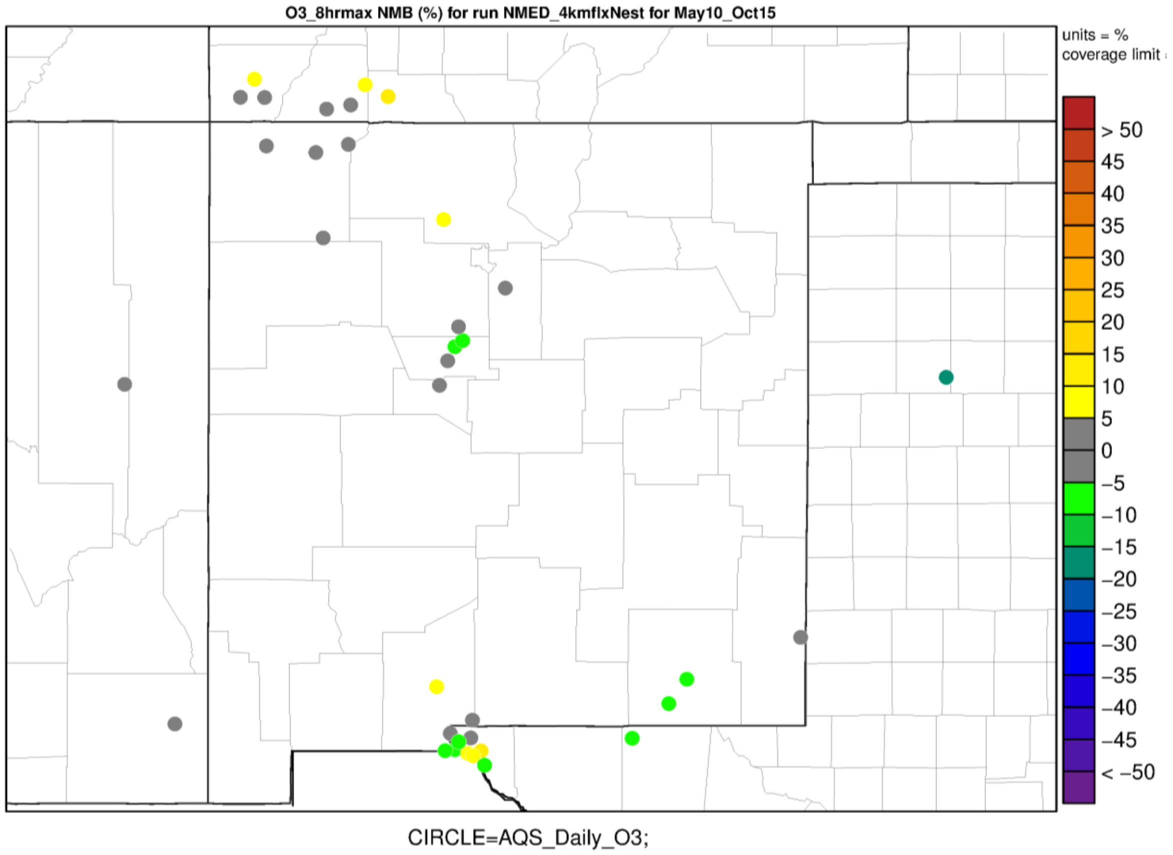
- Ozone nonattainment area designations based on 2014-2026 Design Values that were below 70 ppb 2015 ozone NAAQS
- Since 2018, ozone Design Values in Permian Basin have been exceeding the 2015 NAAQS

MDA8 O3 Normalized Mean Bias (NMB)

Goal: NMB≤±5%
Criterion: NMB≤±15%

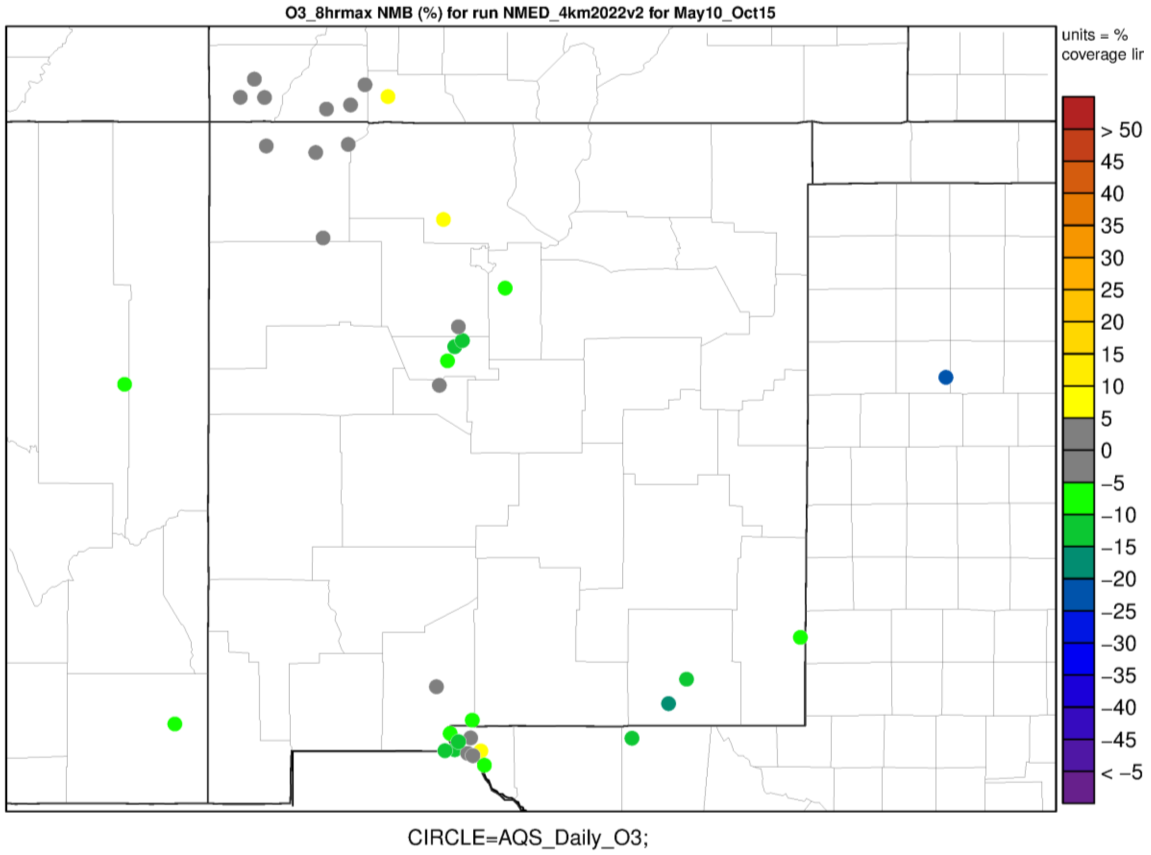
Phase I 4kmflexinest 2022v1
4 km Met / 12 km Emissions

4kmflxnest: 12km Interpolated to 4 km (flexinest)



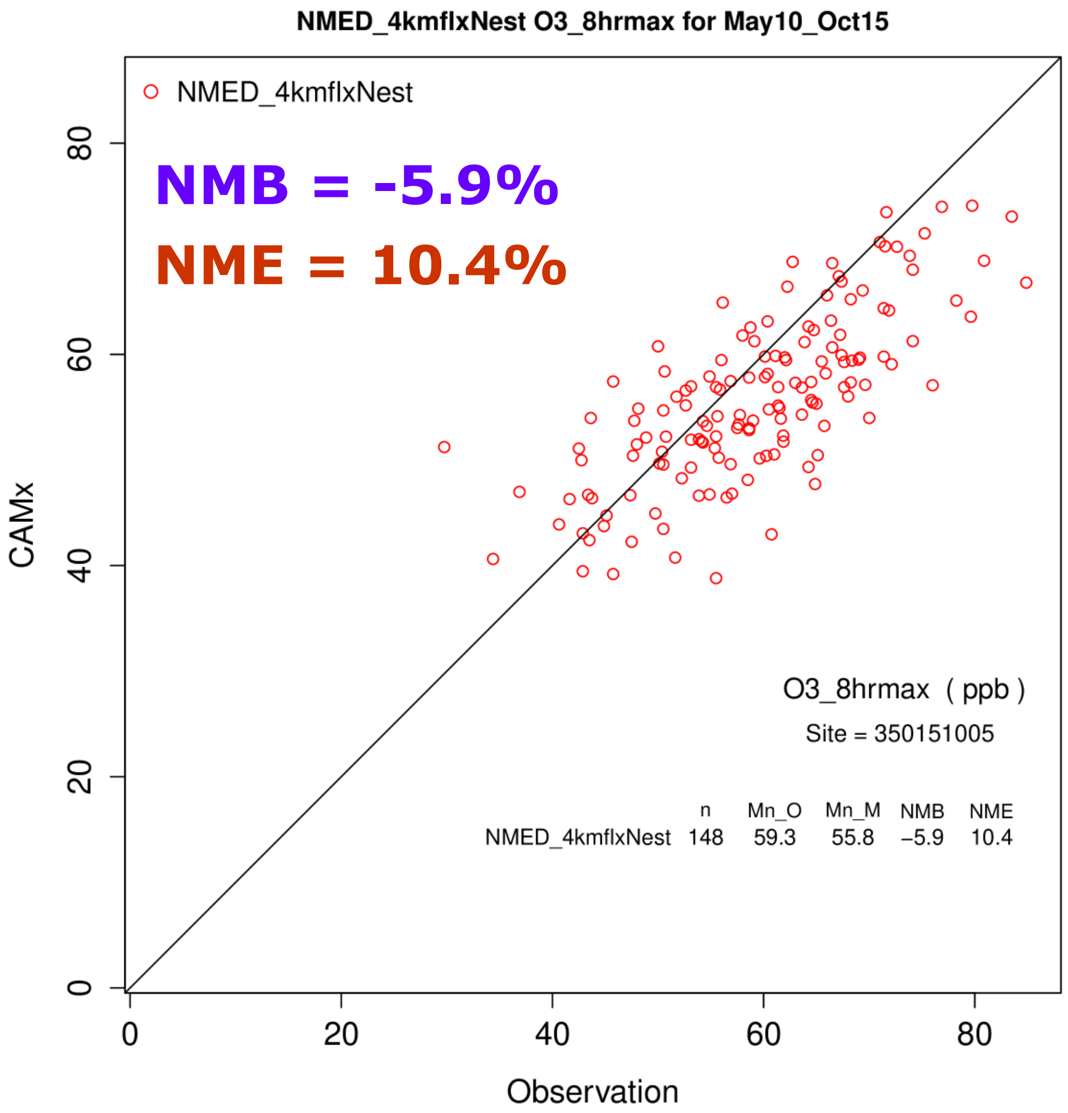
Phase II 4km2022v2
4 km Met & Emissions

4km2022v2: Native 4 km

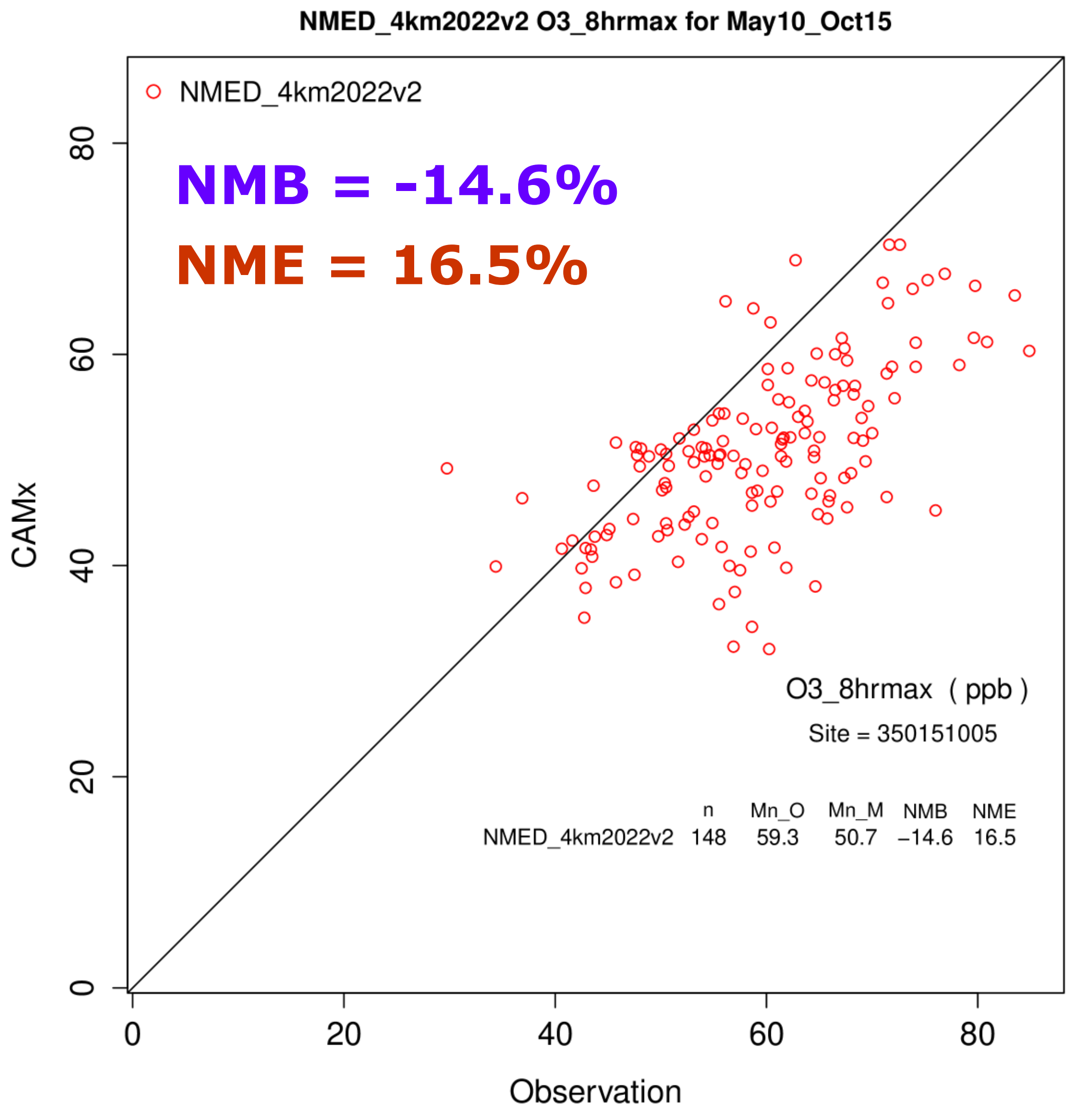


MDA8 O3 NMB May-Oct 2022: Carlsbad City

Phase I: 4kmflxnest2022v1

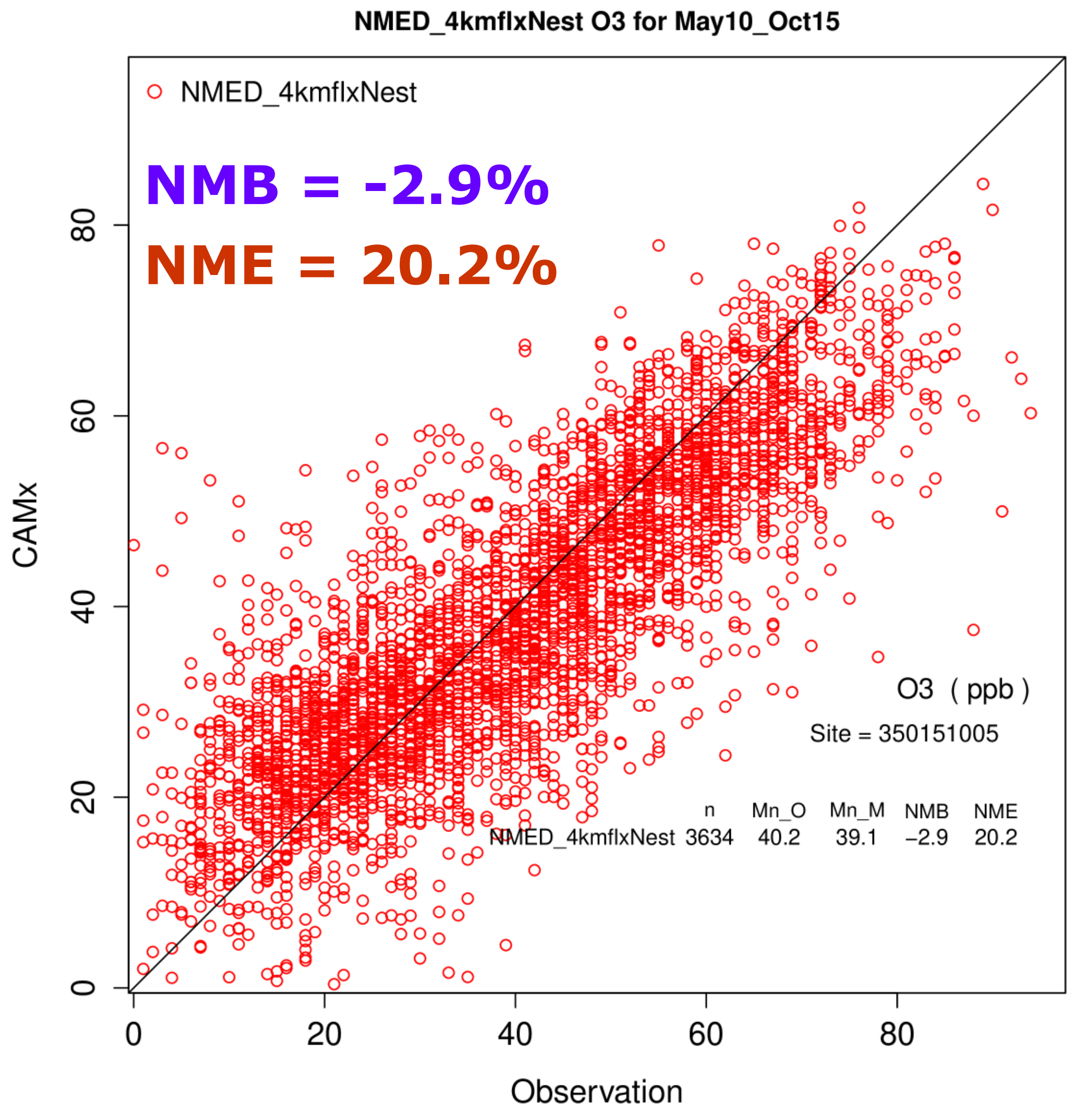


Phase II 4km2022v2

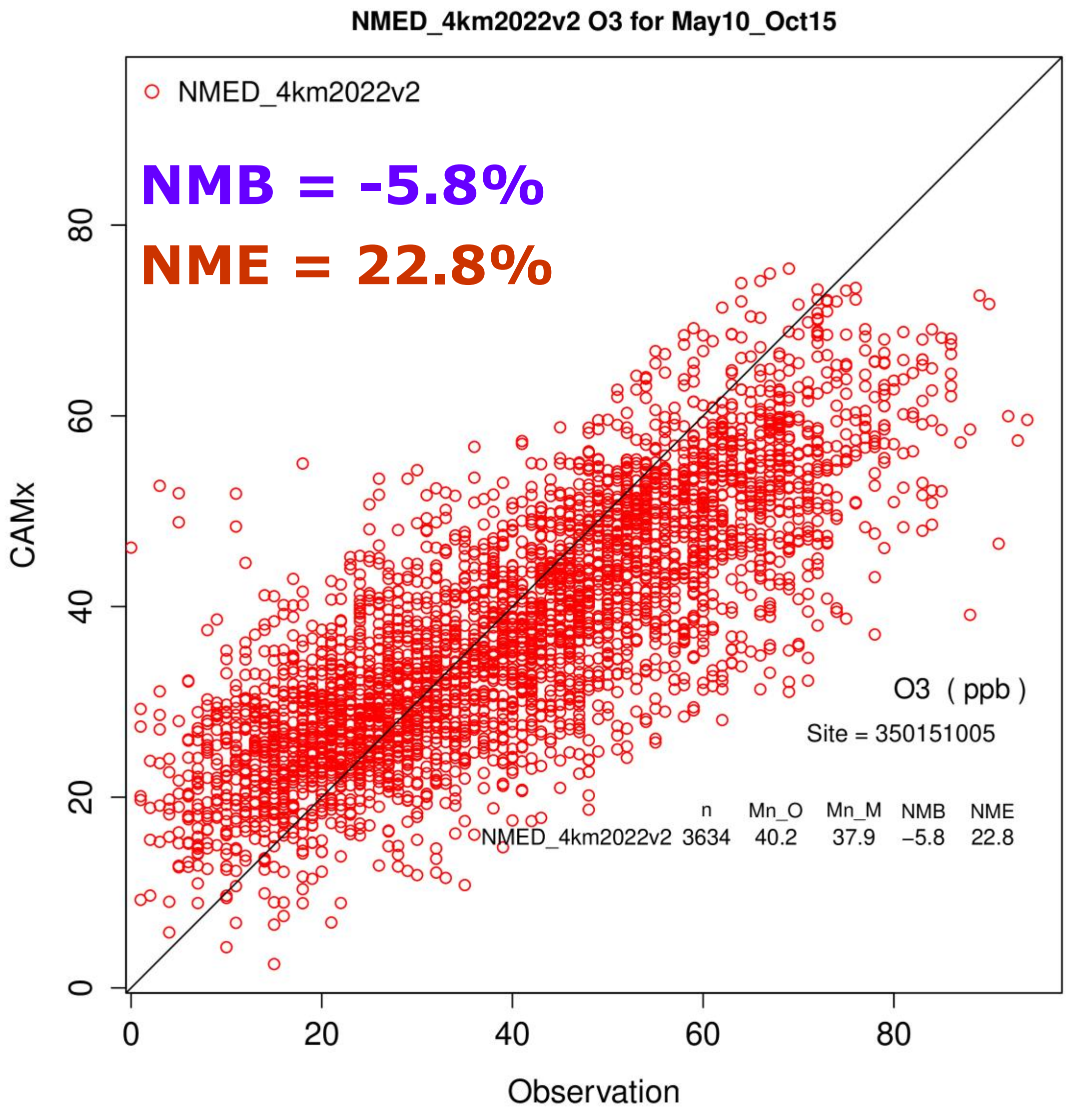


Hourly O3 May-Oct 2022: Carlsbad City

4kmflxnest 2022v1

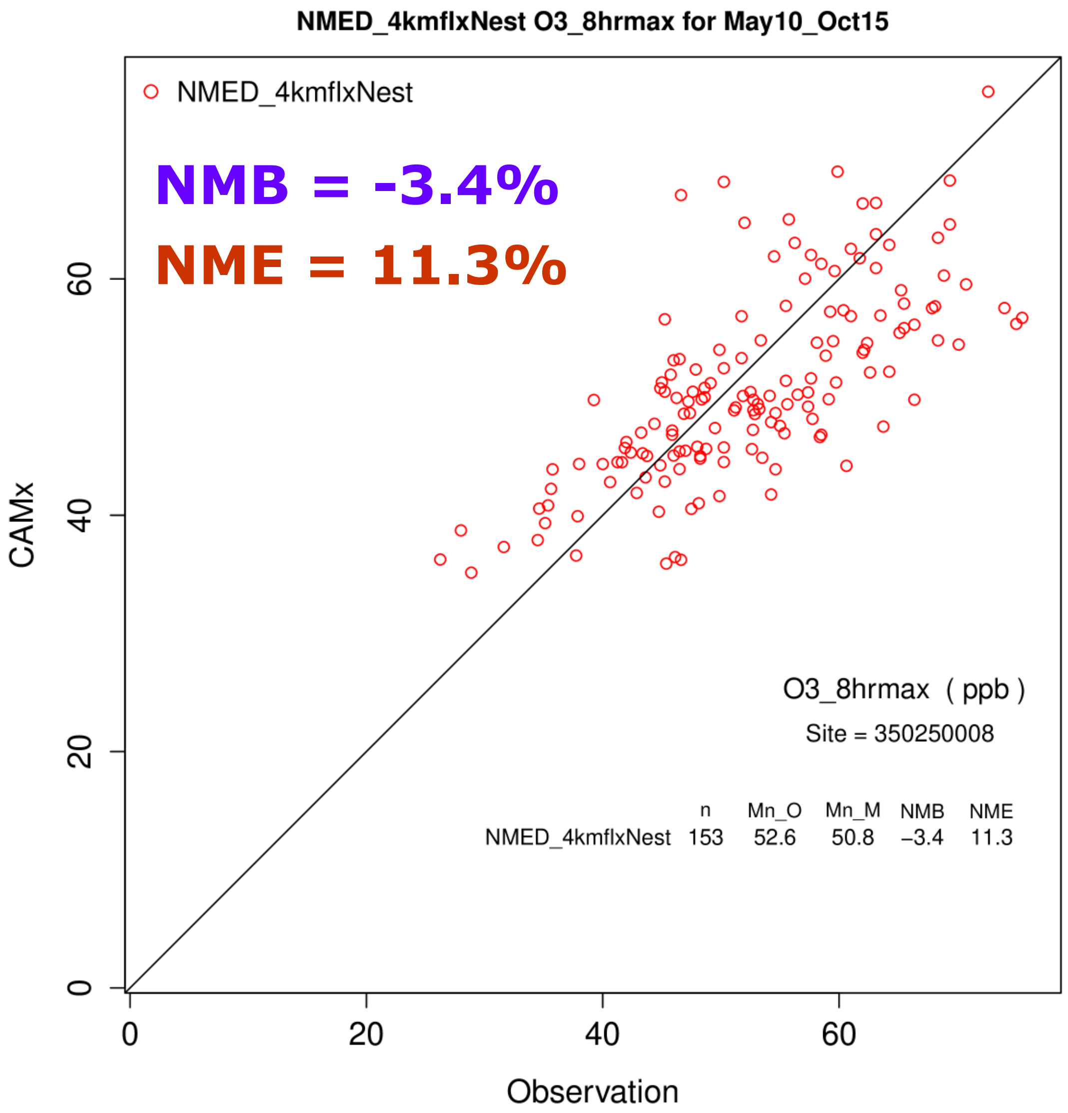


4km2022v2

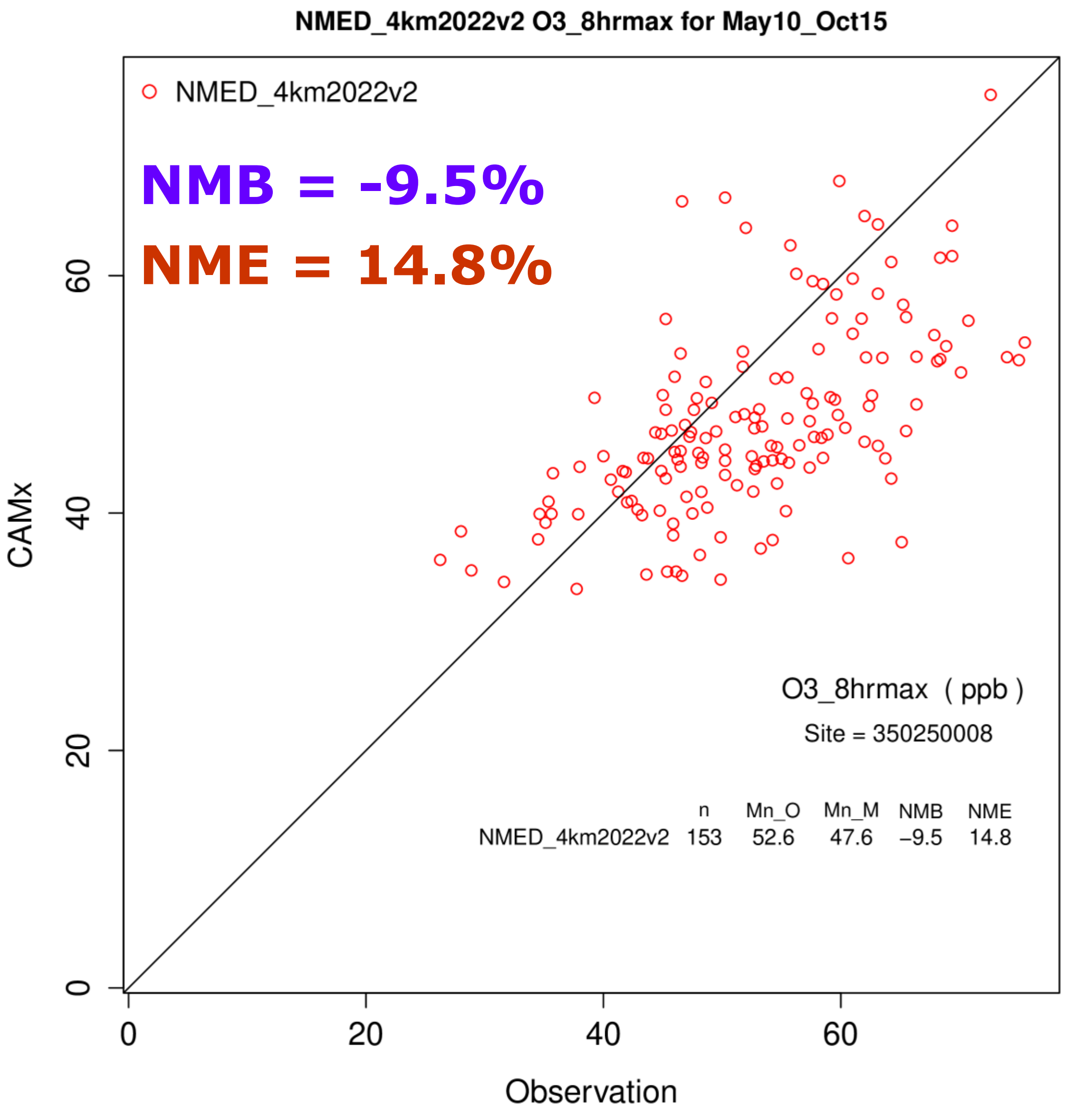


MDA8 O3 NMB May-Oct 2022: Hobbs

4kmflxnest 2022v1

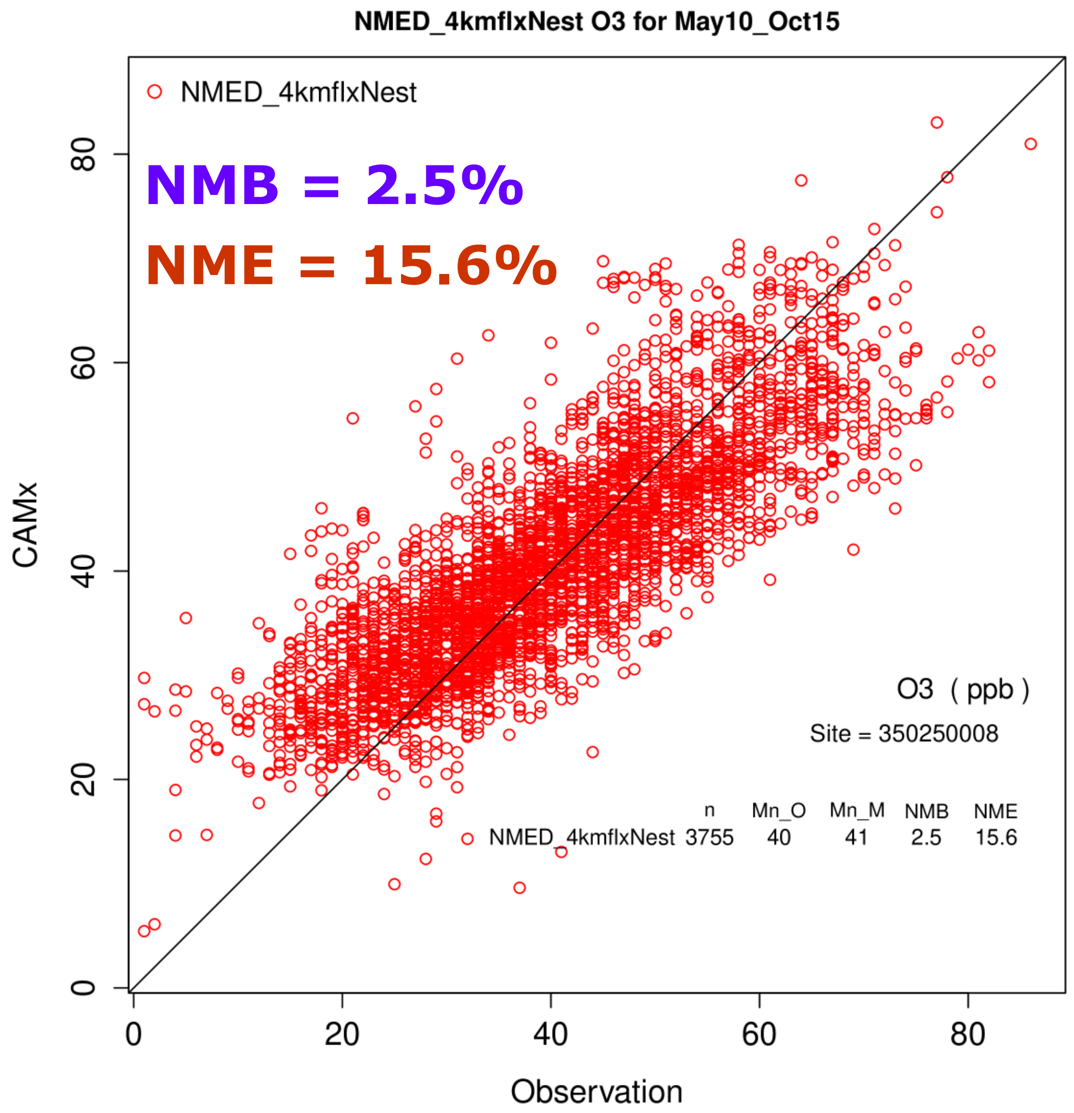


4km2022v2

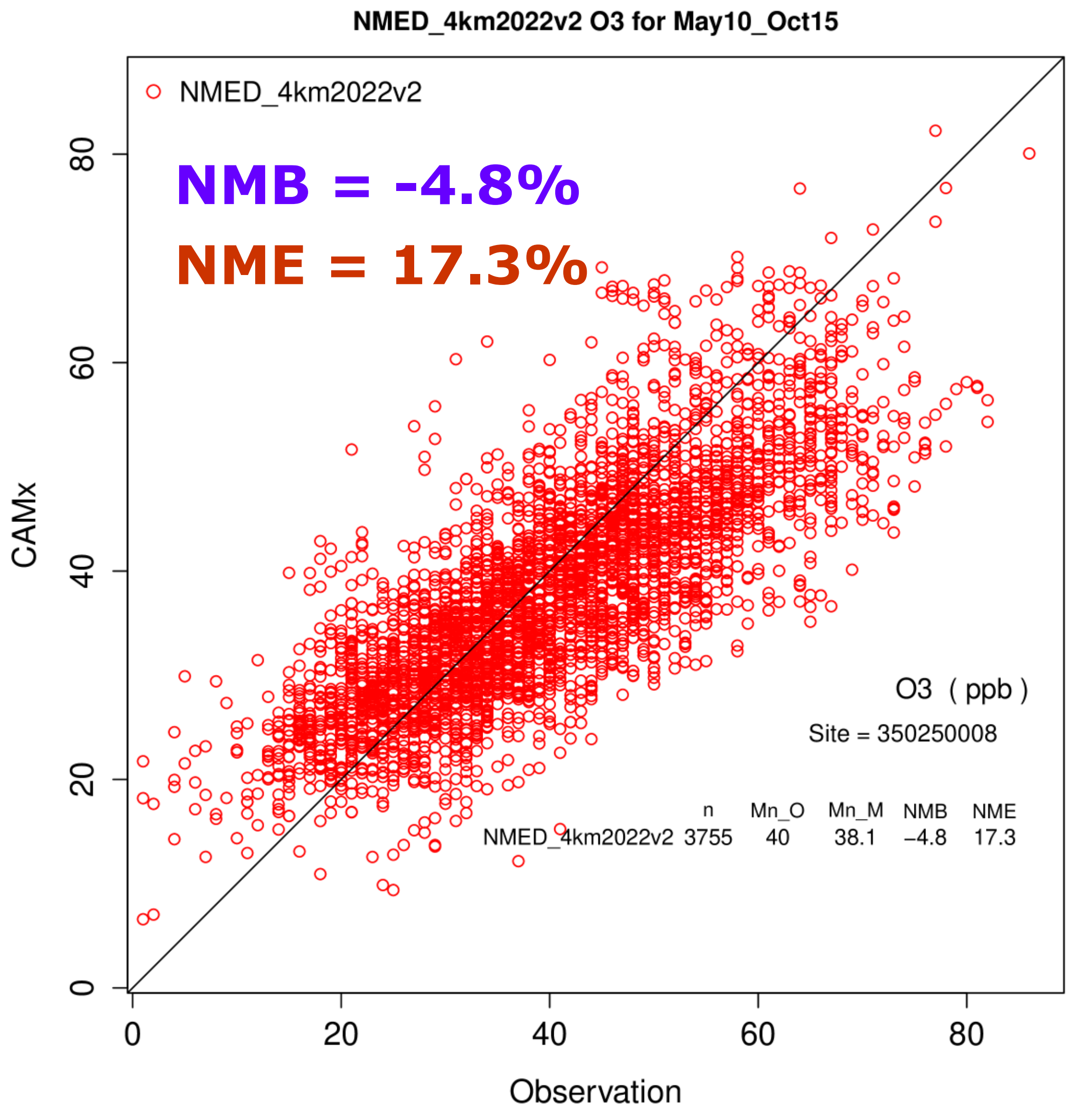


Hourly O3 May-Oct 2022: Hobbs

4kmflxnest 2022v1



4km2022v2

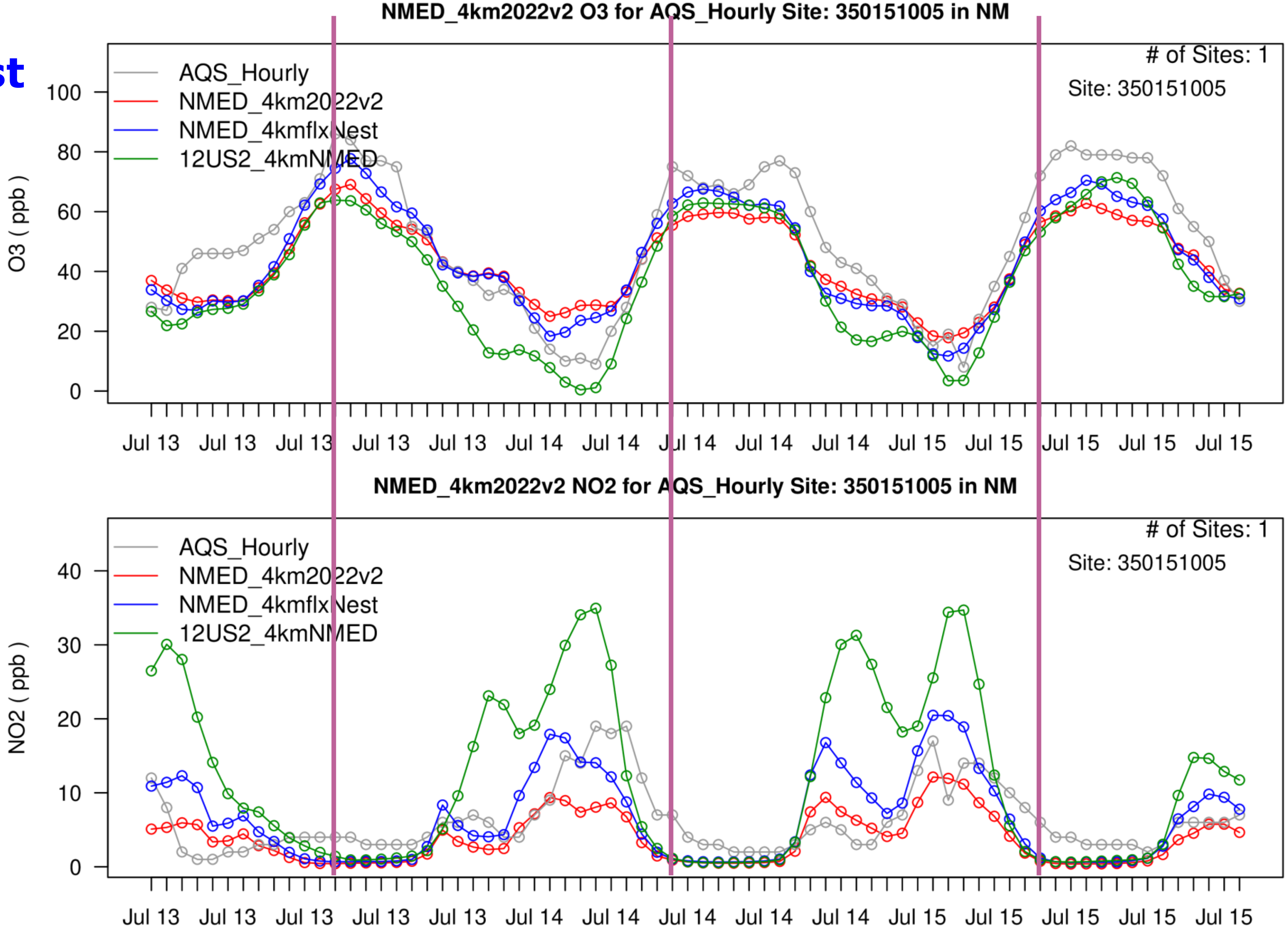


July 13-15, 2022: Carlsbad City: Ozone (top) and NO_2 (bottom)

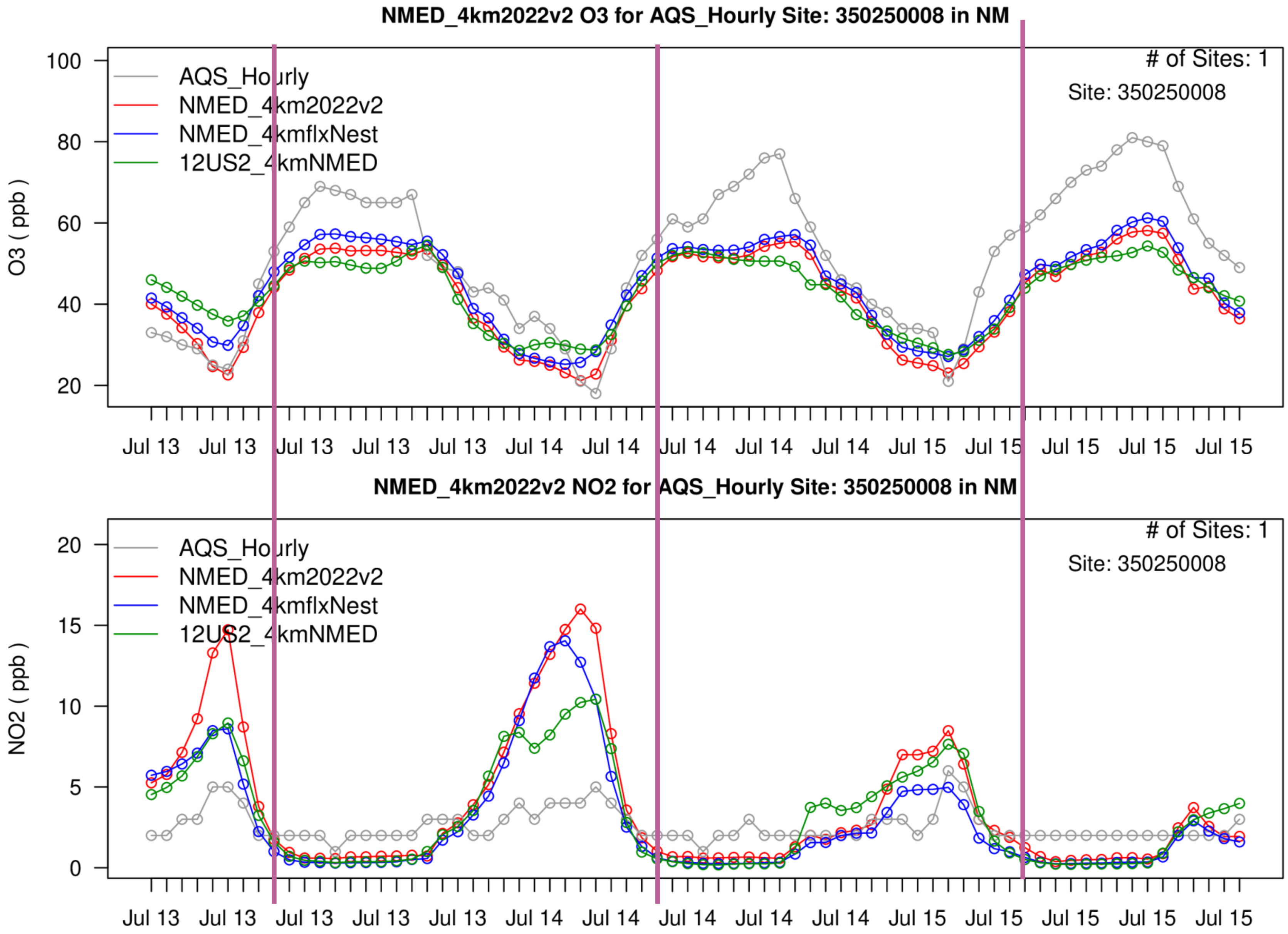
4km2022v2
4km2022v1_flexinest
12km2022v1

Modeled O_3 stalls in early afternoon while observed O_3 keeps rising.

Modeled NO_2 is nearly depleted in early afternoon limiting photochemistry while observed NO_2 stays higher.



July 13-15, 2022: Hobbs – Ozone (top) and NO_2 (bottom)?



Preliminary Ozone and NOx MPE of Initial Phase 2 CAMx 12/4 km Simulation

- **Why did Phase I CAMx 2022v1 4 km flexinest obtain better ozone model performance than Phase II CAMx 4 km 2022v2?** 2022v2 4 km emissions degrade ozone model performance relative to the 2022v1 flexinest platform, particularly in the Permian Basin.
  - Carlsbad City MDA8 ozone NMB underprediction degrades from -6% to -15%

- 2022v2 New Mexico O&G non-point NO_x emissions are 40% lower than 2022v1, excerpt from the 2022v2 EITSD, which may explain the weaker ozone performance

> **2.2.4 Nonpoint Oil and Gas Sector (np_oilgas)**
>
> ***2022v2 updates relative to earlier 2022 emissions modeling platforms***
>
> The 2022v2 emissions changes for the non-point oil and gas sector included the following:
>
> - Nonroad emissions factor correction which significantly reduced NOX emissions (about 74%) from drill rigs and hydraulic fracturing engines

- This implies a 74% reduction in drilling and fracing engine NO_X emissions reduced Non-Point O&G NO_X emissions by 40%, which seems reasonable. The higher O&G NO_X emissions in 2022v1 explains the better ozone performance than obtained using the 2022v2 emission inventory

Preliminary Ozone and NOx MPE of Initial Phase 2 CAMx 12/4 km Simulation

What we learned from hourly timeseries: Observed O_3 continues rising into the afternoon, while modeled O_3 stalls. During these hours, observed NO_2 remains elevated, but modeled NO_2 drops to near zero, shutting down NO_2 photolysis and halting ozone production.

Outstanding Questions:

- Are Permian Basin O&G NO_X and/or VOC emissions understated?
- Could observed NO_2 be higher than modeled simply due to the minimum detection level for NO_2 monitors, especially at Hobbs?
- Can there be NO_2 measurement interference with other species (e.g., PAN, PNA, HNO3) resulting in higher measured “NO_2”?

Next Steps: While developing 2032 emissions, investigate CAMx ozone model performance using additional performance approaches and conduct sensitivity tests for a selected episode in May-October 2022:

- Vertical mixing sensitivity tests: to check for NO_2 over-dilution
- Emissions sensitivity tests: because Permian Basin O&G emissions might be understated

CarCavAQS Evaluation

2022 modeling VS. 2021 Measured VOC and NOx

Evaluation Against 2021 CarCavAQS Data

- CSU, NPS and others collected ozone, NOx and VOC samples during 2019 and 2021 summer periods at Carlsbad Caverns NP
- Although not concurrent with our summer 2022 modeling episode, comparing the distributions of concentrations provide indication of model performance for ozone precursors

Carlsbad Caverns Intensive Air Quality Study

Measurements

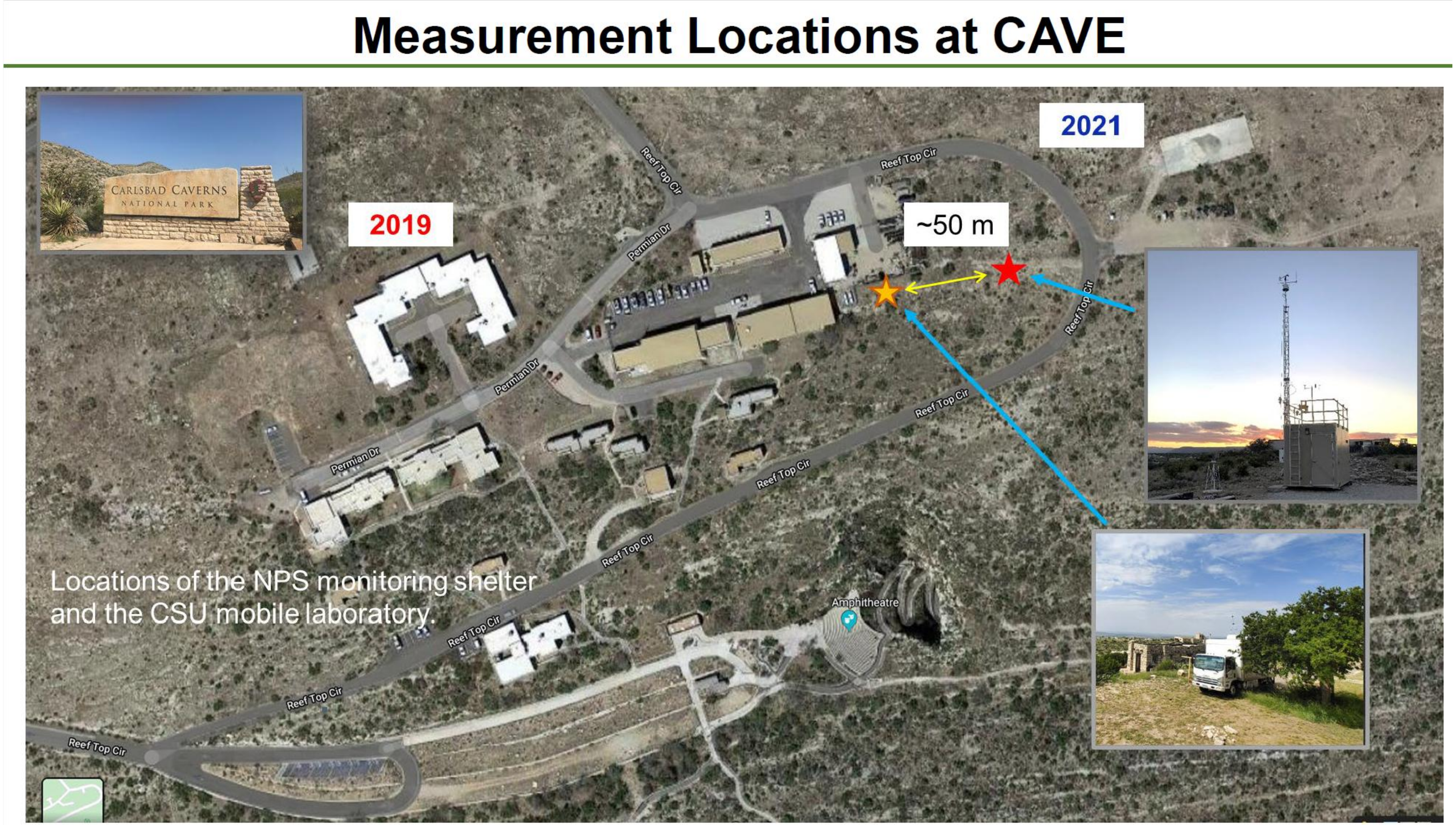
2019
7/24 → 9/3

- NO, NO_2, NO_y
- CH_4, NH_3, CO_2
- PAN, PPN
- Real-time GC: C_2-C_{10} NMHCs, C_1-C_5 alkyl nitrates, C_1-C_2 halocarbons, OVOCs, etc.
- PTR-MS: VOCs, OVOCs, S cmpds
- $PM_{2.5}$ mass and composition (Na^+, NH_4^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, Acetate, Formate, Glycolate, Oxalate)
- 24-hr NH_3, HNO_3, SO_2, & $PM_{2.5}$ composition
- Carbonyl cartridges (10 AM – 5 PM)
- Aethalometer (black carbon)
- NPS/ARS operated real-time O_3, SO_2, CO and meteorology
- GUMO O_3 and Meteorology

2021
7/17 → 8/19

- NO, NO_2, NO_y
- CH_4, C_2H_2, CO_2
- Real-time GC: C_2-C_{10} NMHCs, C_1-C_5 alkyl nitrates, C_1-C_2 halocarbons, OVOCs, etc.
- EPA Remotely Operated Canister Sampler (ROCS) – 4 locations
- Sensor $PM_{2.5}$ & PM_{10} (CAVE & GUMO)
- NOAA GEM, THg & RM
- UNR Passive Hg Samplers (GUMO)
- SENSIT SPOD
- Entanglement AROMA-VOC
- NPS/ARS operated real-time O_3 & meteorology
- GUMO O_3 and Meteorology

CarCavAQS 2019 and 2021 Monitoring Sites



VOC Evaluation (MPE) using 2021 CarCavAQS

The Challenge to Compare VOCs

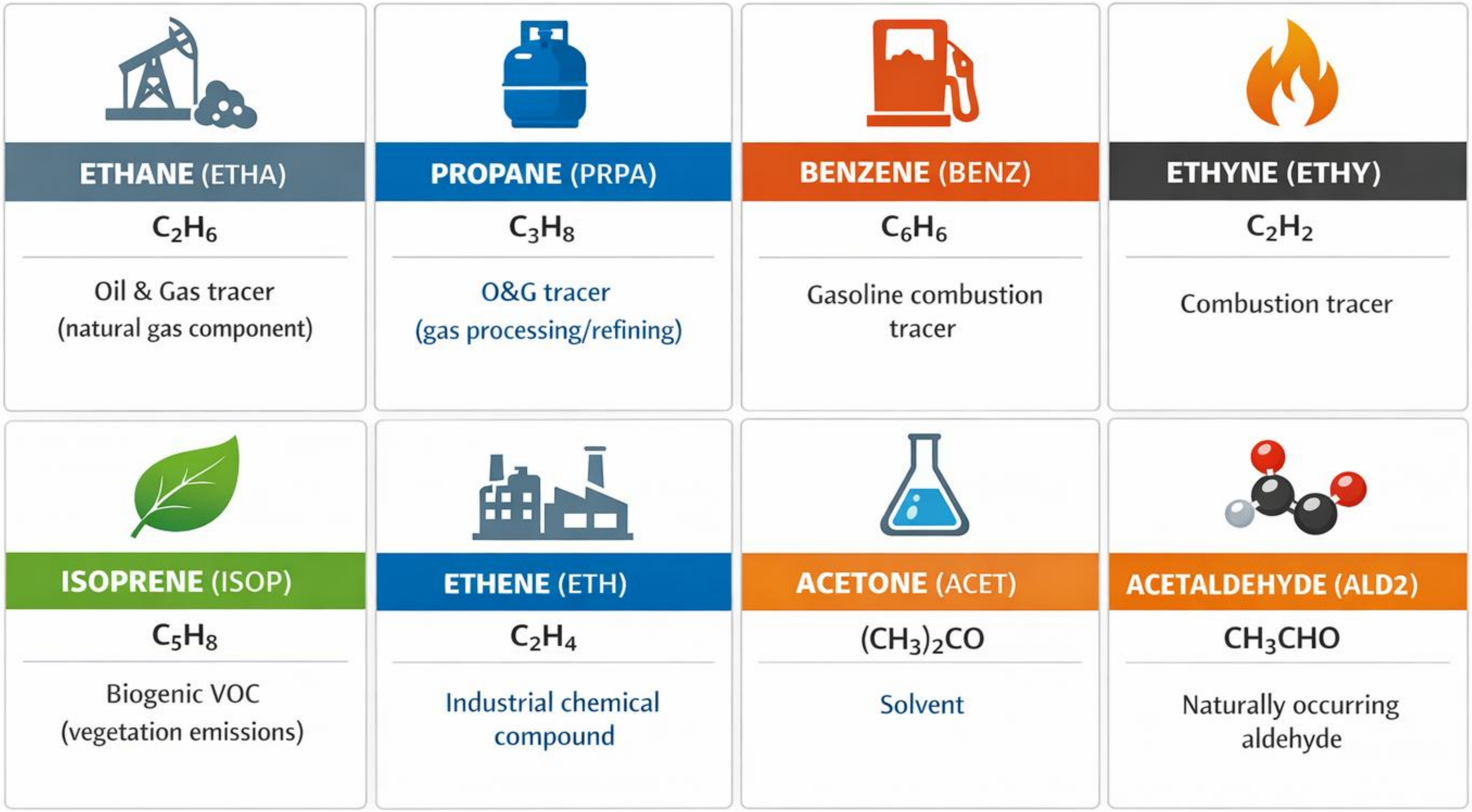
- CAMx 2022v2 12/4 km uses the CB7r1 chemical mechanism.
- CB7r1 “lumps” thousands of individual VOCs into ~100 reactivity-based groups, limiting one-to-one comparison with observations.
- Only a handful of VOCs are treated explicitly, so evaluation must rely on these few species to infer broader model performance.

CAMx VOCs Evaluation Process

The CAMx 2022v2 12/4 base case was evaluated for 8 explicit VOC species in the CB7r1 chemical mechanism using 2021 CarCavAQS measurement data

MODEL (CAMX 2022 12/4KM)	OBSERVATIONS (CarCavAQS 2021)	COMPARISON METHOD	DIAGNOSTIC INSIGHT
Explicit VOC outputs (8 species)	Field VOC measurements (July 17 - August 19, 2021)	Box-and-whisker plots	Distribution bias (under/over-prediction)
Hourly modeled concentrations	Hourly and integrated observations	Diurnal cycle analysis	Evaluates mixing and chemistry differences. Avoids time-alignment issues between model and observations

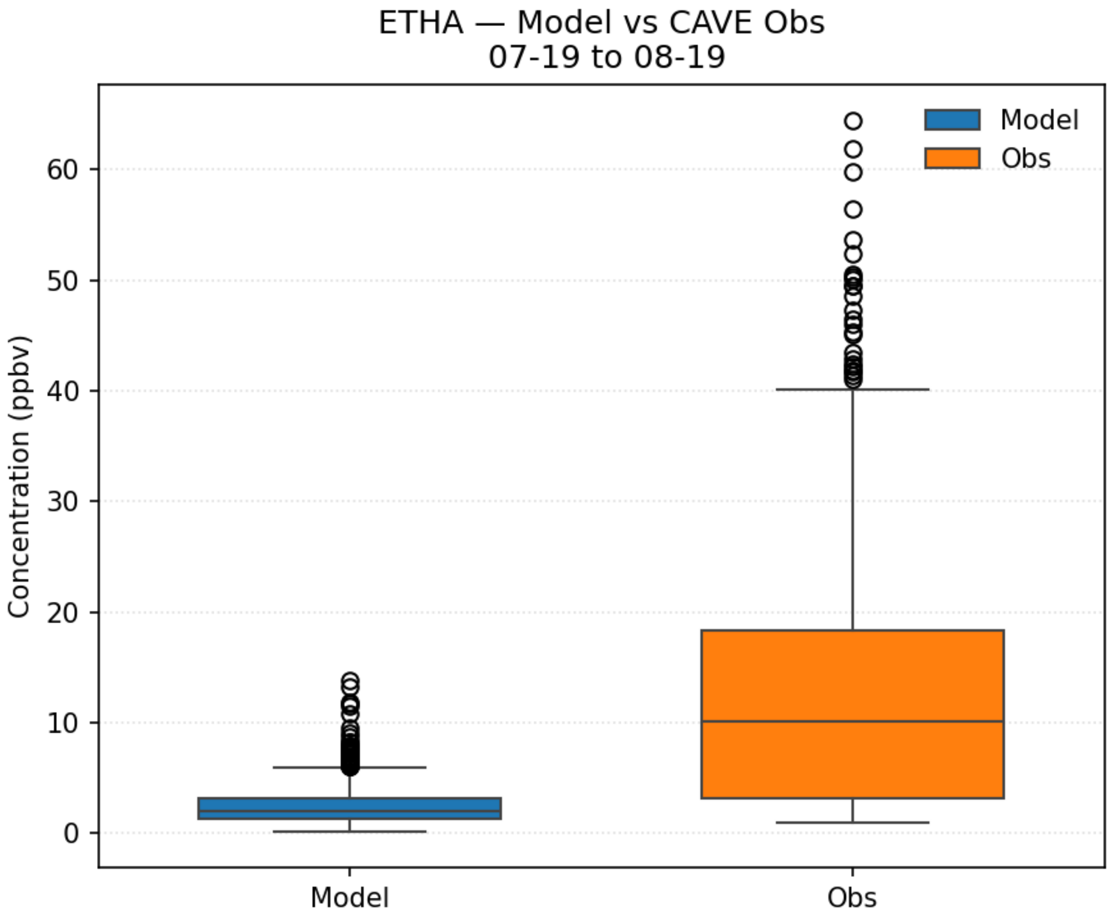
Evaluation for 8 Explicit VOC Species in CB6r5



Example Box and Whisker Plot for Ethane (ETHA)

Box and Whisker Plots

- The Box is the Interquartile Range (IQR) representing the 25th and 75th Percentiles of the distribution
- The Whiskers are highest (top) or lowest (bottom) value within 1.5*IQR
- Symbols above and below the Whiskers are “outliers”
- The line in the Box is the Median

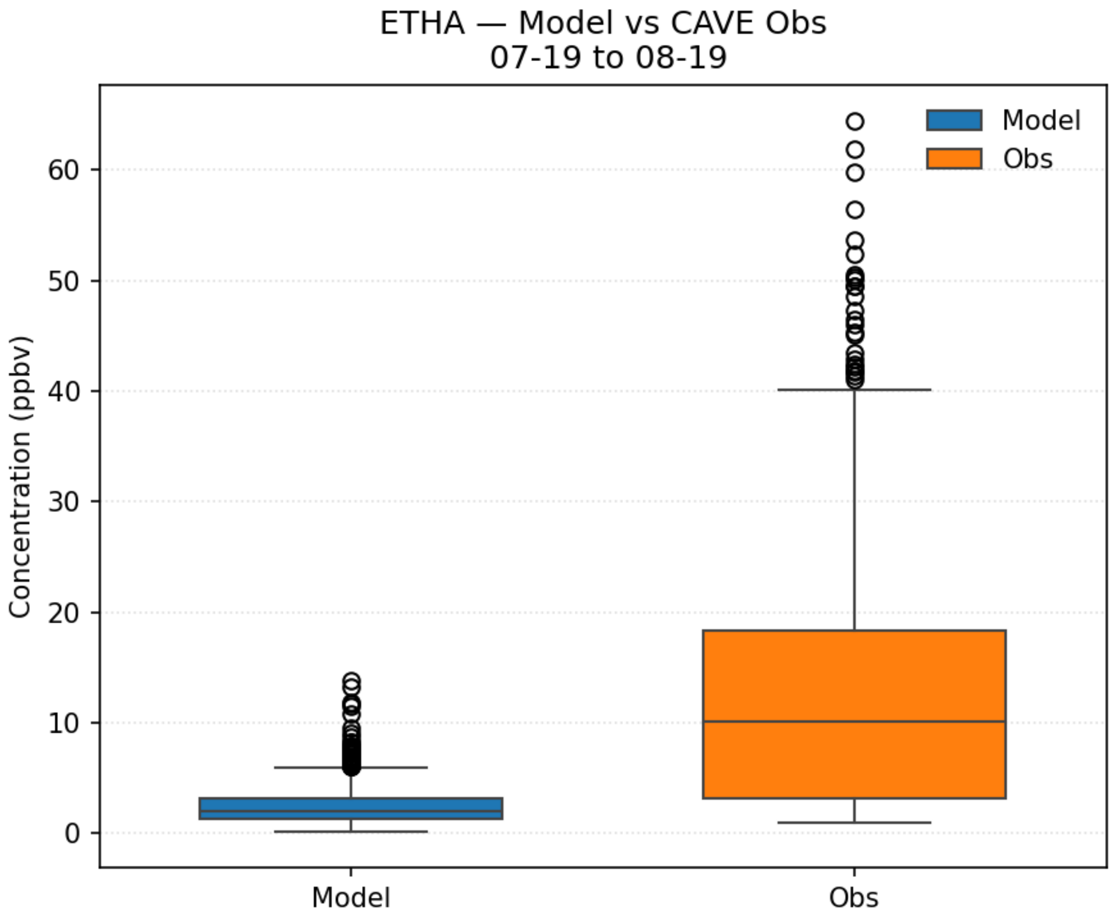


Ethane (ETHA) and Propane (PRPA) -- Oil and Gas Tracers

Results suggests 2022 oil and gas VOC emissions inventory may be understated in the Permian Basin

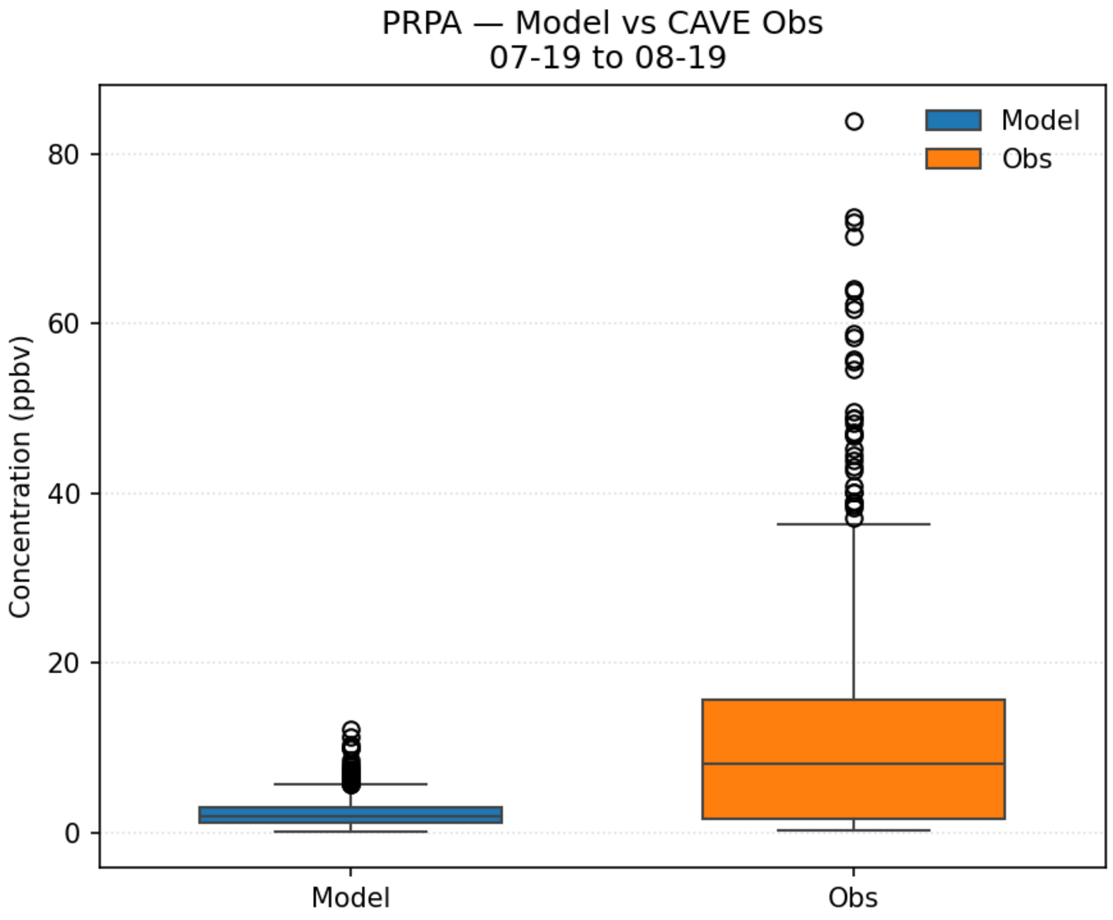
Ethane

- Median Underprediction: **5.3** times (10 vs 2 ppb)
- Mean Underprediction: **5.2** times (13 vs 3 ppb)



Propane

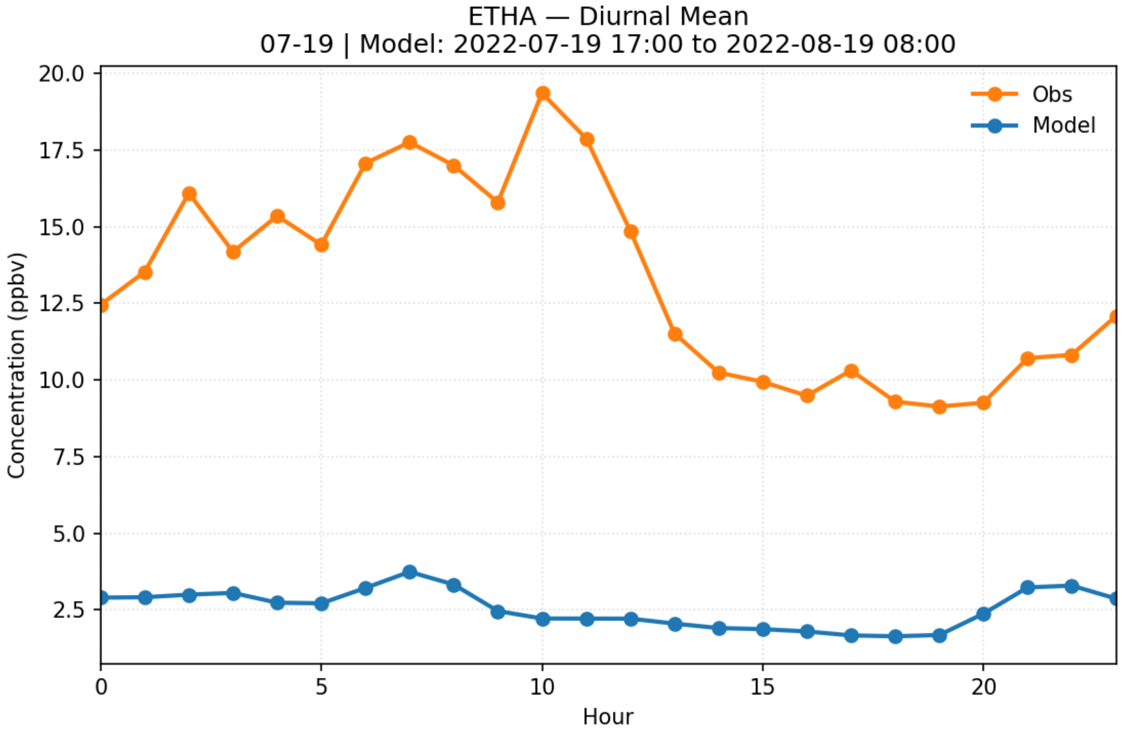
- Median Underprediction: **4.4** times (8 vs 2 ppb)
- Mean Underprediction: **5.2** times (12 vs 2 ppb)



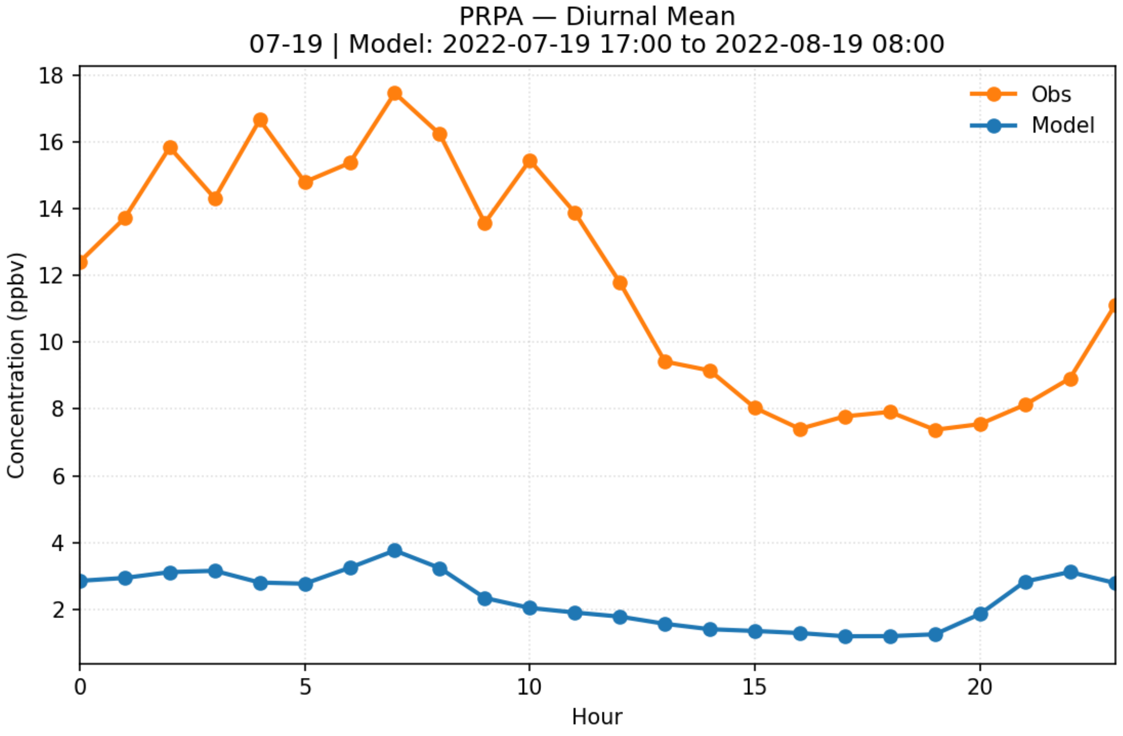
Ethane and Propane Average Diurnal Variation (O&G)

- Observed >> modeled concentrations
- Afternoon decrease in both datasets
- Observed ~30% drop > modeled drop

Ethane

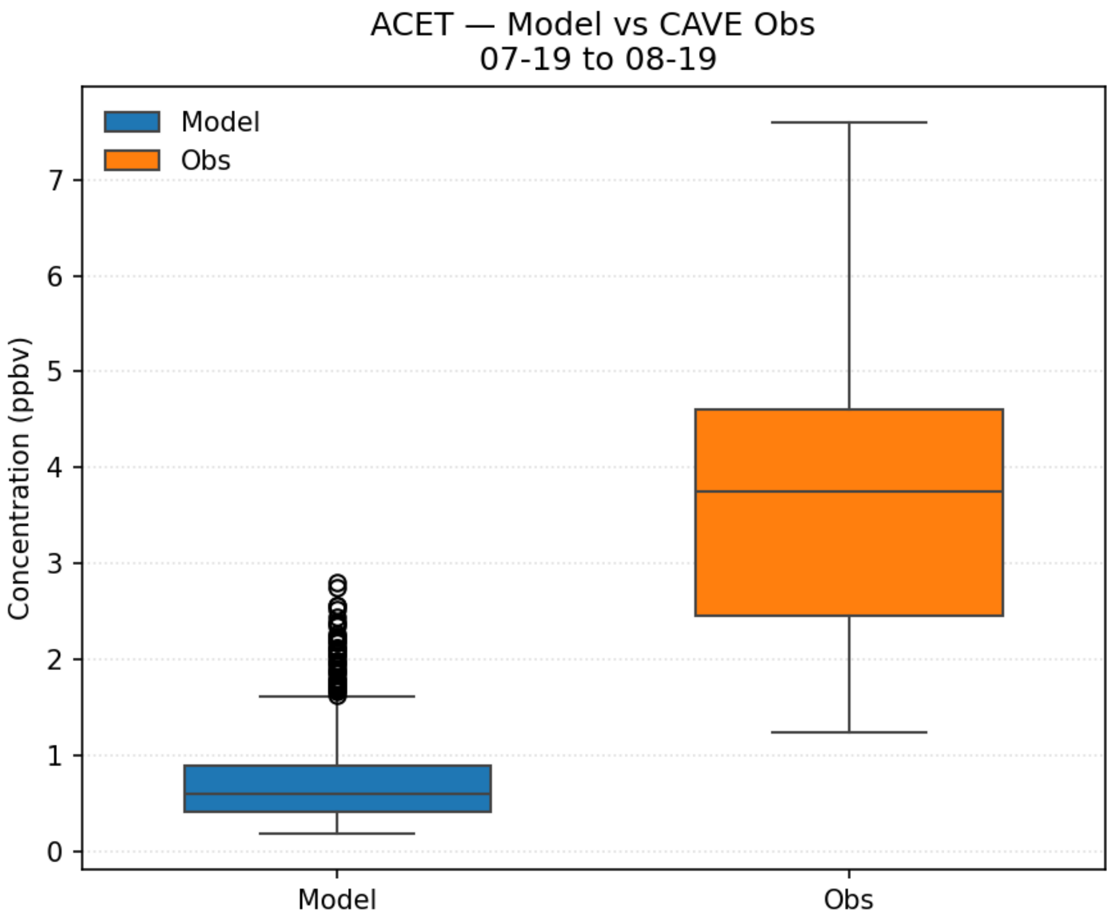


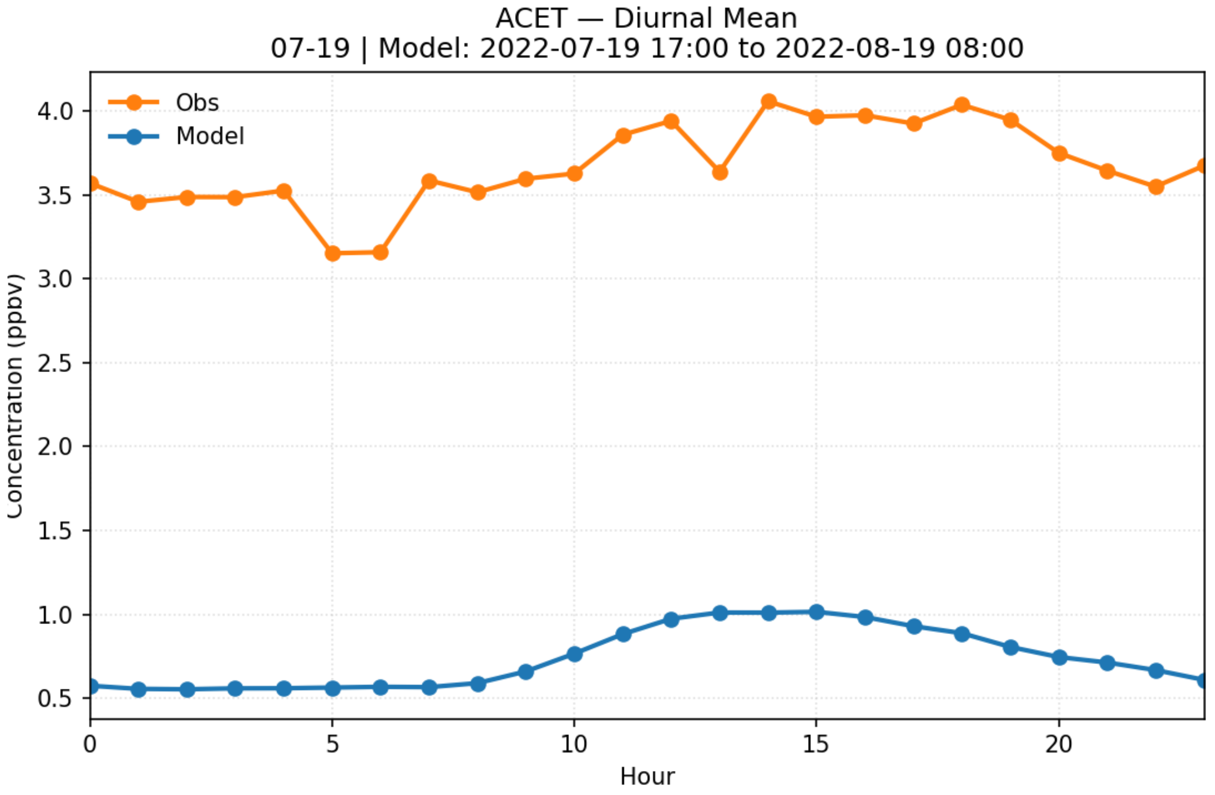
Propane



Acetone – Solvent used in O&G production

- Acetone is greatly underestimated by the model by factor of **5-6** on average (3.7 vs. 0.7 ppb) with the 75th percentile modeled value below the 25th percentile observed value

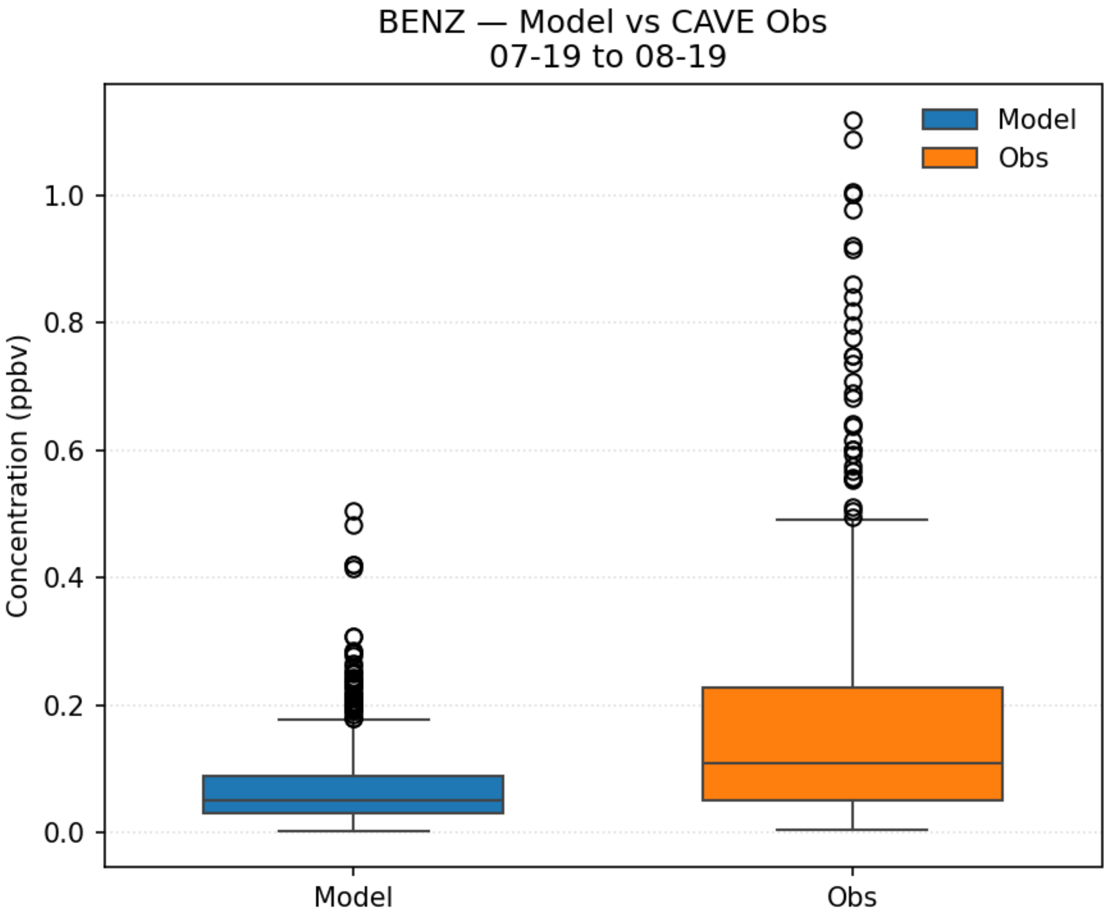




Benzene (Gasoline Combustion) and Ethyne (Combustion)

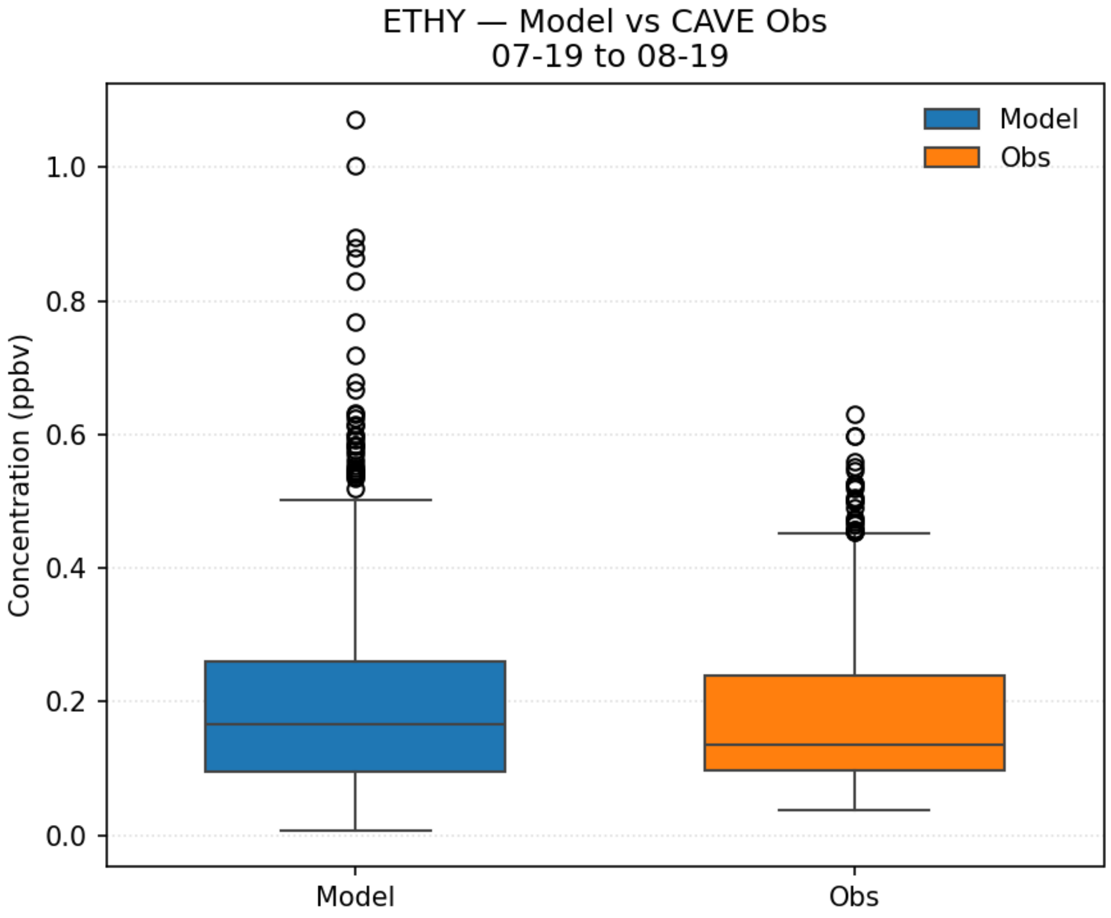
Benzene

- Median Underprediction: **2.2** times
- Mean Underprediction: **2.4** times



Ethyne

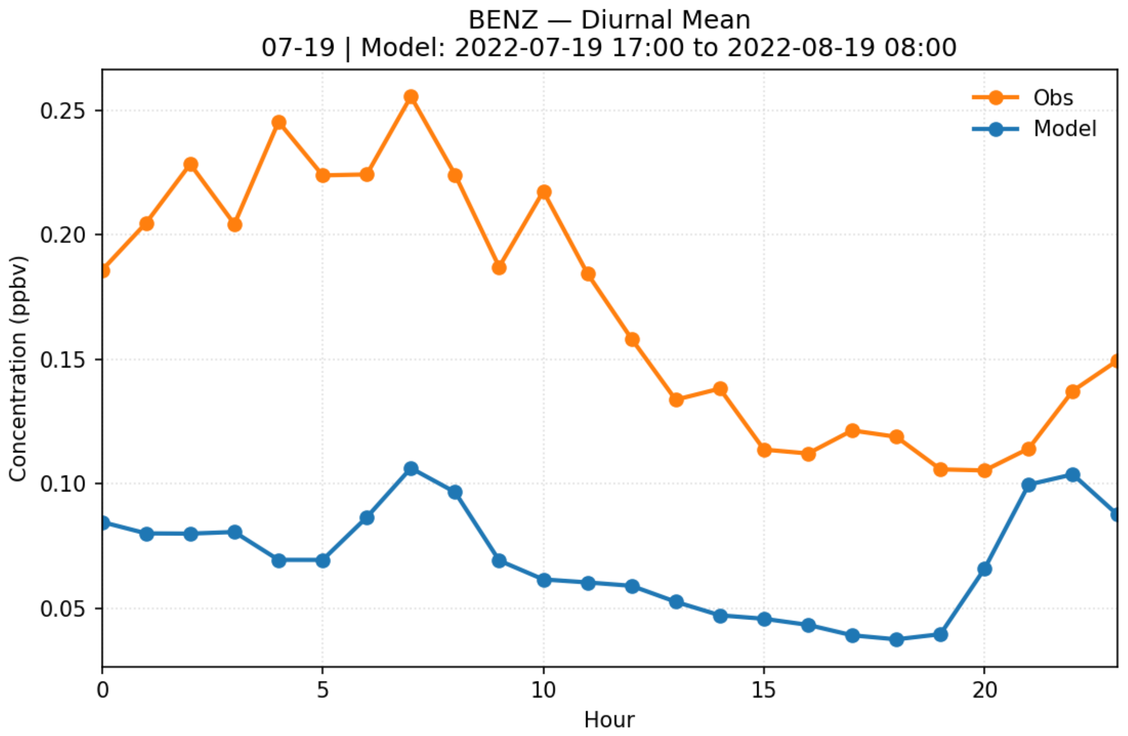
- Good agreement: median and mean within 10 to 15%
- Good match in IQR: 25% to 75%



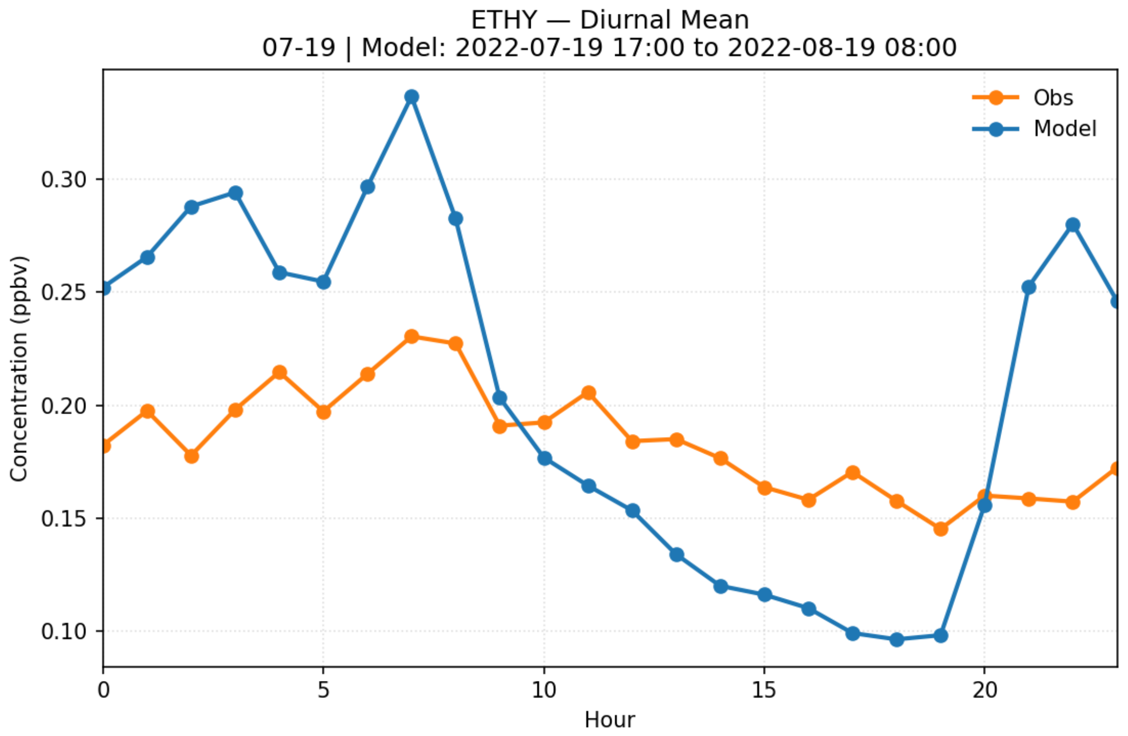
Benzene (Gasoline Combustion) and Ethyne (Combustion)

- Morning and afternoon commute periods evident in both species
- Modeled afternoon Ethyne lower than observed

Benzene

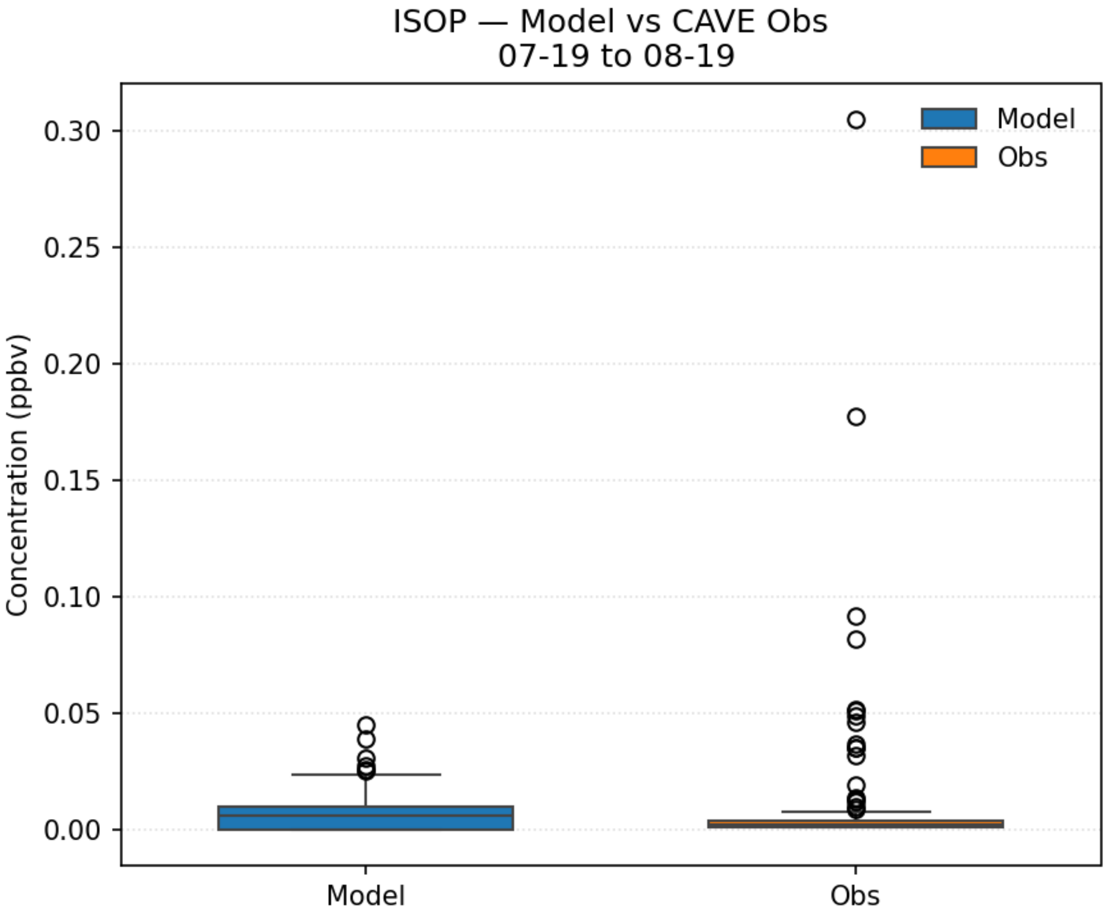


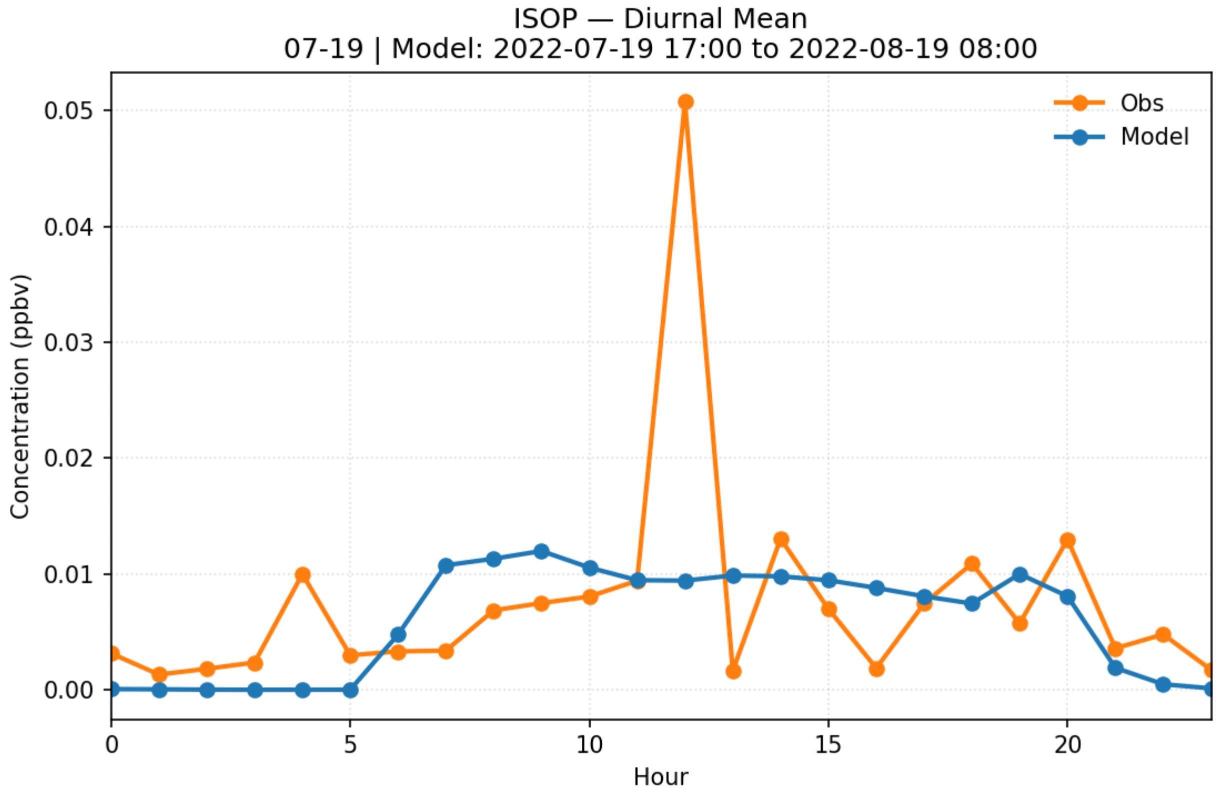
Ethyne



Isoprene (Biogenic)

- **Observed and modeled isoprene are generally comparable**, both remaining at very low concentrations (<0.02 ppb). Observations show more outliers.
- **Average observed (0.009 ppb) and modeled (0.007 ppb) values are similar**, though the median observed (0.002 ppb) is lower than modeled (0.007 ppb), likely due to detection limits



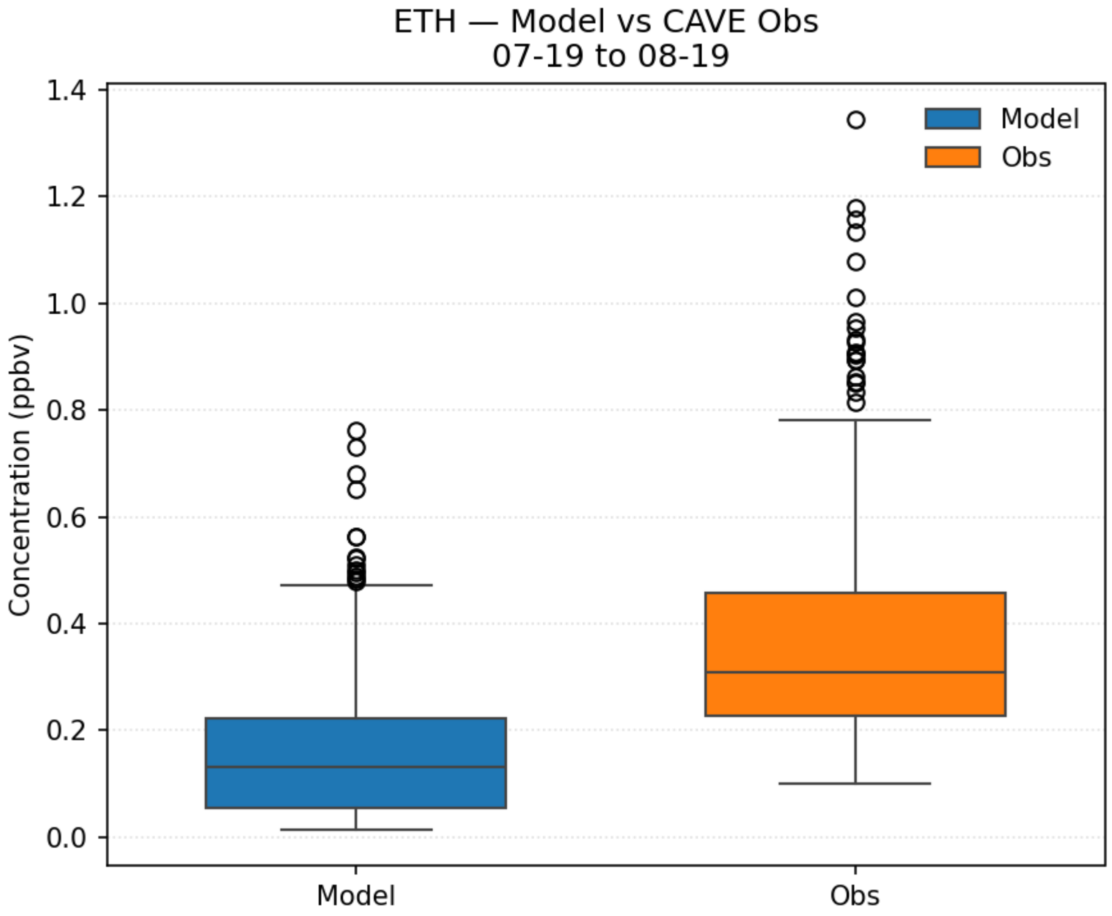


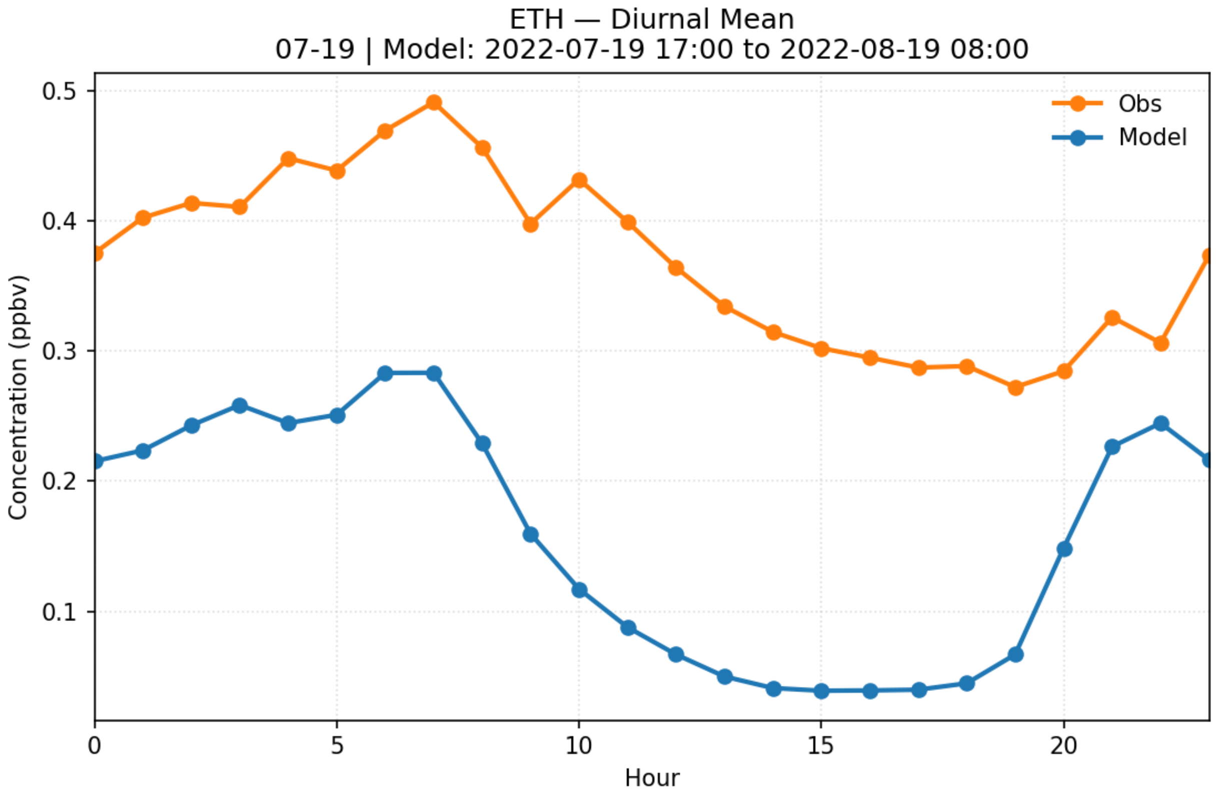
Ethene/Ethylene (ETH)

Ethene

- Median Underprediction: **2.4** times (0.31 vs 0.13 ppb)
- Mean Underprediction: **2.4** times (0.36 vs 0.15 ppb)

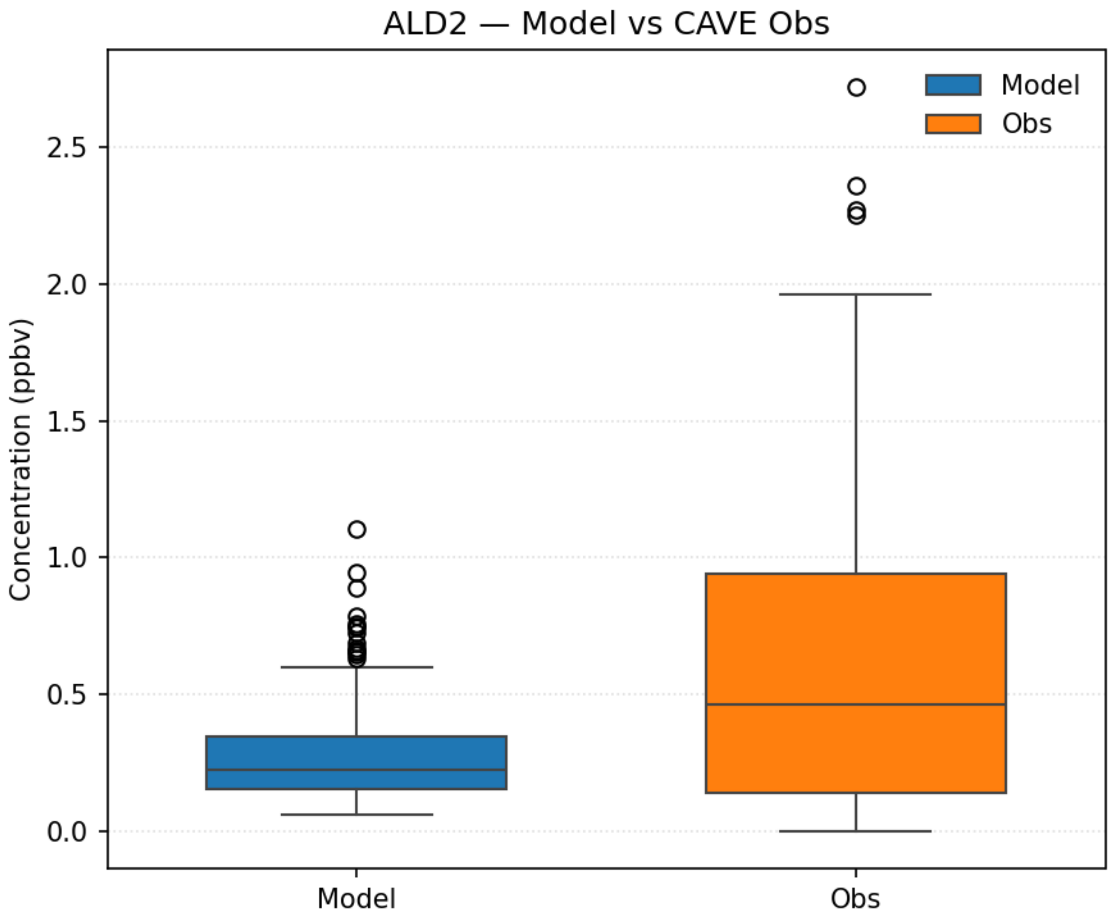
Similar diurnal profiles. Observed concentrations are 50 to 100% higher than modeled

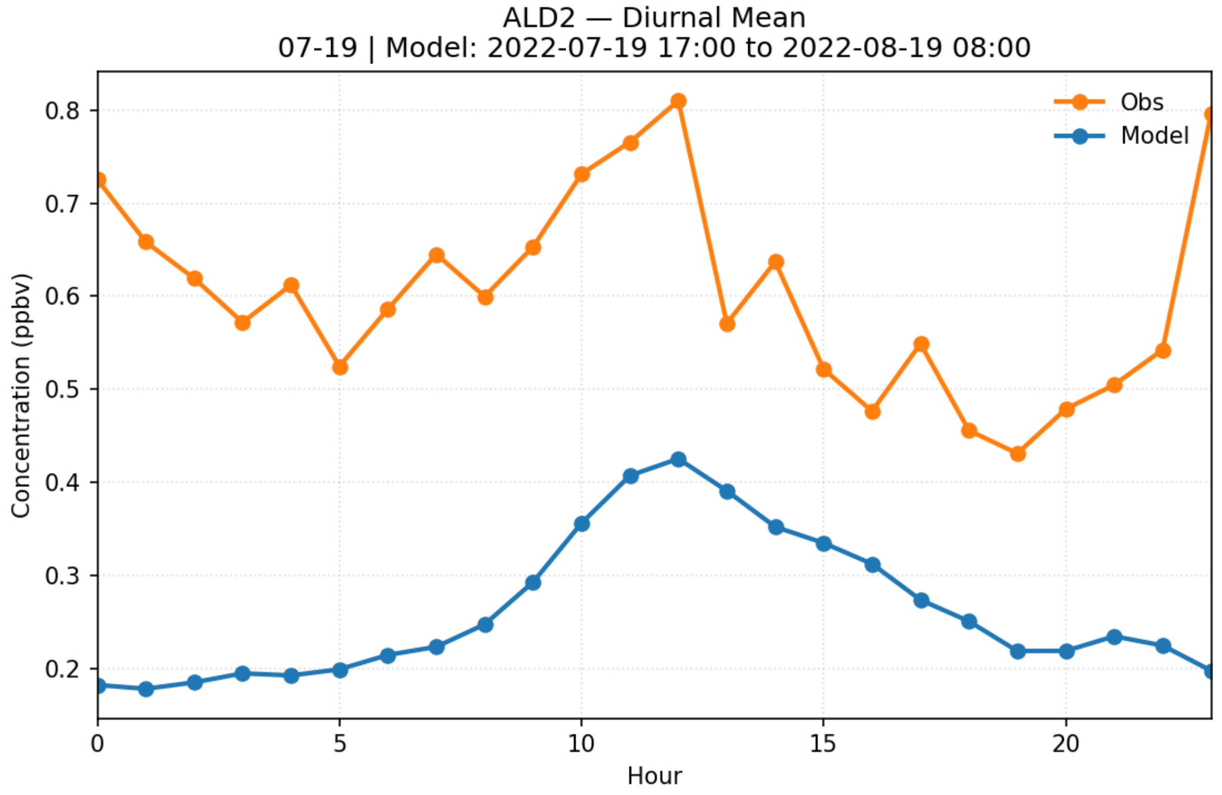




Acetaldehyde (ALD2)

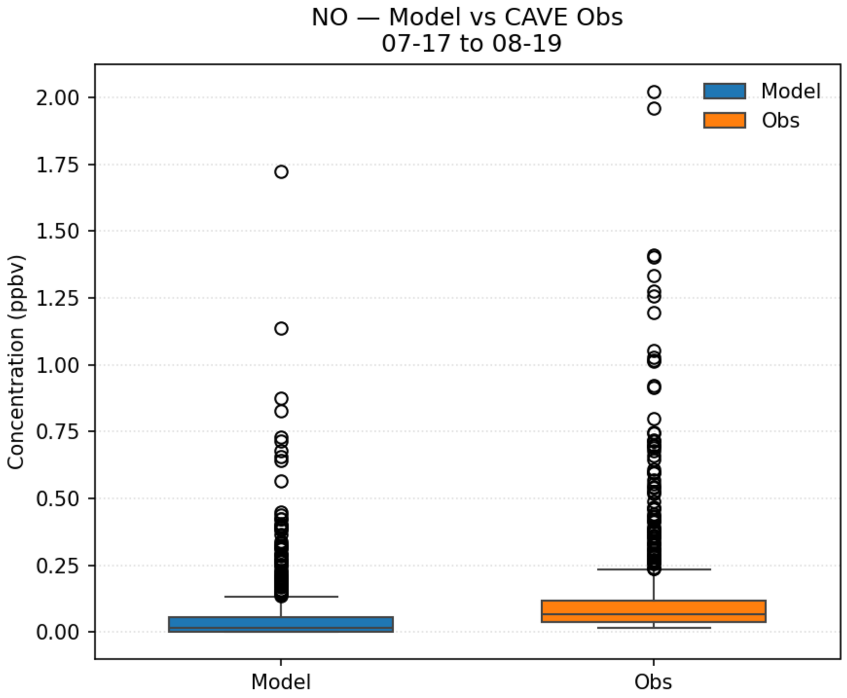
- ALD2 is underestimated by approximately a factor of **2** (2.1 median and 2.3 mean)
- Approximately 50% of ALD2 is secondarily formed much of it from Alkanes so this underestimation may be related to understated O&G VOC emissions

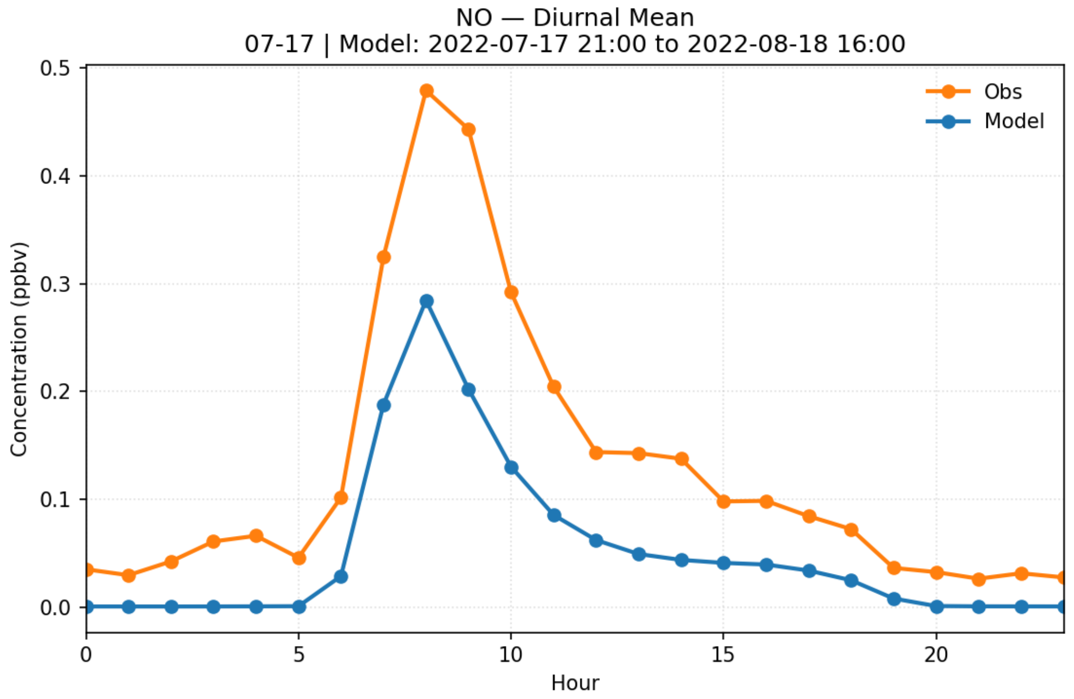


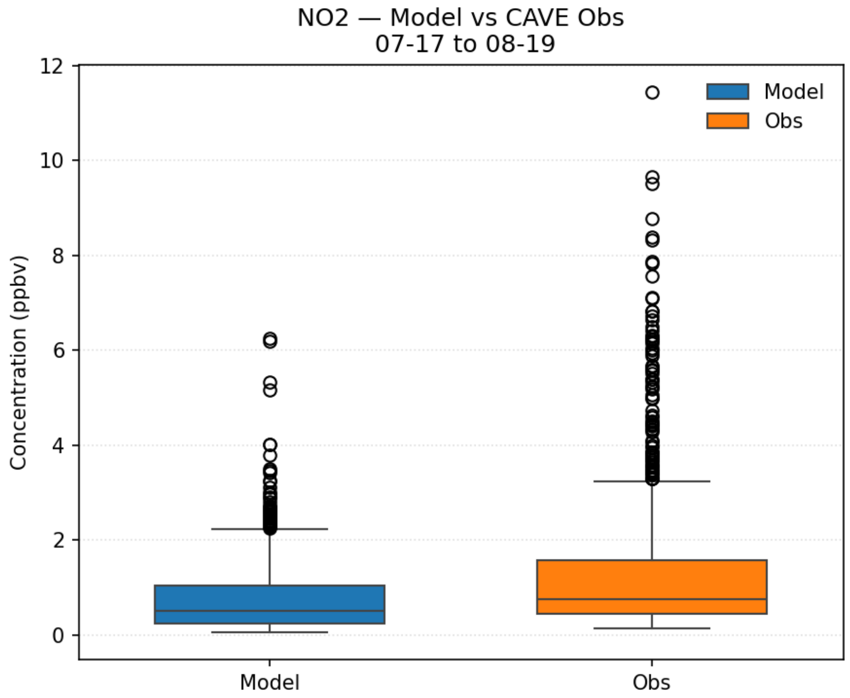


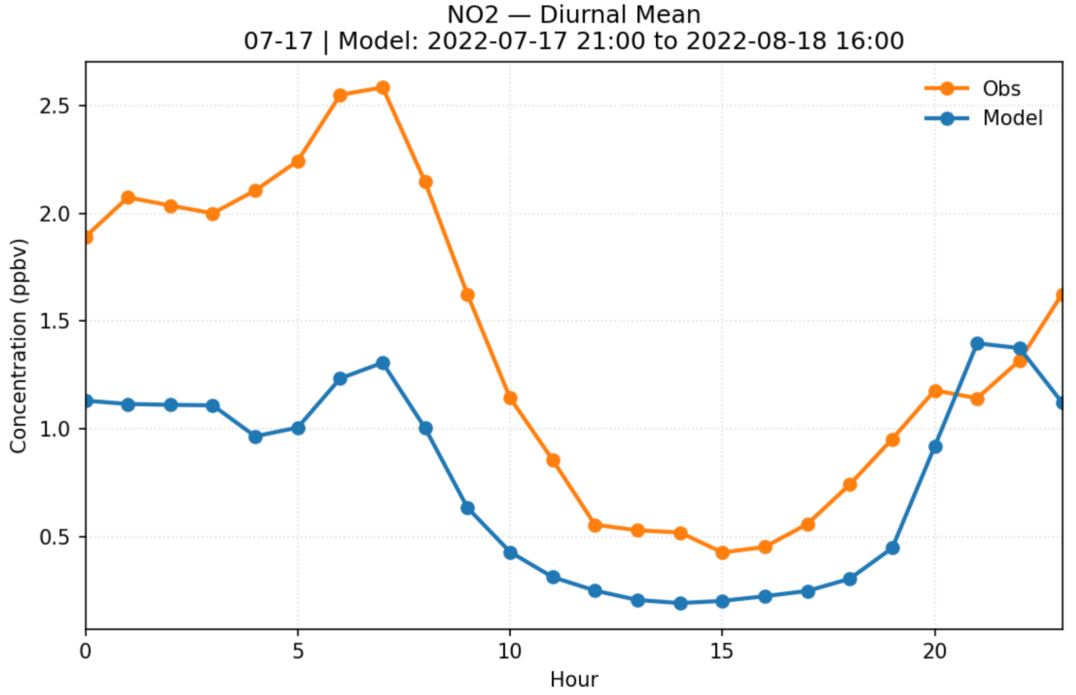
NO & NO_2

- NO shows a wide range of concentrations due to its primarily emitted nature
- NO is underestimated by ~**4.1×** (median) and ~**2.5×** (mean)
- Underestimation of primary emitted species is common in grid models
- NO_2 is underestimated by ~**1.5×** (median) and ~**1.8×** (mean).









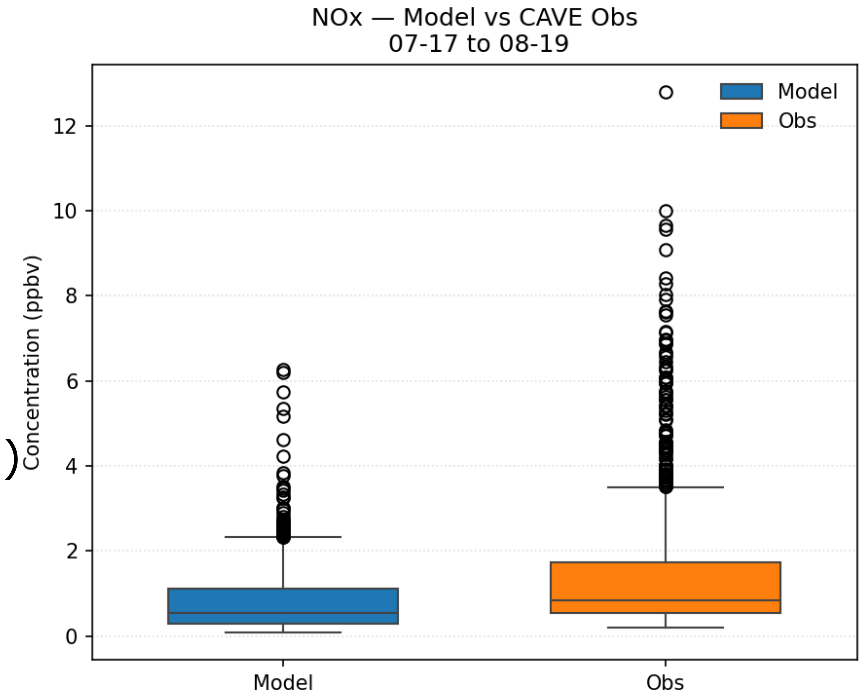
NO_X & NO_Y

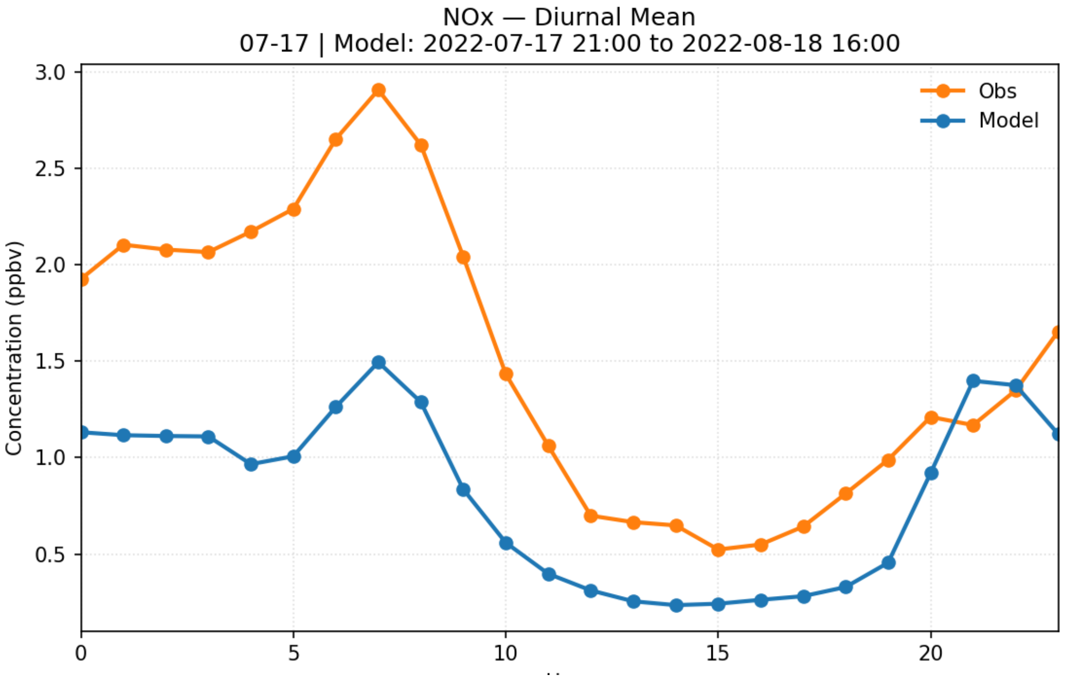
- NO_X follows NO_2 performance: underestimated by factors of **1.6** (median) and **1.9** (mean)

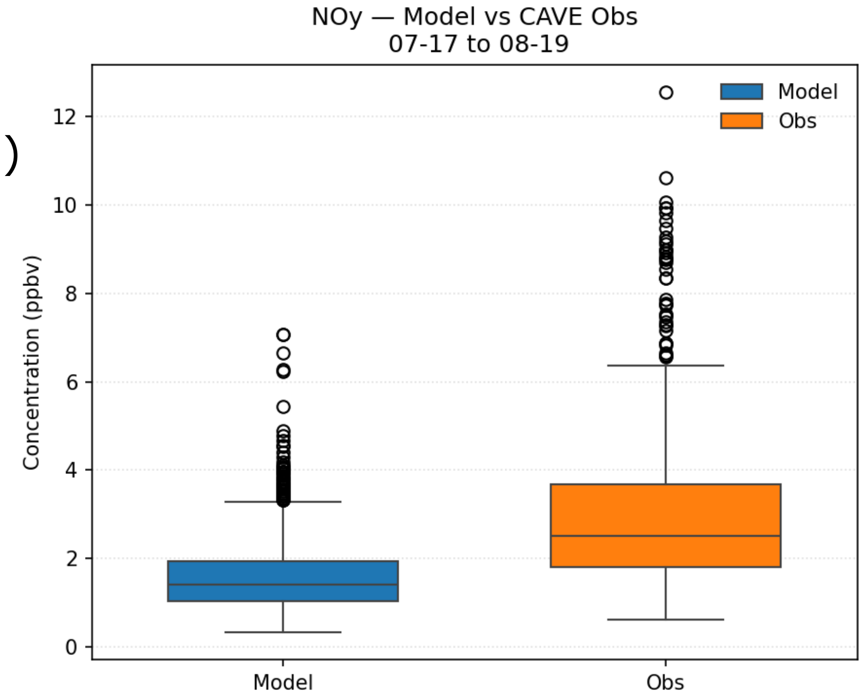
- NO_Y performance similar to NO_X underestimated by factors of **1.8** (median) and **1.9** (mean)

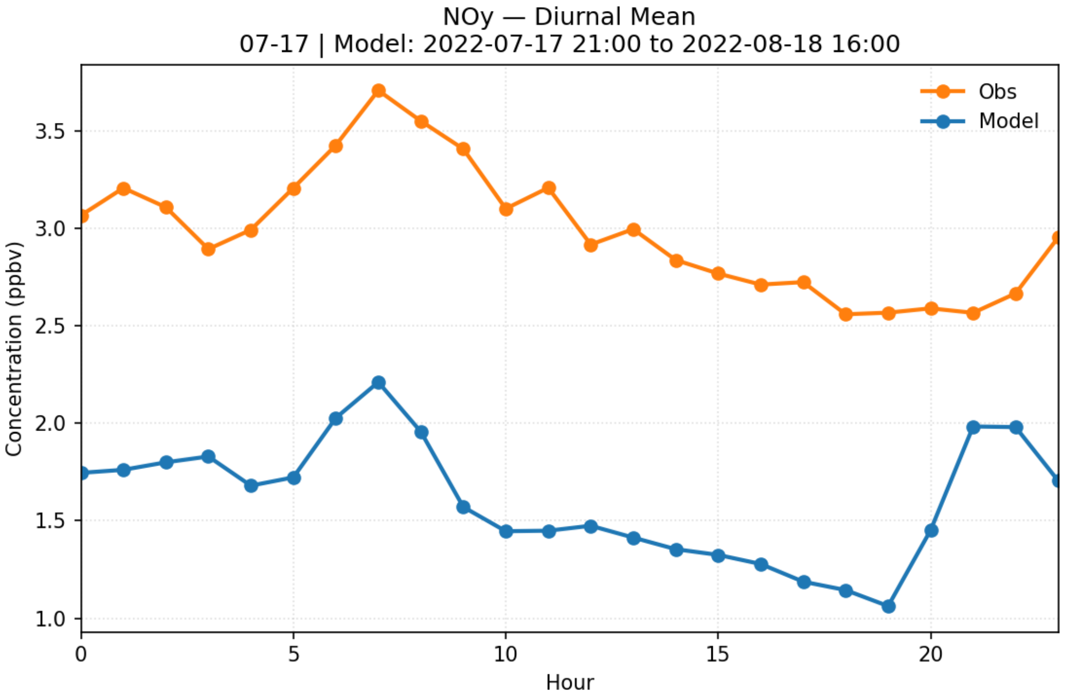
$NO_X = NO + NO_2$

$NO_Y = NO_X + PAN + PPN + HNO_3 + etc.$





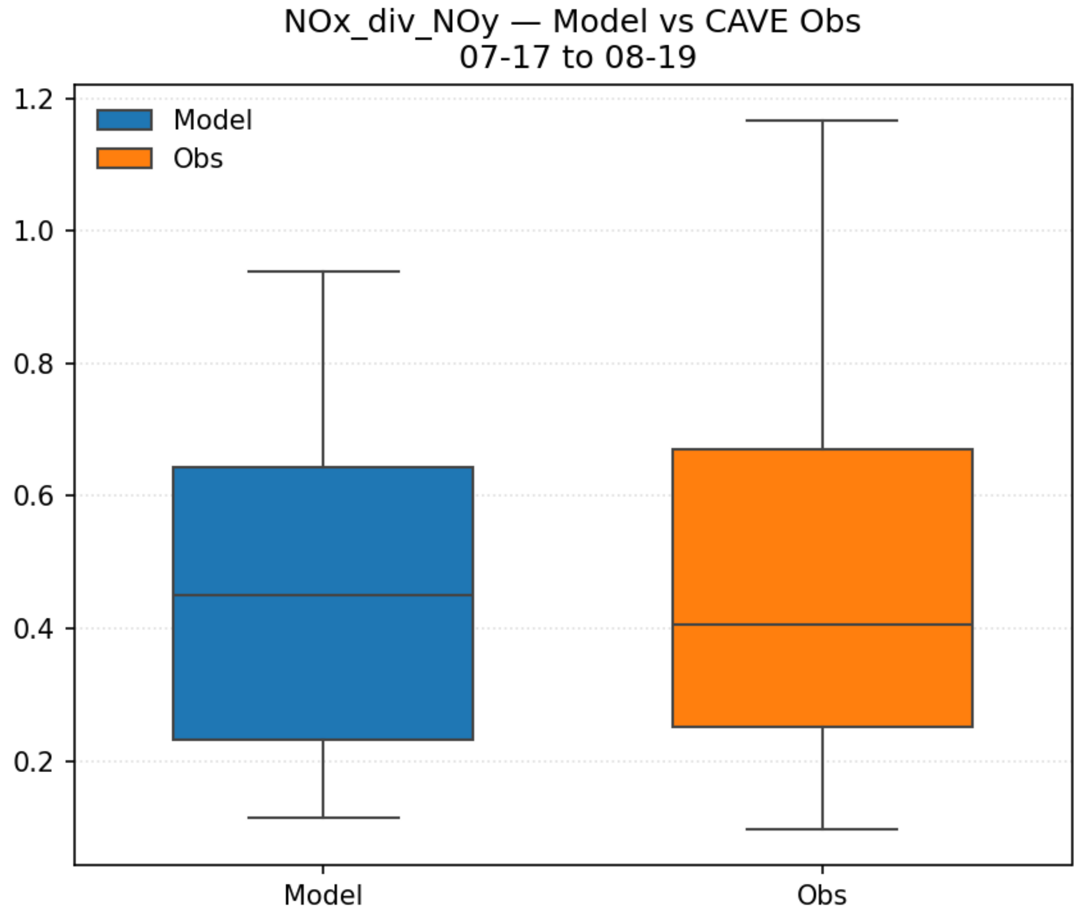




Conclusions CarCavAQS VOC/NO_X Model Evaluation

- O&G VOC tracers (Ethane and Propane) are underestimated by a factor of ~5 at the Carlsbad Caverns site
  - Suggests 2022v2 O&G VOC emissions are understated
- Combustion tracers underestimated by factor of ~2 (Benzene) to good agreement on average (Ethyne) – could be related to 4 km grid cell averaging in model
- Isoprene (Biogenic) concentrations are very low and model has good agreement with observations
- Acetone has large underestimation (5x) – used in O&G production
- NO_2, NO_X and NO_Y show slight underestimation - May be due to grid cell dilution

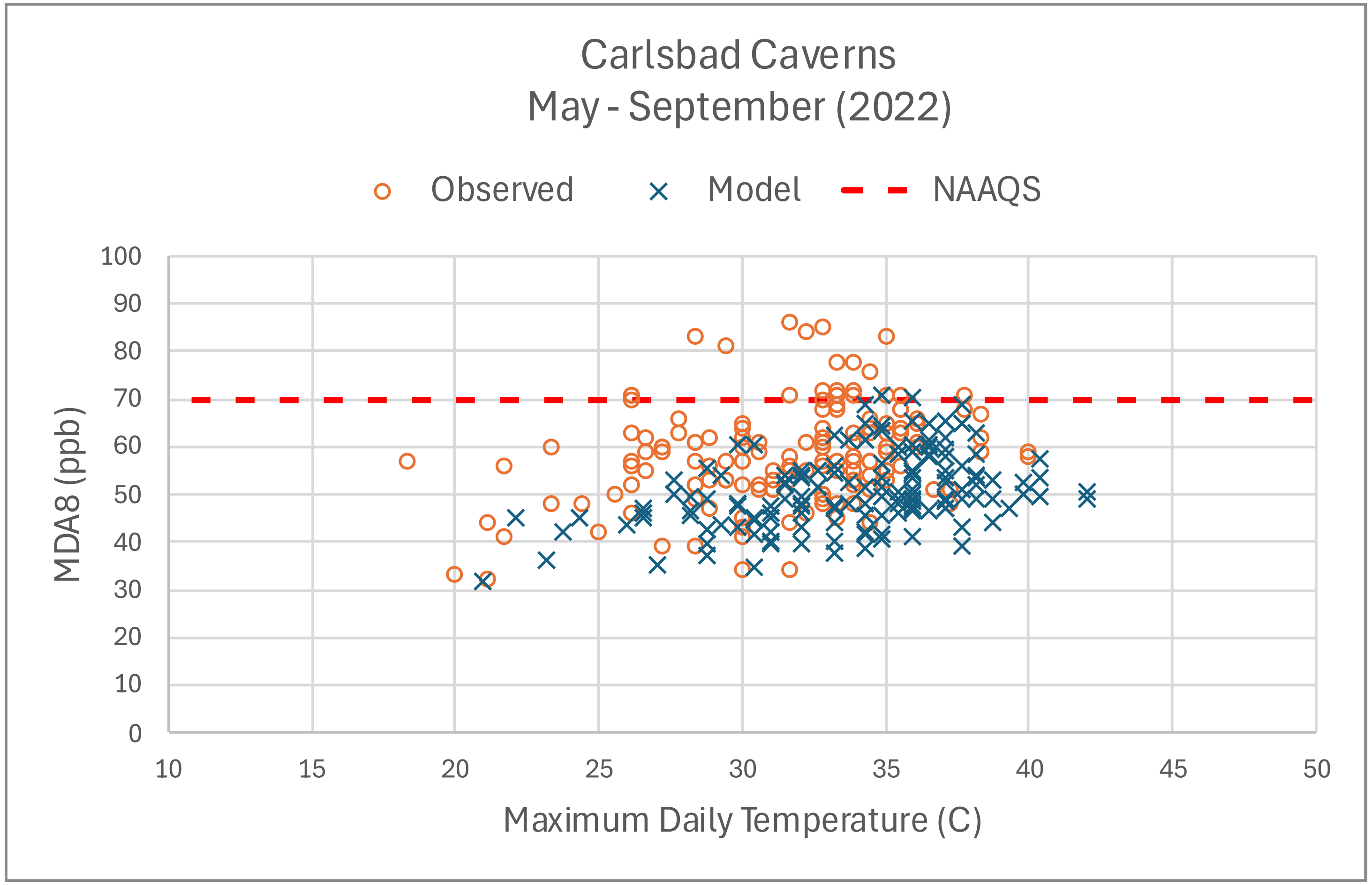
NO_X/NO_Y Ratios – measure of aging of NO_X emissions with good agreement (within 10% on average between observations and model ~0.4)

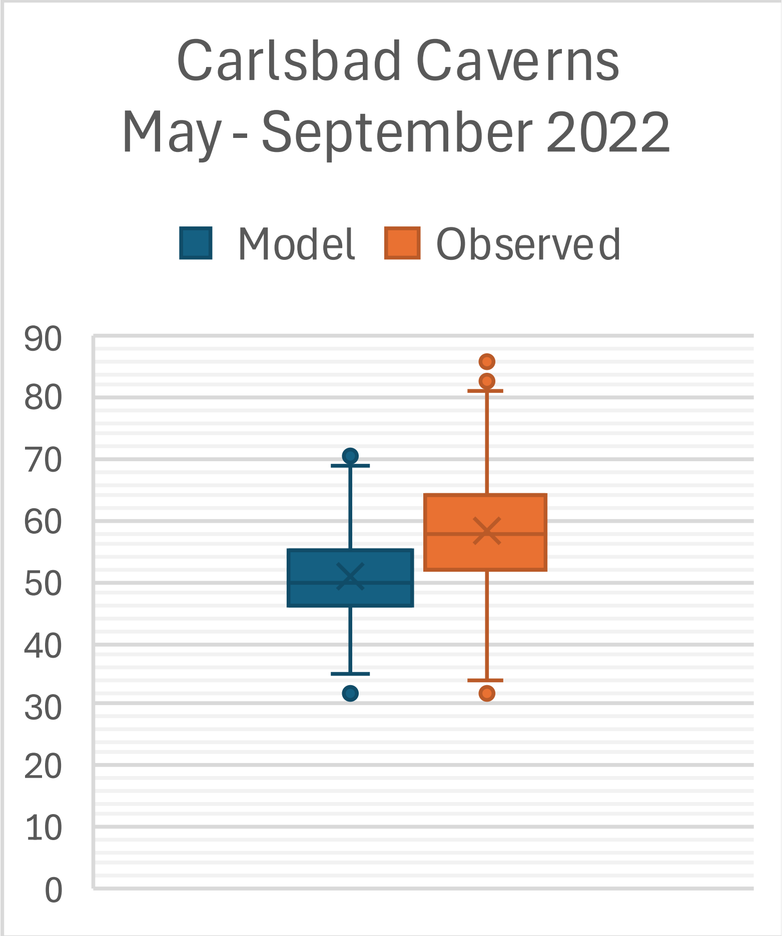


Ozone vs Daily Temperature Evaluation

MDA8 O_3 vs. Max Daily Temperature – Carlsbad Caverns

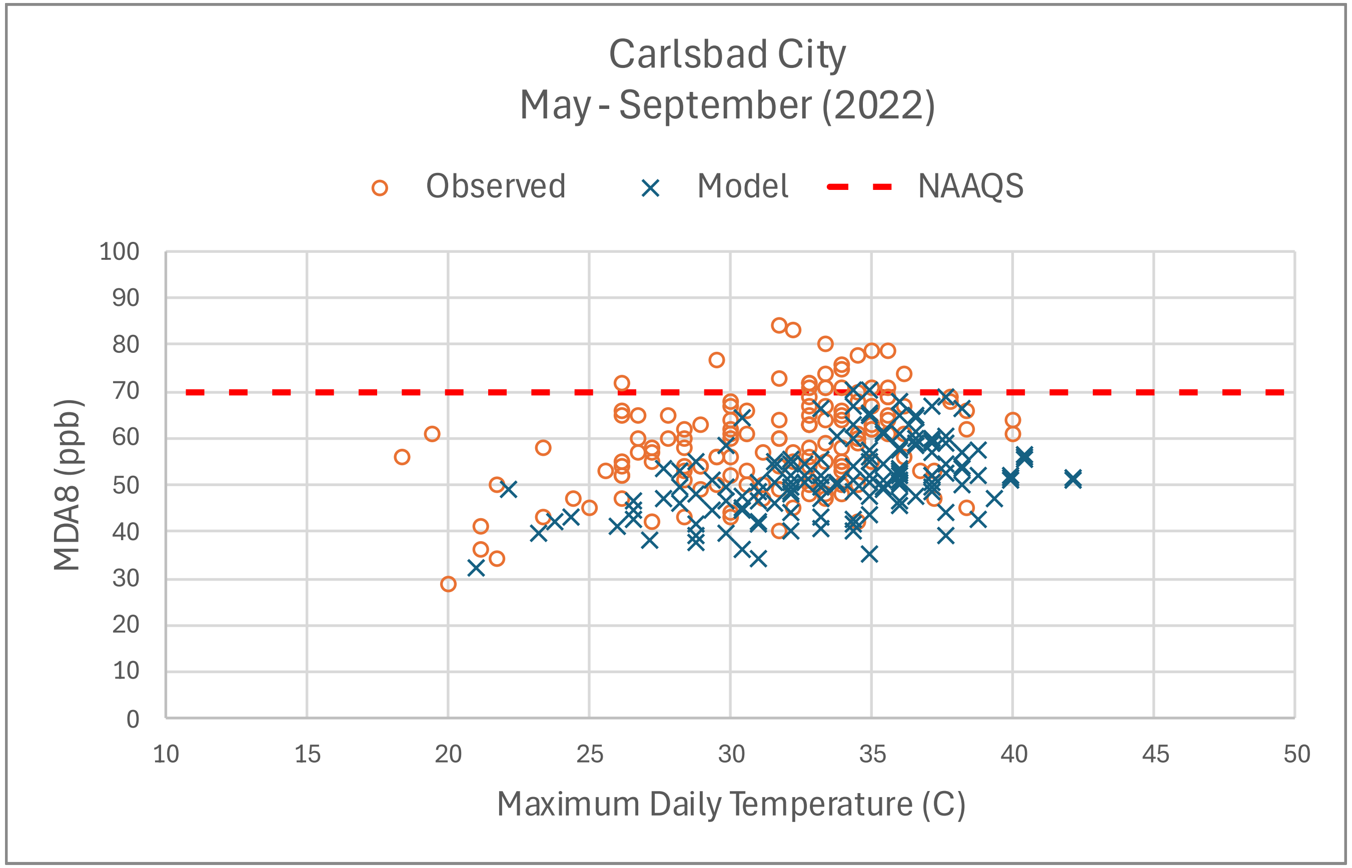
- Modeled O_3 rarely achieves 70 ppb; observed O_3 has many exceedances (Top Whisker at ~80 ppb)
- Observed exceedances mostly occur under temperatures of 27-35 C (81-95 F)
- Model shows higher maximum daily temperatures (40 C = 104 F)

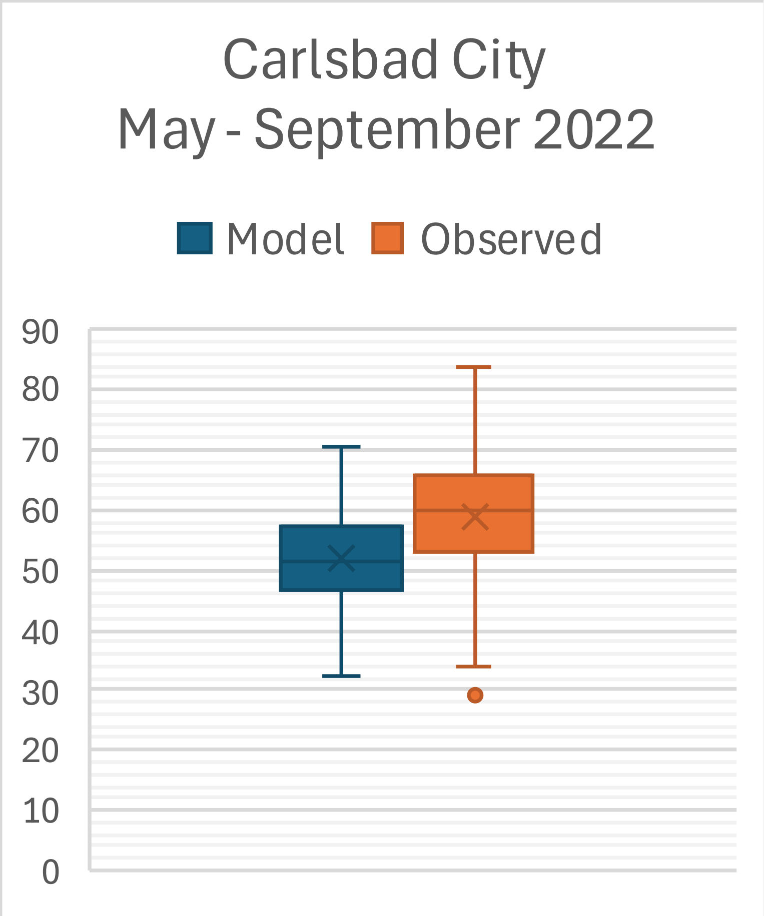




MDA8 O_3 vs. Max Daily Temperature – Carlsbad City

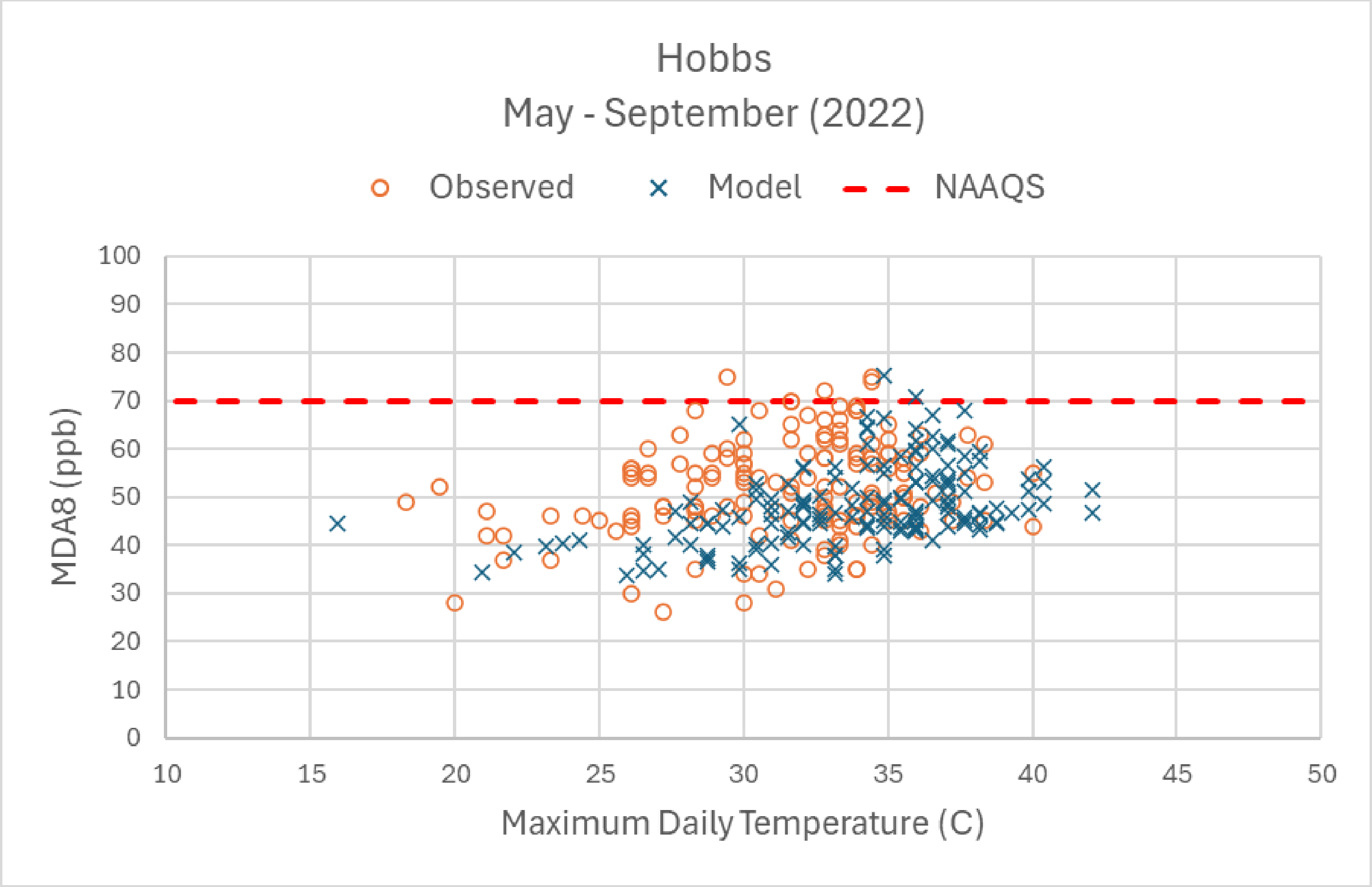
- Modeled O_3 rarely achieves 70 ppb; observed O_3 has many exceedances (Top Whisker of ~84 ppb)
- Observed exceedances mostly occur under temperatures of 27-37 C (81-98 F)
- Model shows higher maximum daily temperatures

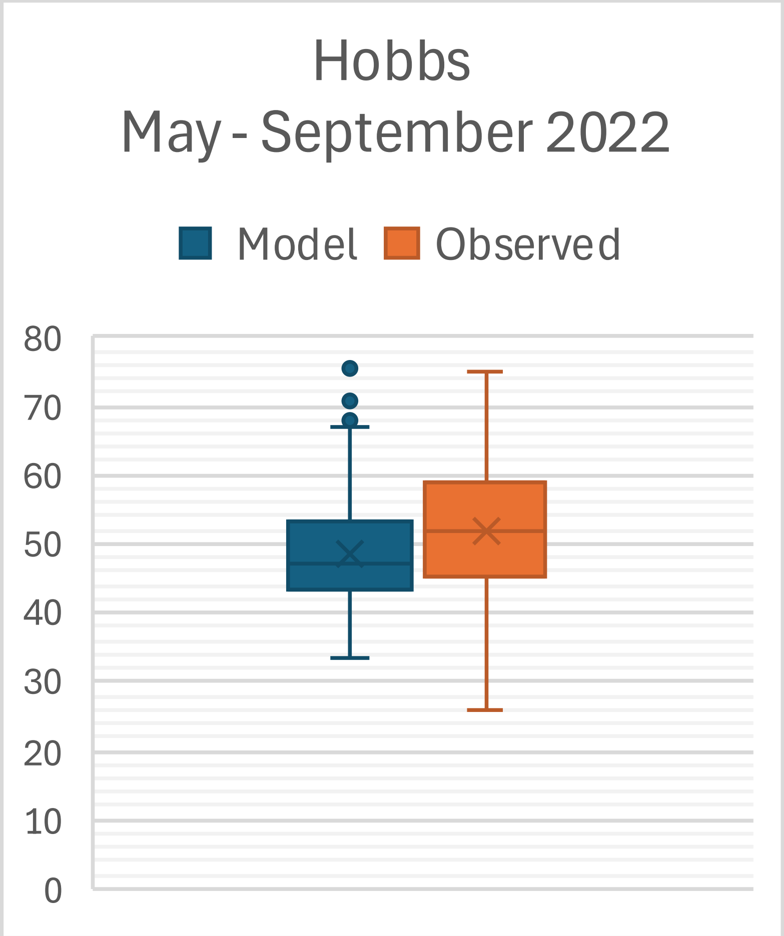




MDA8 O_3 vs. Max Daily Temperature – Hobbs

- Modeled O_3 rarely achieves 70 ppb; observed O_3 also not as many exceedances as Carlsbad
- Observed 75th percentile O3 (~60 ppb) higher than modeled (~53 ppb)
- Model shows higher maximum daily temperatures

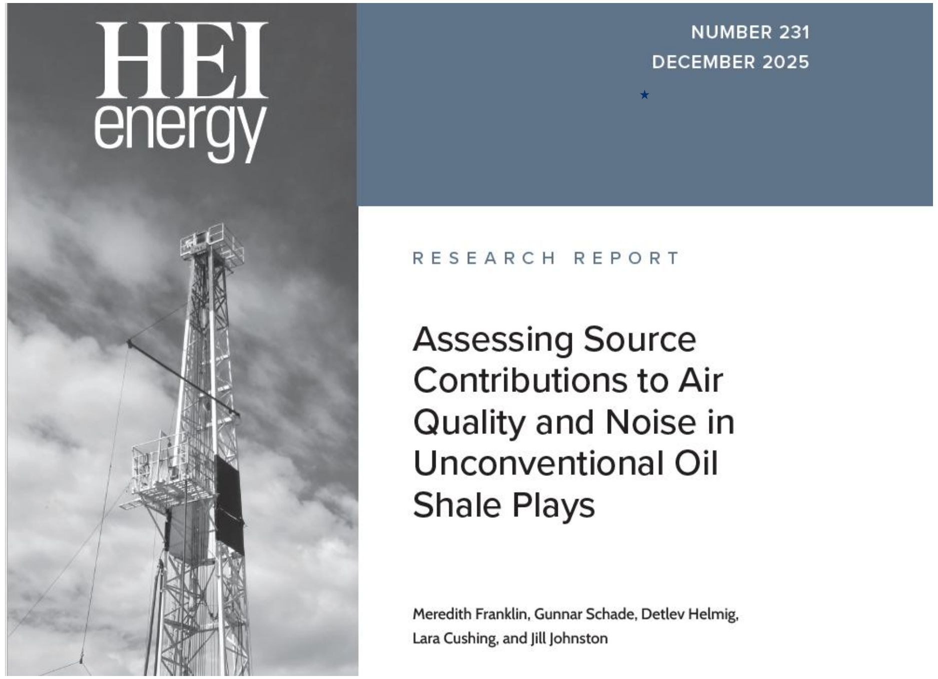




Boulder Air Evaluation

2022 modeling VS. 2023-2024 Measured VOC and NOx at Loving, NM

Loving, NM (LNM) VOC and NO_X: May 2023 – June 2024


HEI energy

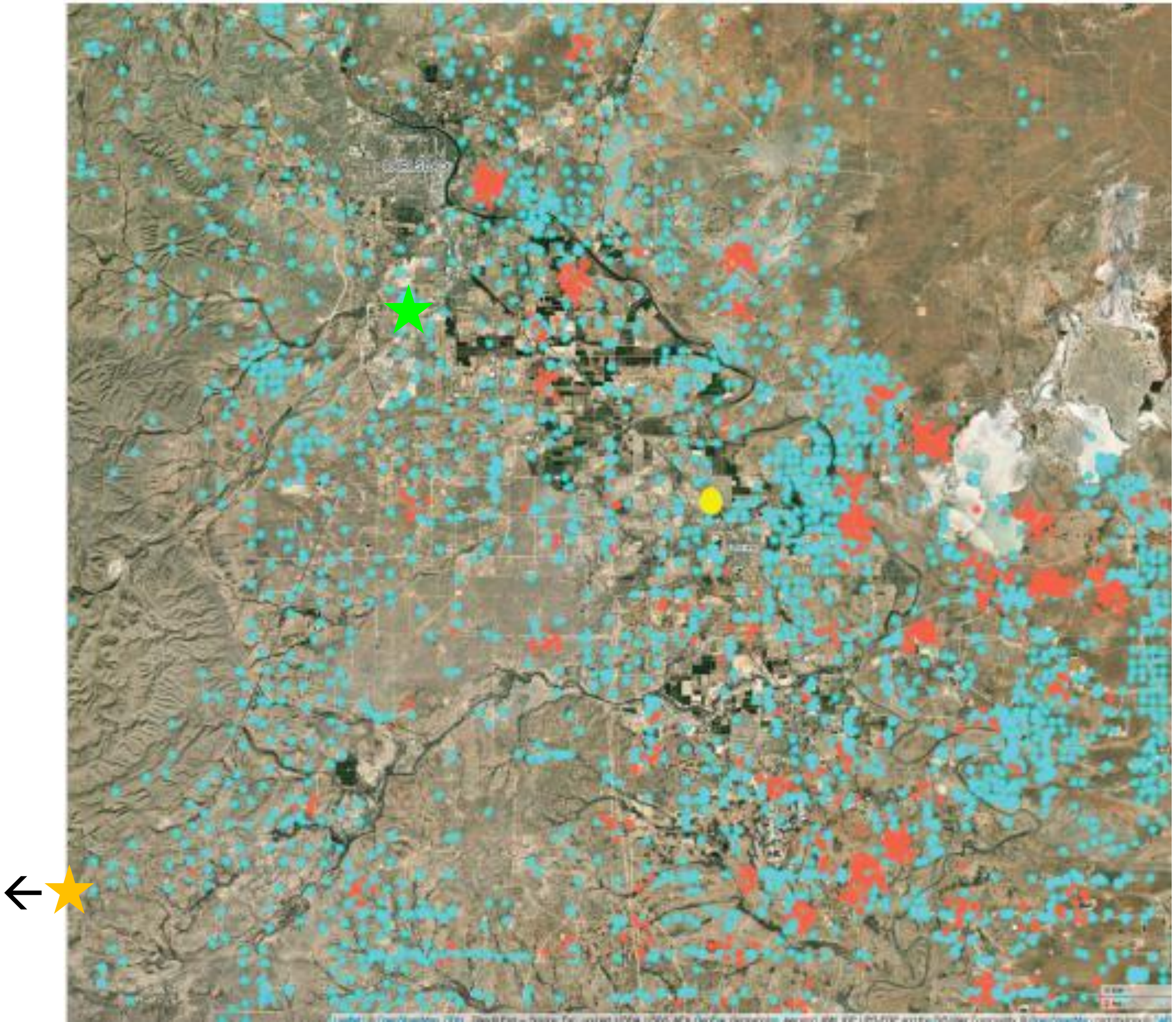
NUMBER 231
DECEMBER 2025

RESEARCH REPORT

Assessing Source Contributions to Air Quality and Noise in Unconventional Oil Shale Plays

Meredith Franklin, Gunnar Schade, Detlev Helmig, Lara Cushing, and Jill Johnston

- Yellow Circle = Loving, NM site
- Green Star = Carlsbad City Site
- Orange Star = CarCavAQS Site (further west)
- Cyan Dots = Active Wells
- Red Dots = Satellite Flare Detection



LNM Ethane and Propane -- Oil and Gas Tracers

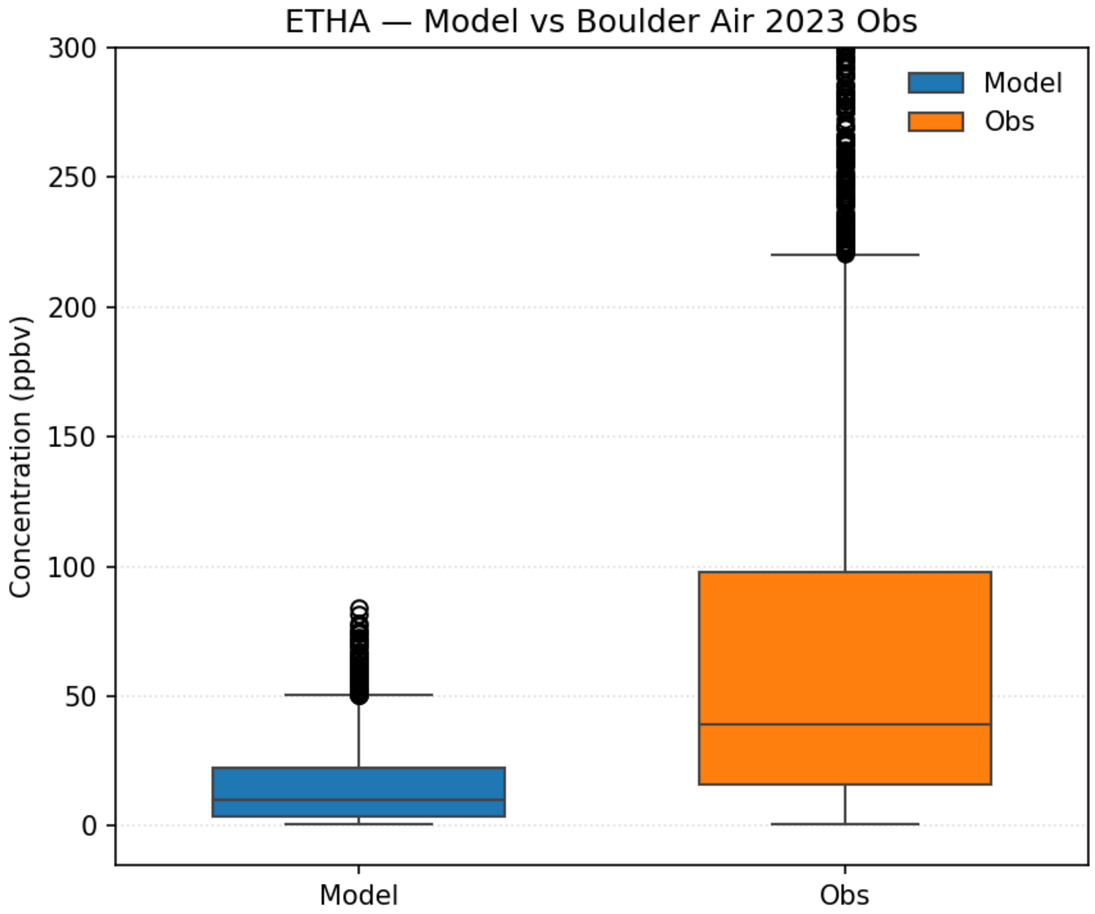
Results suggests 2022 oil and gas VOC emissions inventory may be understated in the Permian Basin

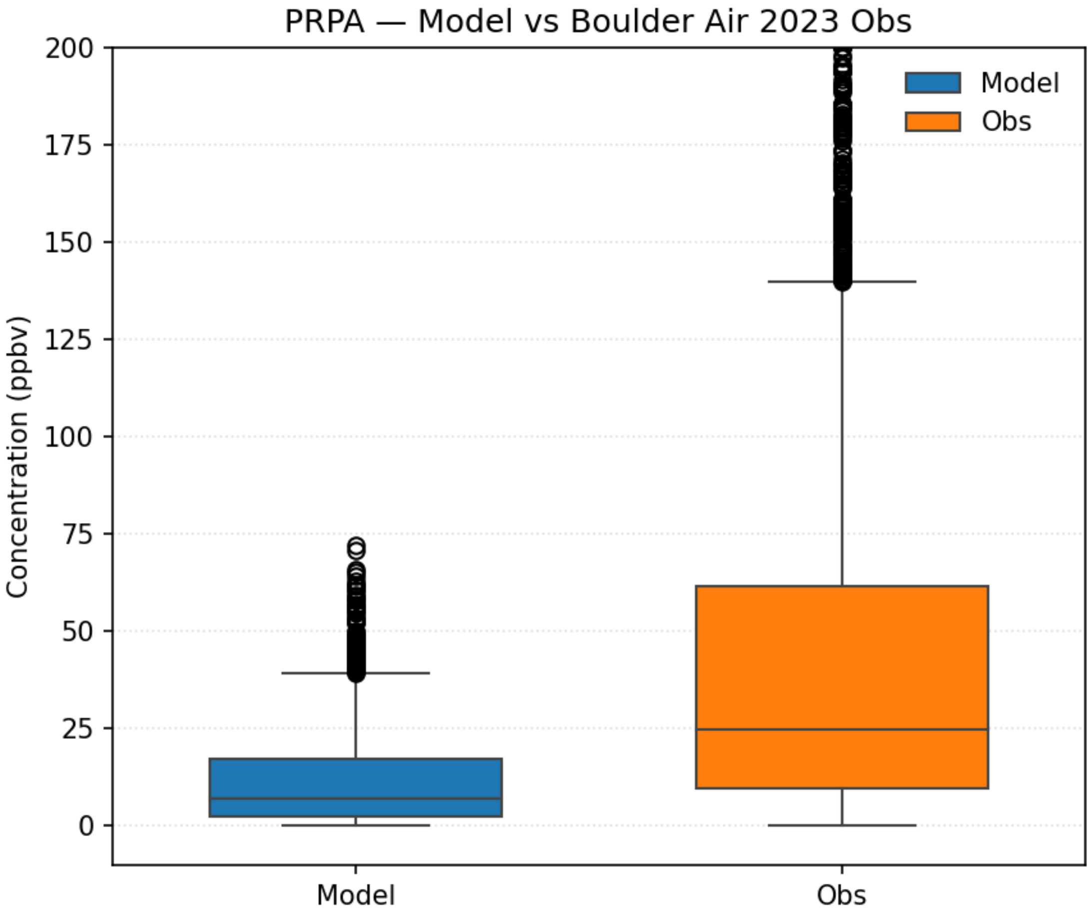
Ethane

- Median Underprediction: **4.0** times (39 vs 10 ppb)
- Mean Underprediction: **5.4** times (79 vs 15 ppb)

Propane

- Median Underprediction: **4.4** times (8 vs 2 ppb)
- Mean Underprediction: **5.2** times (12 vs 2 ppb)





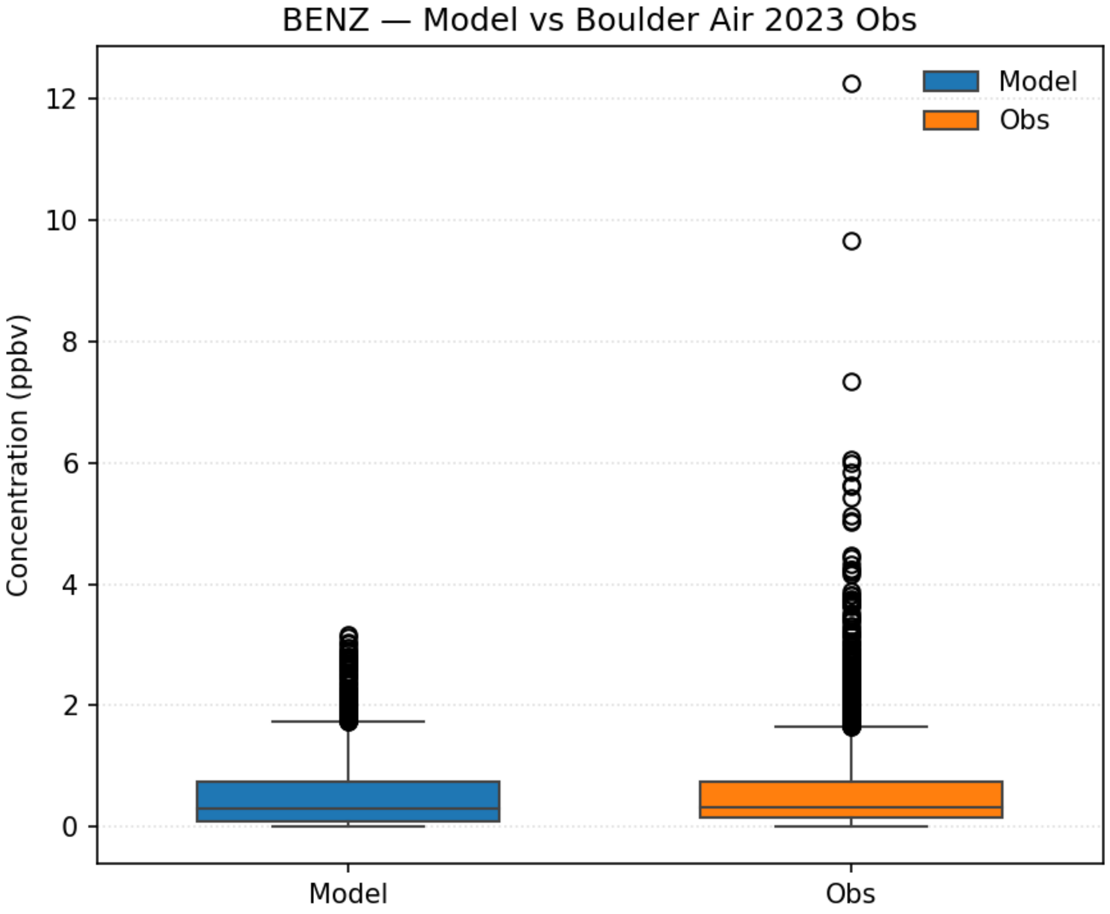
LNM Benzene (Gasoline Combustion) and Ethene

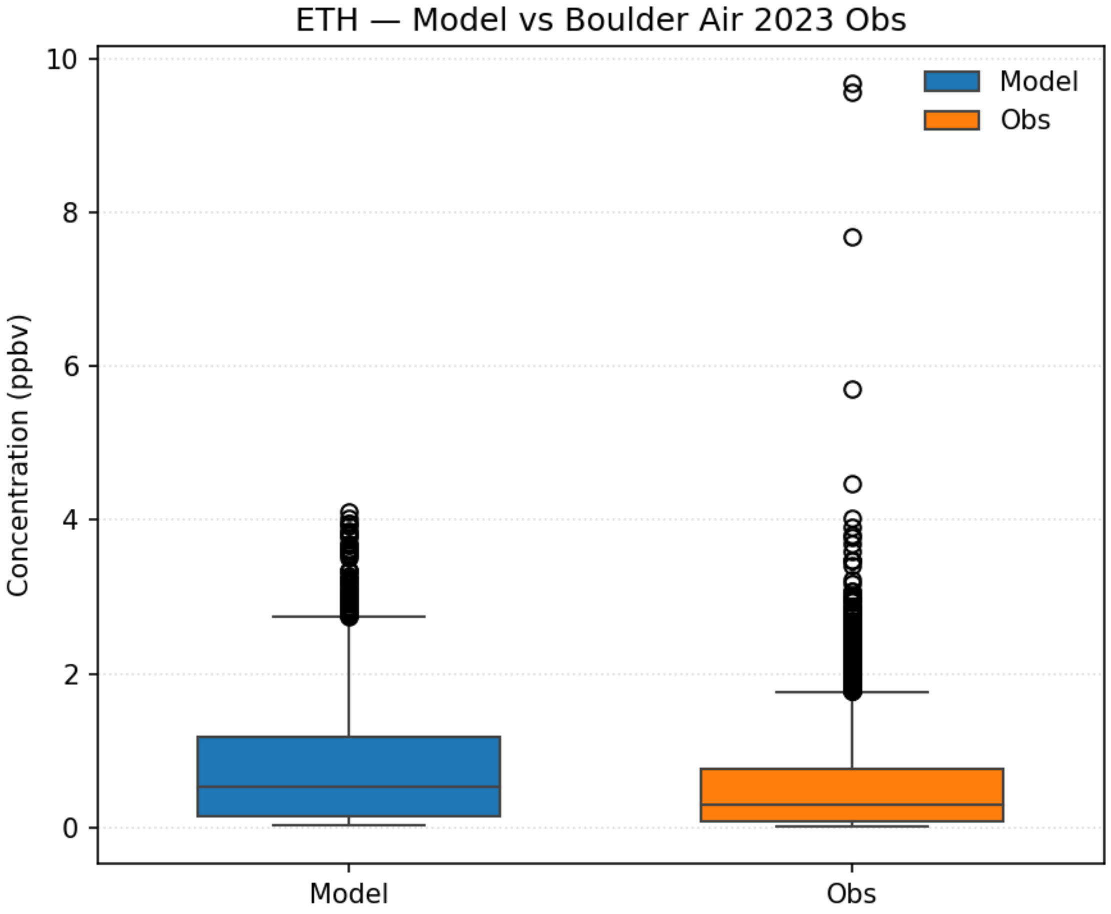
Benzene

- Median Within 10% (**1.1** times)
- Mean Within 20% (**1.2** times)

Ethene

- Median Understated (**0.6** times)
- Mean Understated (**0.7** times)

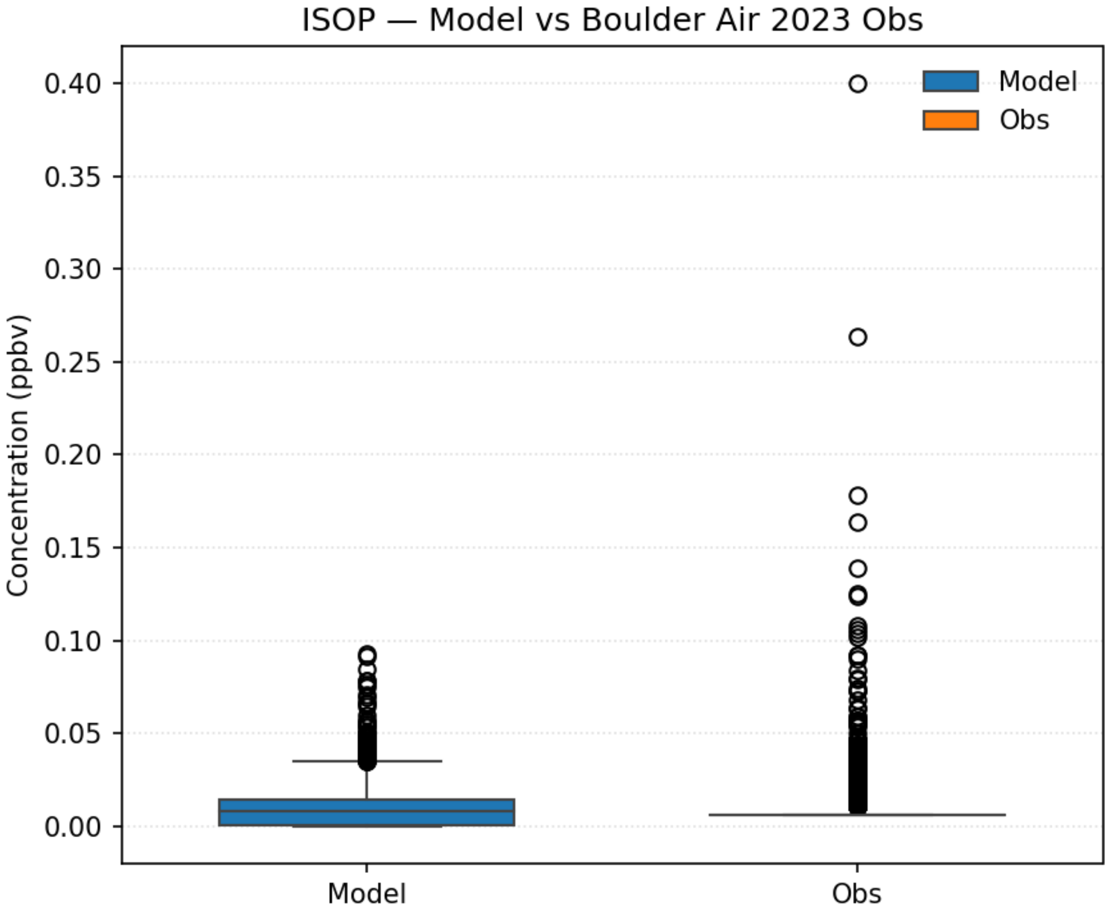




LNM Isoprene (Biogenic) and Nitric Oxide (NO)

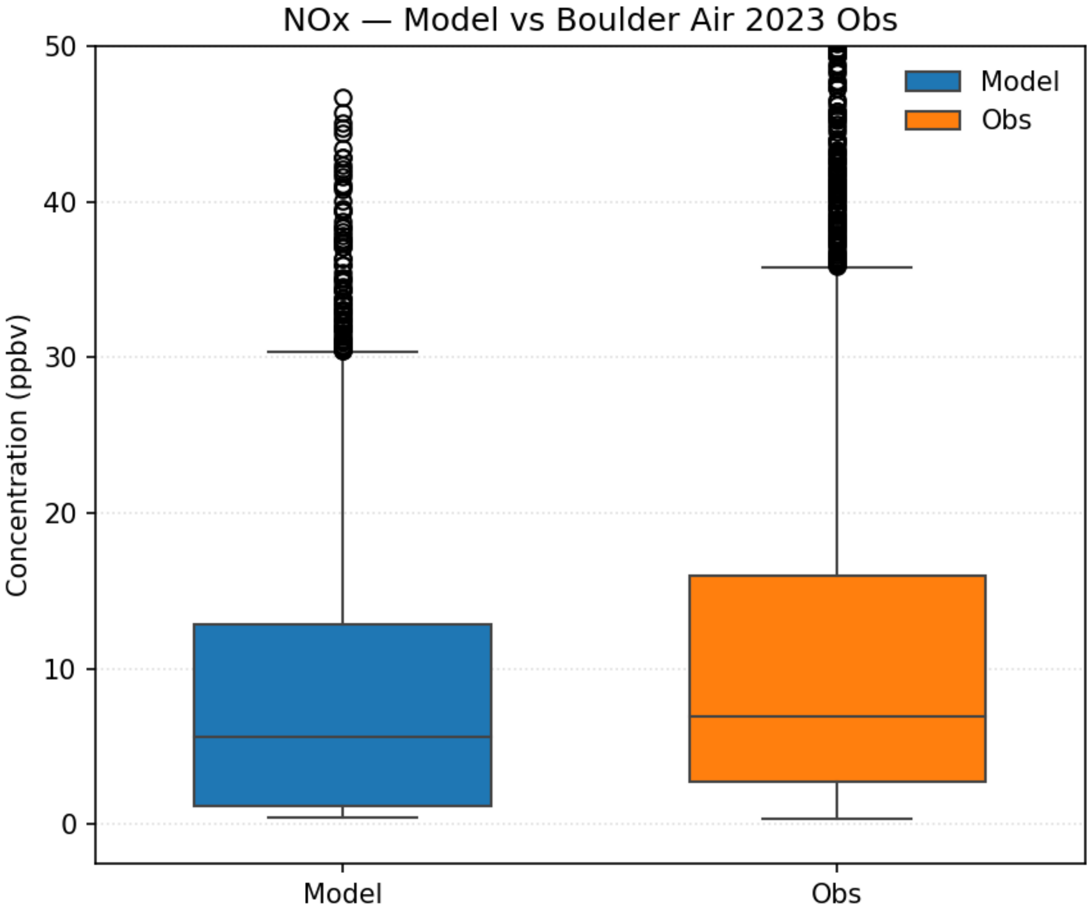
Isoprene

- Median Obs & Model Low (0.008 vs. 0.006 ppb)
- Mean Low and Identical (0.0096 vs. 0.0095 ppb)



Nitric Oxide

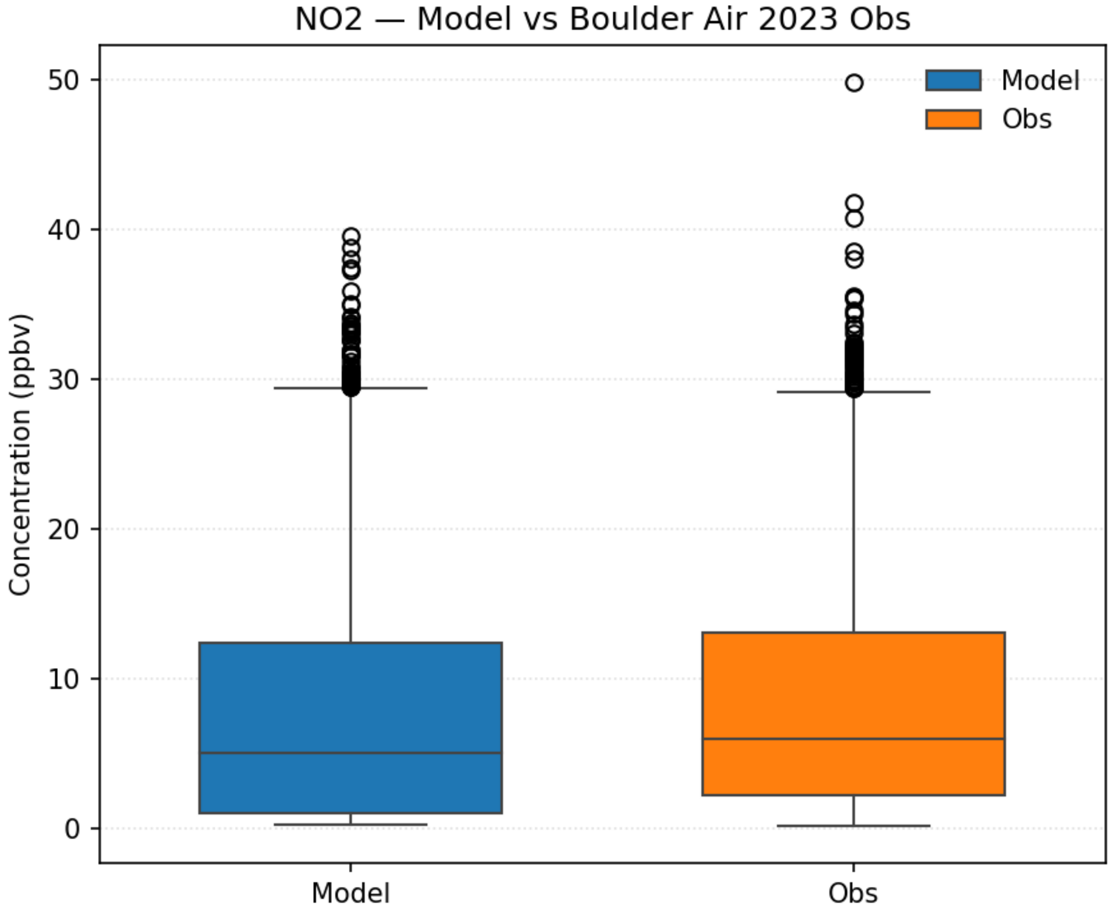
- Median Underprediction: **2.9** times (0.5 vs 0.2 ppb)
- Mean Underprediction: **5.9** times (11.7 vs 8.2 ppb)



LNM NO_2 and NO_x

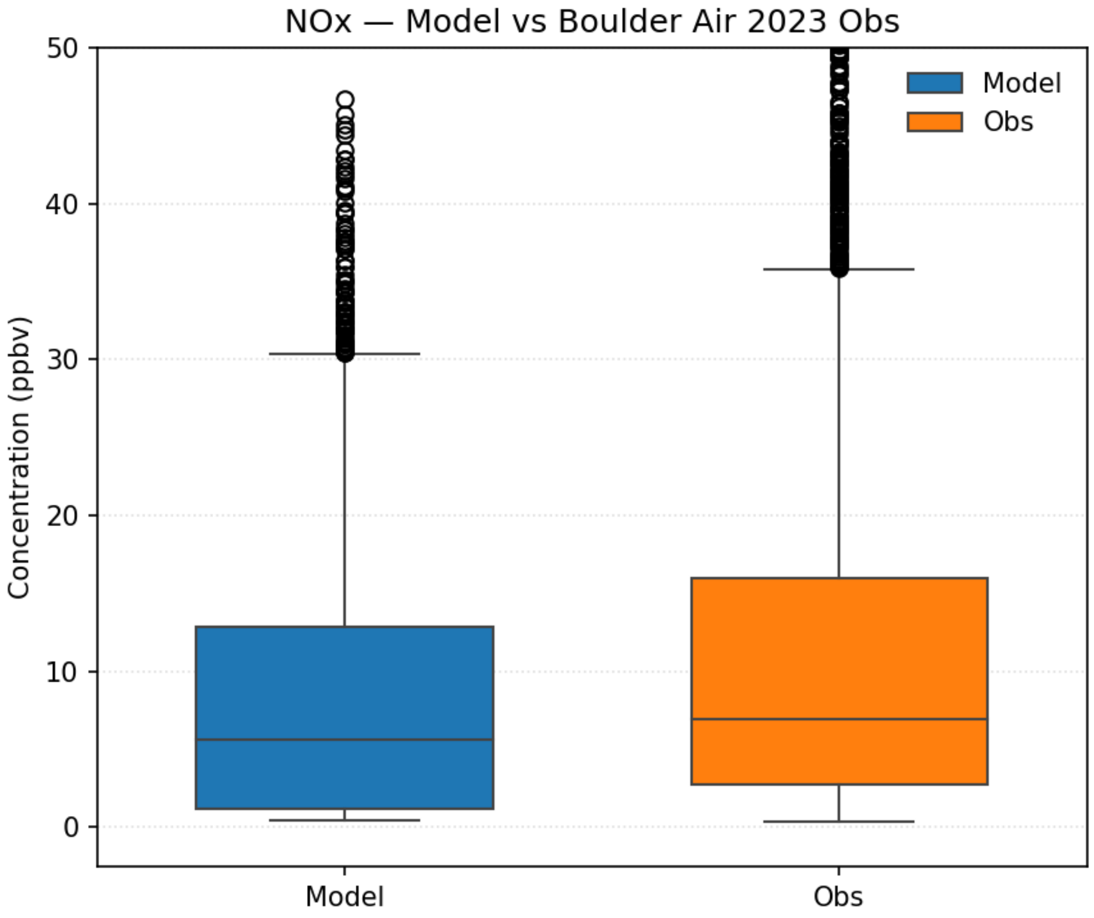
NO_2

- Median Underprediction: **1.2** times (6.0 vs 5.1 ppb)
- Mean Underprediction: **1.1** times (8.5 vs 7.6 ppb)



NO_x

- Median Underprediction: **1.2** times (7 vs 6 ppb)
- Mean Underprediction: **1.4** times (12 vs 8 ppb)



Ram

Conclusions: Loving, NM VOC/NO_X Evaluation

Key Takeaway: Both special field study monitoring datasets indicate that Permian Basin O&G VOC emissions in the 2022v2 platform are understated. O&G NO_X emissions may also be understated

LNM much closer to O&G activities than CarCavAQS so measures higher concentrations

Species/O&G Tracer	Observed LNM vs CarCavAQS	Model LNM vs CarCavAQS	Model Bias (against Obs)
Ethane	4–6× higher	5–6× higher	~4-5× too low
Propane	3-4× higher	4-5× higher	~4-5× too low
Benzene	3x Higher	6-7x Higher	2× low @ CarCavAQS
NOx	8x Higher	10x Higher	~1.5-2× too low

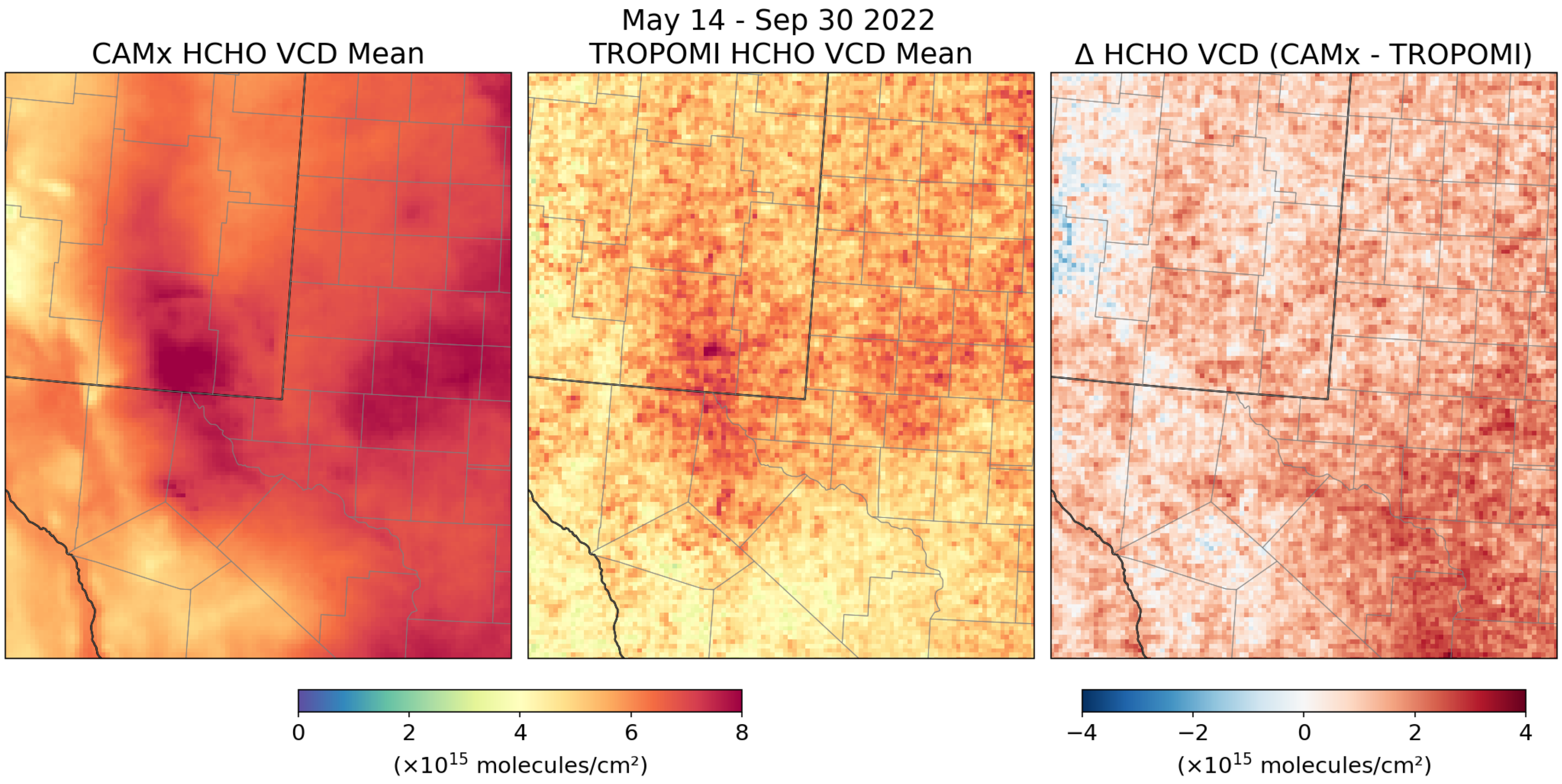
TROPOMI Satellite Evaluation

TROPOMI Satellite Evaluation NO_2 & Formaldehyde (HCHO)

- Tropospheric Monitoring Instrument (TROPOMI) satellite measures vertical column density (VCD) of **NO2** and **HCHO** (formaldehyde) one time per day at a ~7 x ~3.5 km^2 resolution
- TROPOMI was launched in October 2017 so was available during summer 2022 modeling period
  - Newer TEMPO satellite launched late 2023 satellite provides higher horizontal and temporal resolution
- CAMx 2022v2 12/4 km base case (4km2022v2) obtained 3-D concentration output that were processed to obtain modeled VCD of NO2 and HCHO for comparison with TROPOMI
- Comparing TROPOMI VCD NO2 provides an evaluation of the NO_X emission inventory
  - Satellite observations have high uncertainties and can have interference (e.g., clouds)
- HCHO originates from direct primary sources and, more significantly, formed secondarily in the atmosphere from VOC oxidation (e.g., isoprene and methane)
- Comparing the HCHO to NO2 ratios (FNR) provides an indication of whether ozone formation is more NO_X-sensitive or VOC-sensitive.

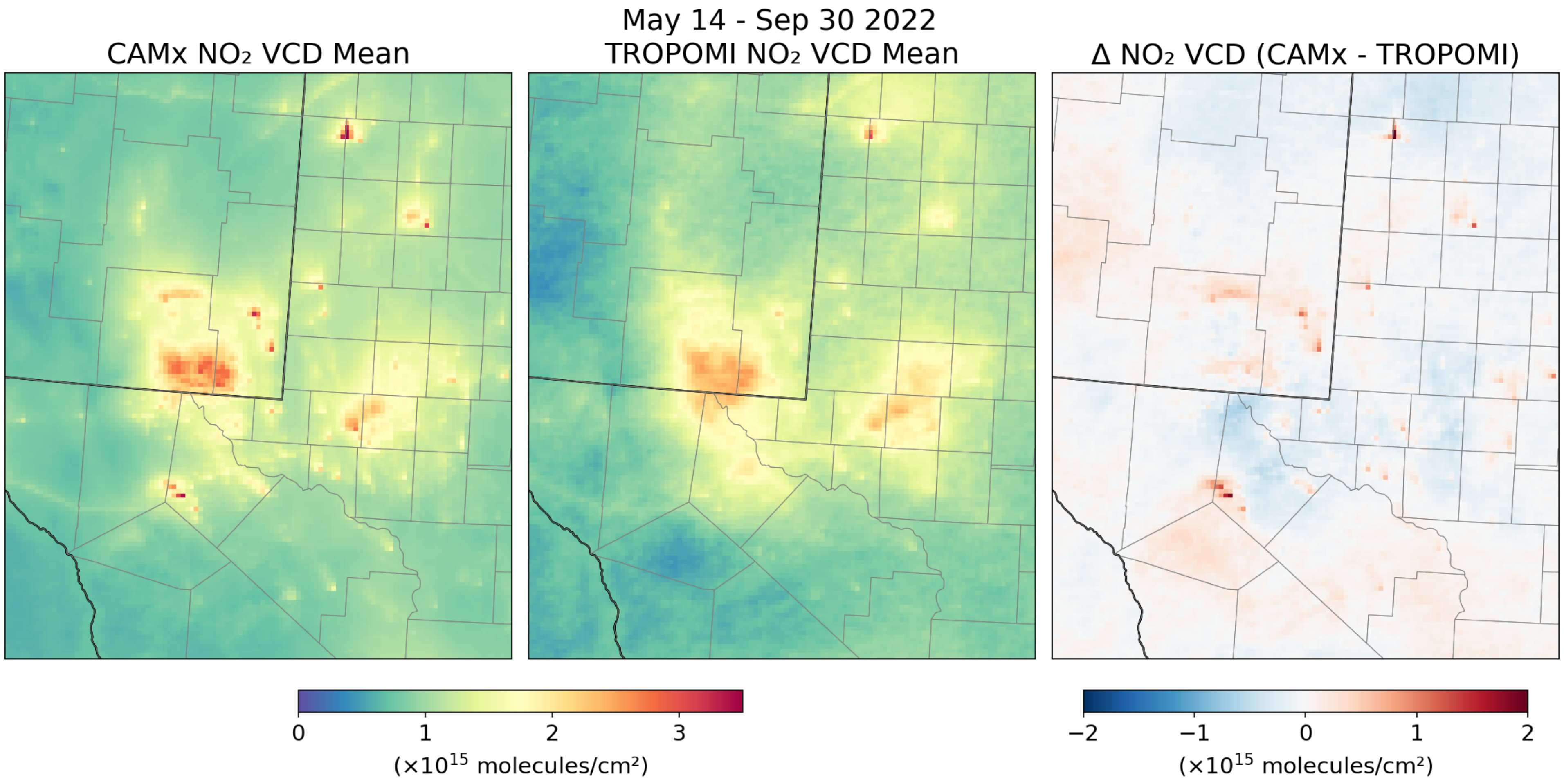
CAMx-TROPOMI VCD HCHO May 14 – Sep 30, 2022

- CAMx HCHO mostly higher than TROPOMI in Eddy and Lea Counties



CAMx-TROPOMI VCD NO2 May 14 – Sep 30, 2022

- CAMx NO2 sometimes higher and sometimes lower than TROPOMI
- O&G area in southern Eddy County CAMx tends to be higher than TROPOMI but lower next door in TX

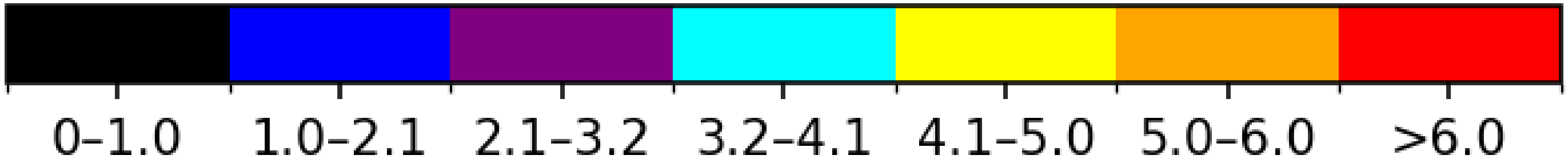


FNR (HCHO/NO_2) Indicator of Ozone NO_X/VOC Regime

- Several researchers have proposed alternative FNR cut-points that indicate when ozone formation is more NO_X-sensitive or more VOC-sensitive [this is an inexact science and usually ozone formation has elements of both]

Reference	Data	VOC-sensitive	Transition	NO_X-sensitive
Duncan et al., 2010	Model, OMI	FNR < 1.0	1.0 < FNR < 2.0	FNR > 2.0
Jin et al., 2020	Surface Obs	FNR < 3.2	3.2 < FNR < 4.1	FNR > 4.1
Souri et al., 2020	Box Model+	FNR < 1.0	1.0 < FNR < 4.0	FNR > 4.0

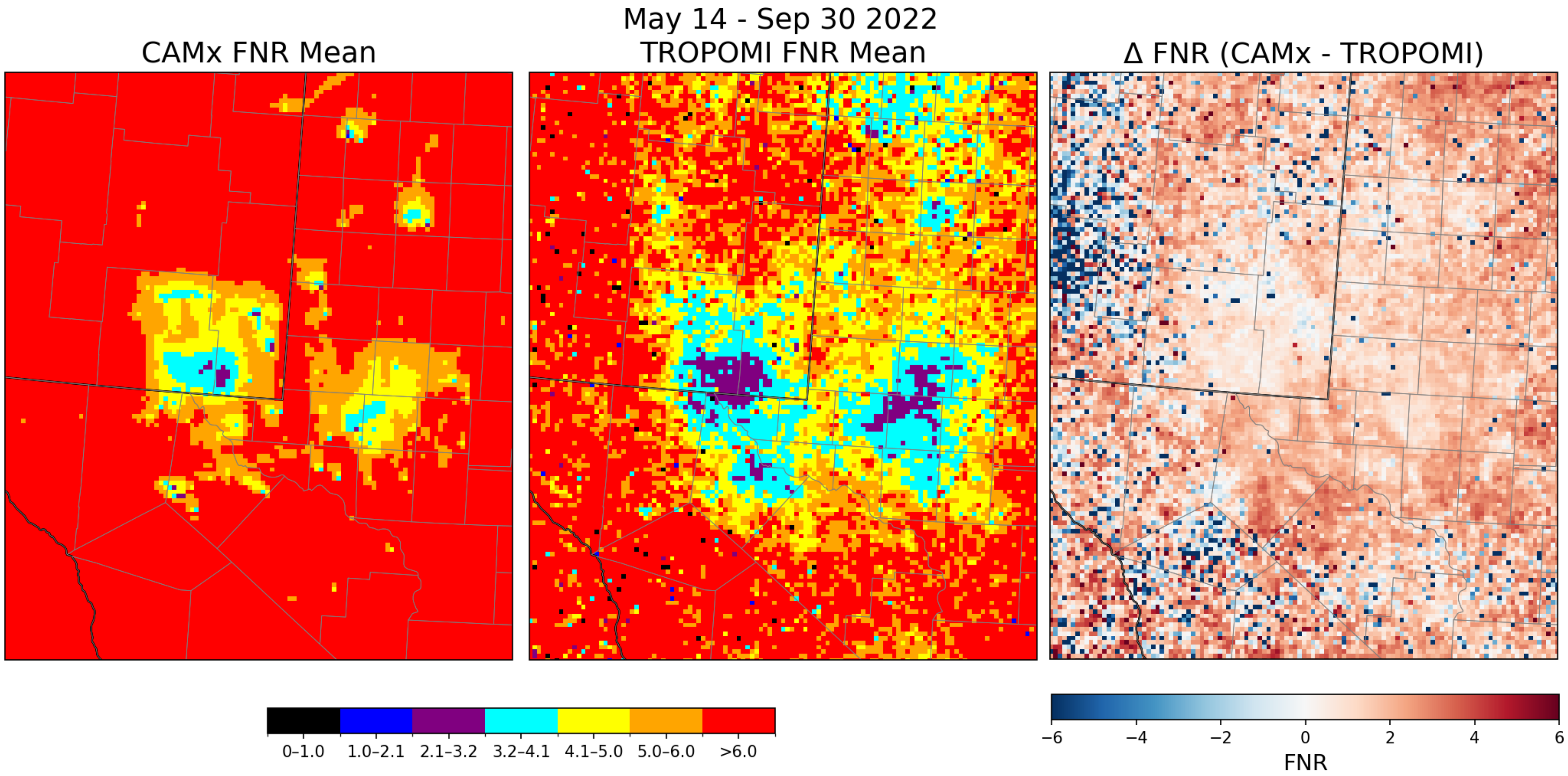
- For plotting the FNR we have adopted the following scale:



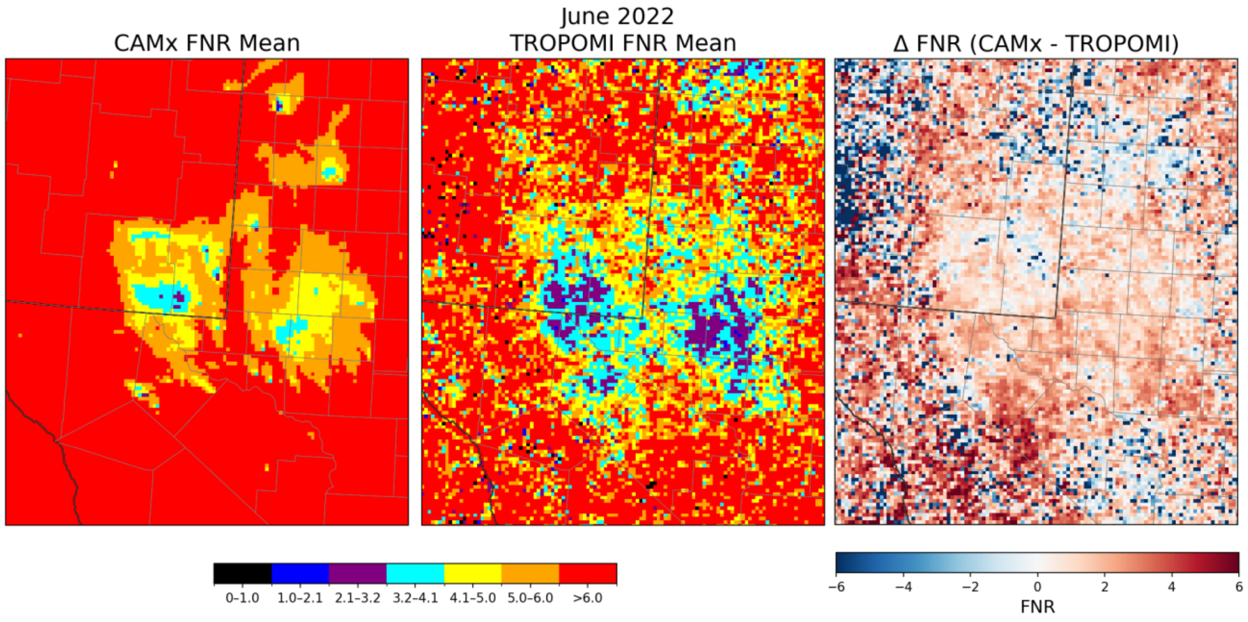
- **Black**: clearly VOC-sensitive
- **Dark Blue**: likely VOC-sensitive but may be Transition
- **Purple**: likely Transition but may be VOC-sensitive
- **Light Blue**: Transition
- **Yellow**: likely NO_X-sensitive
- **Orange** and **Red**: clearly NO_X-sensitive

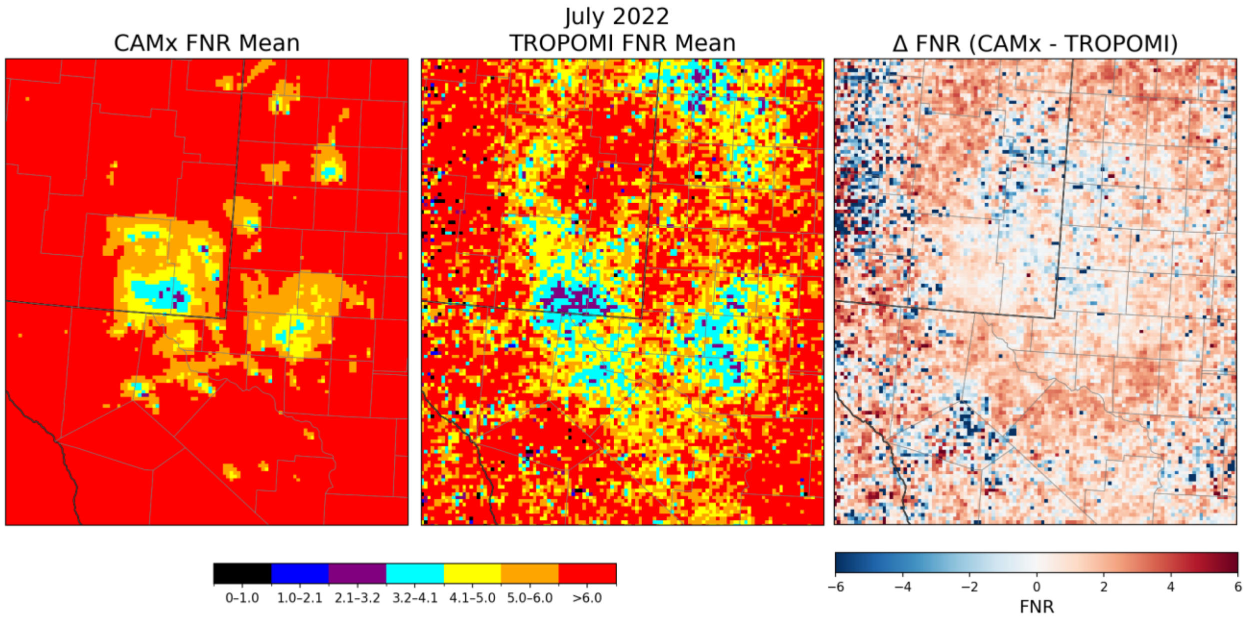
CAMx-TROPOMI FNR May 14 – Sep 30, 2022

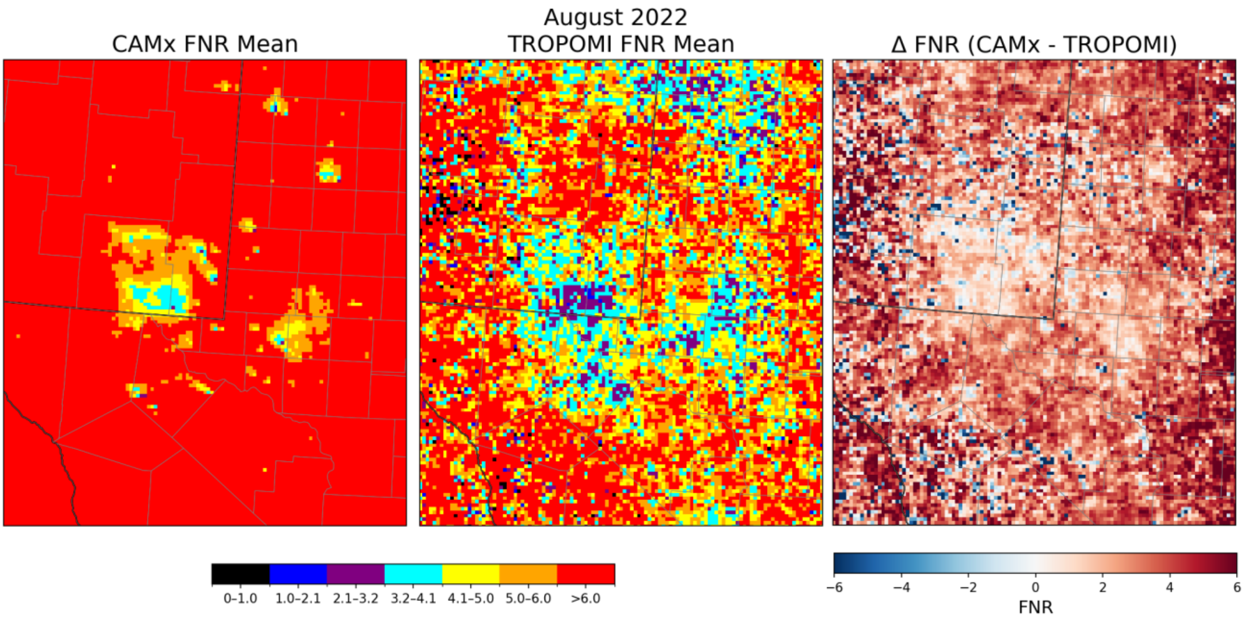
- Observed FNR has more likely VOC-sensitive ozone formation (dark) in southern Eddy and southwest Lea counties than modeled FNR
- Larger FNR ozone formation transition area in observations compared to model
- Model may understate benefits of VOC controls in the Permian Basin for reducing ozone concentrations

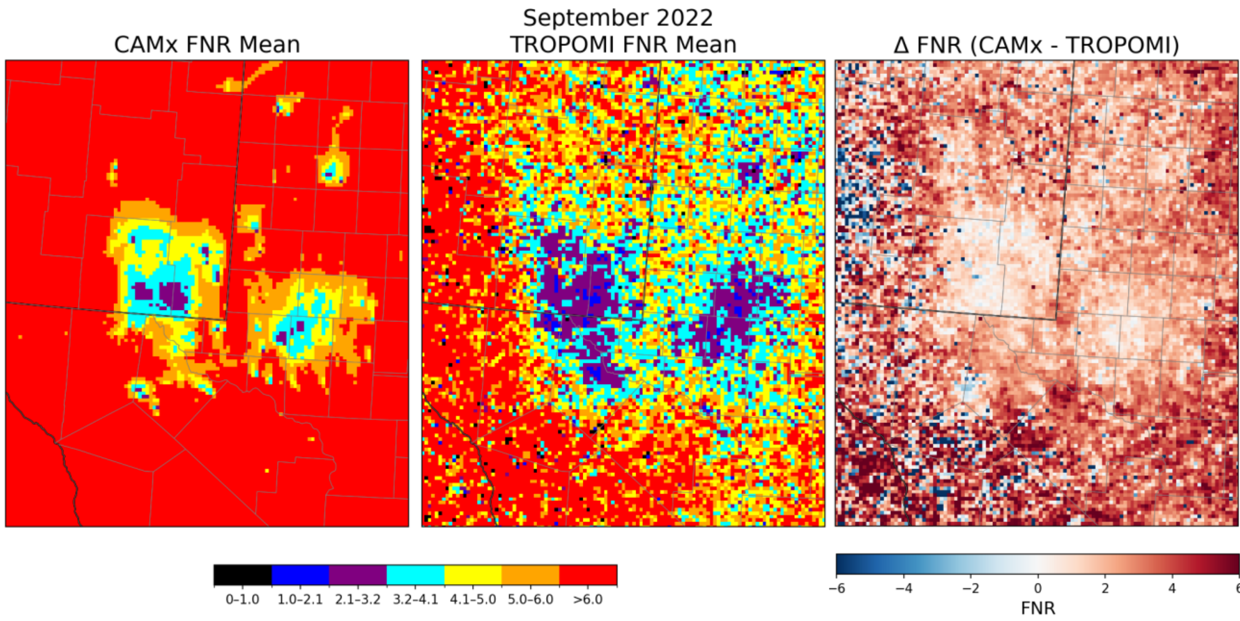


Monthly 2022 FNR Comparisons: Jun, Jul, Aug and Sep

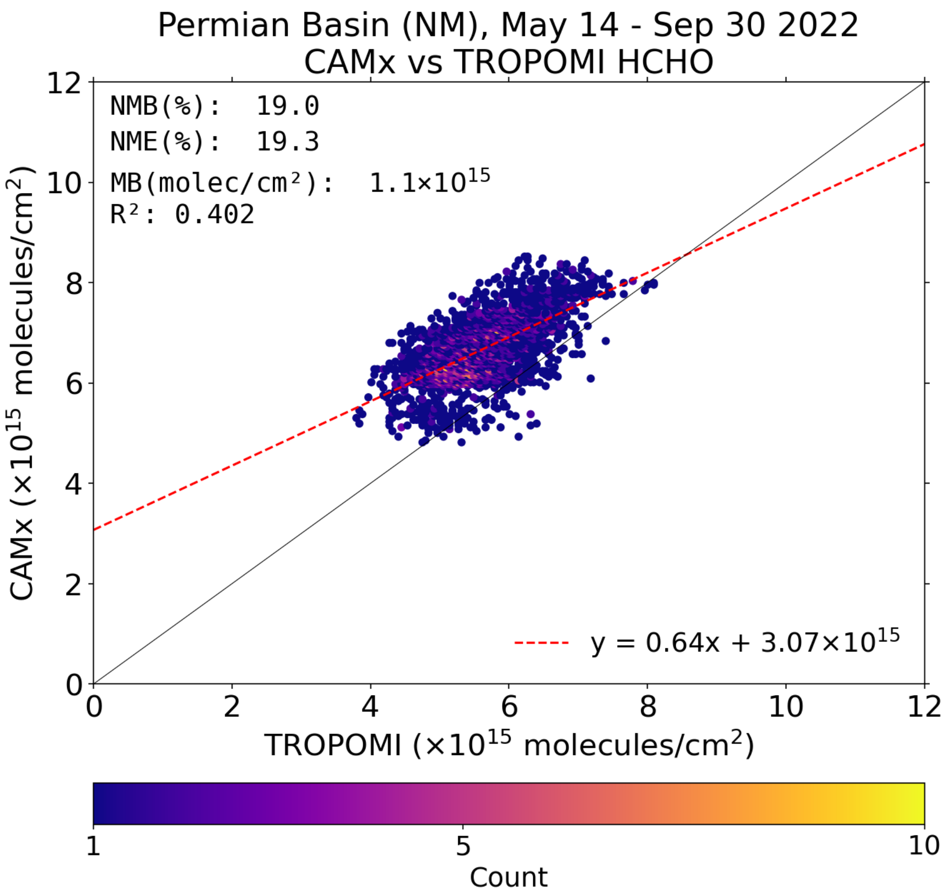




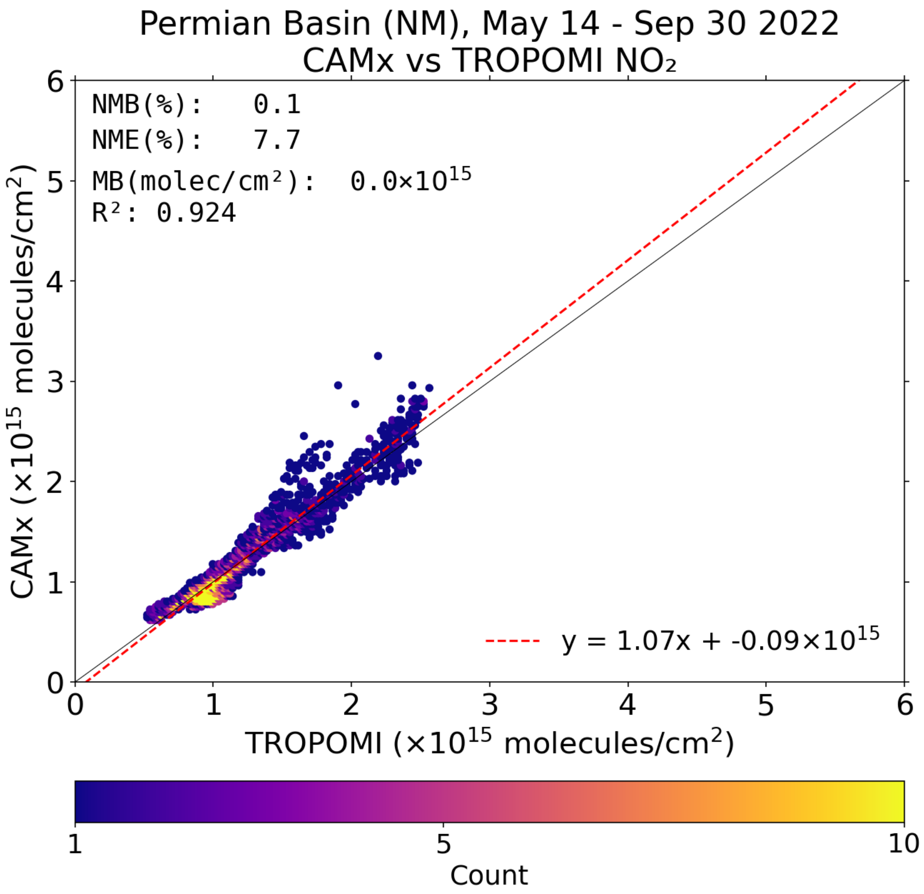




Scatter: CAMx vs TROPOMI New Mexico Permian Basin

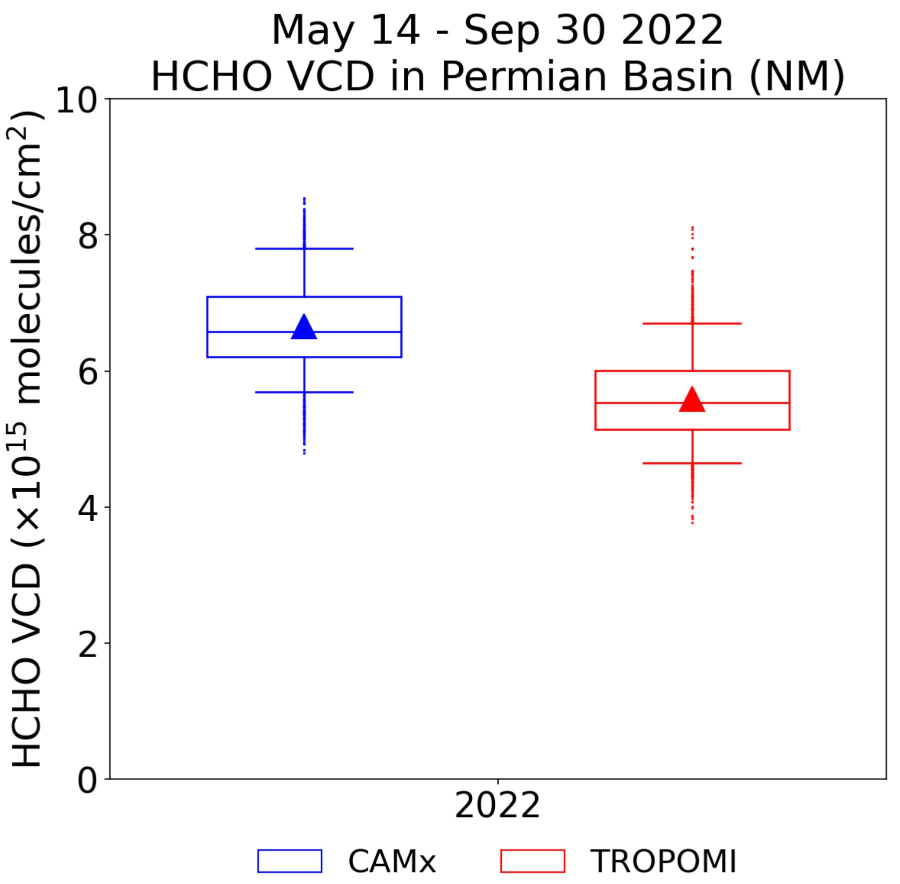


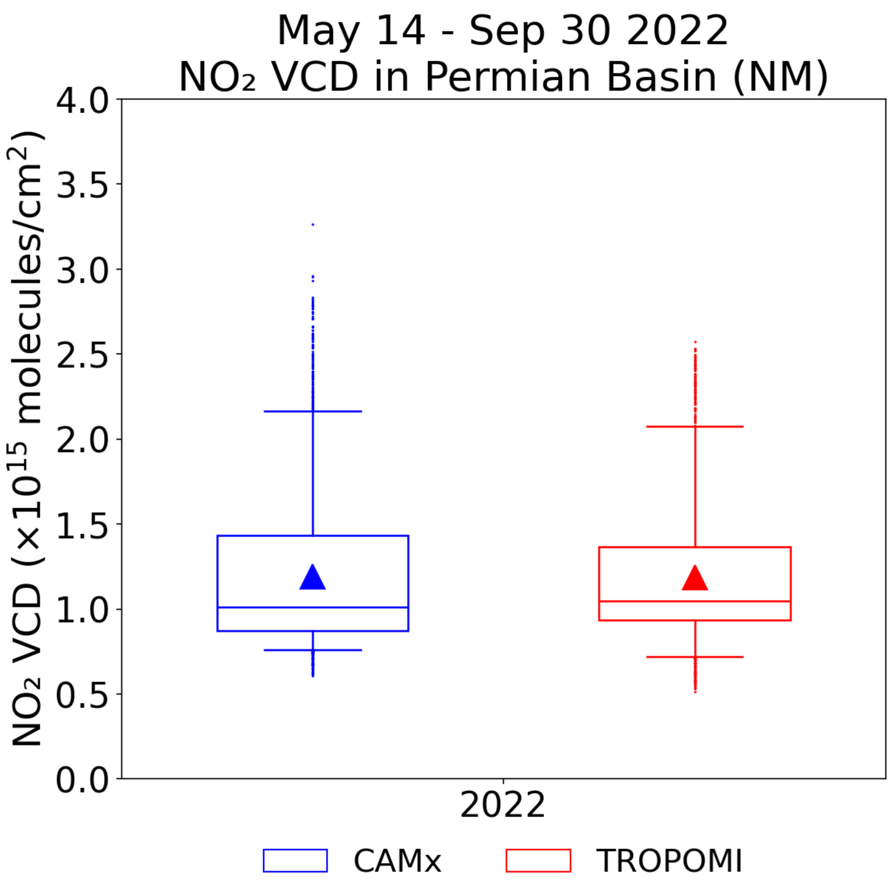
Modeled HCHO columns higher than observed



Good agreement for NO2 columns between CAMx and TROPOMI

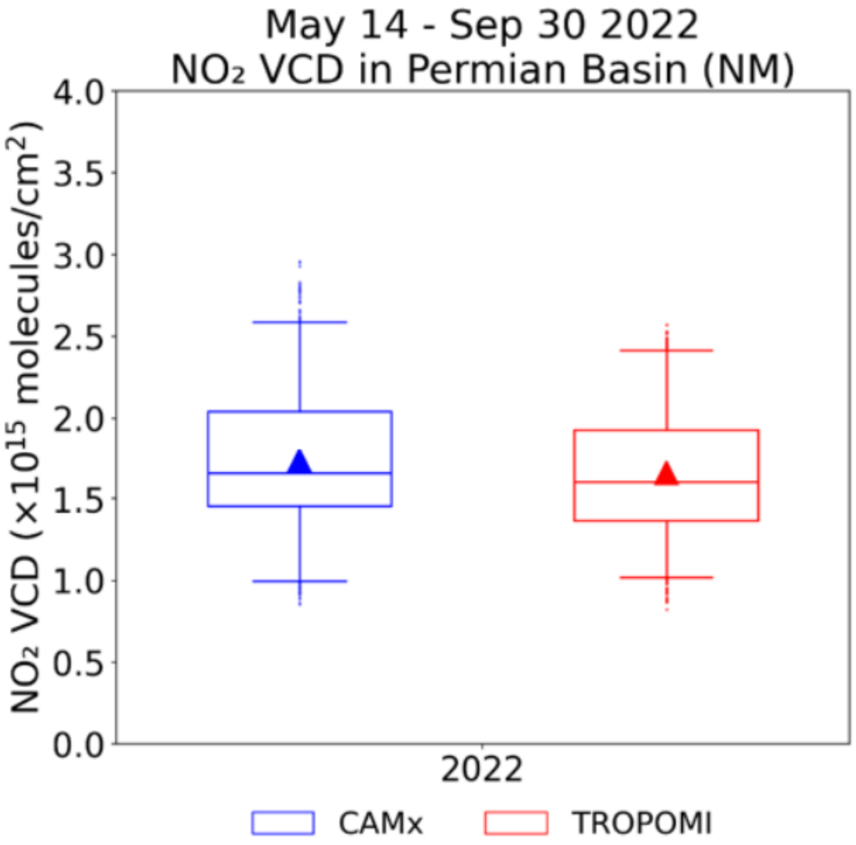
Box/Whisker: CAMx vs TROPOMI in NM Permian Basin

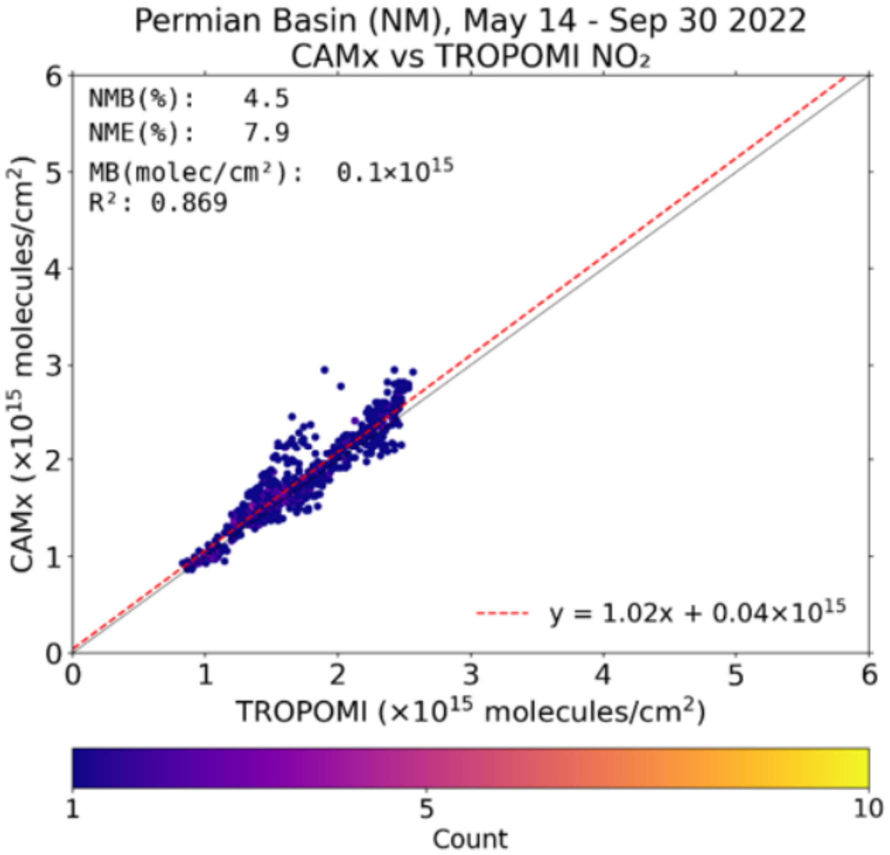




CAMx vs. TROPOMI NO_2 when O&G NO_X > 0.02 TPD

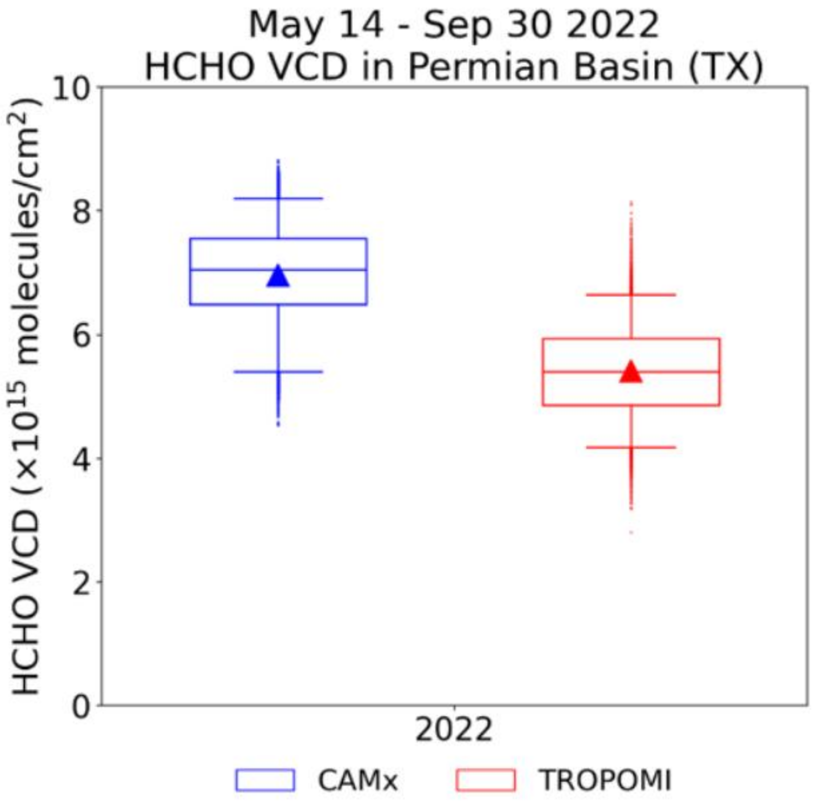
- CAMx higher VCD NO_2 at locations of larger point NO_X point sources due to higher horizontal resolution in CAMx (4 km) than TROPOMI

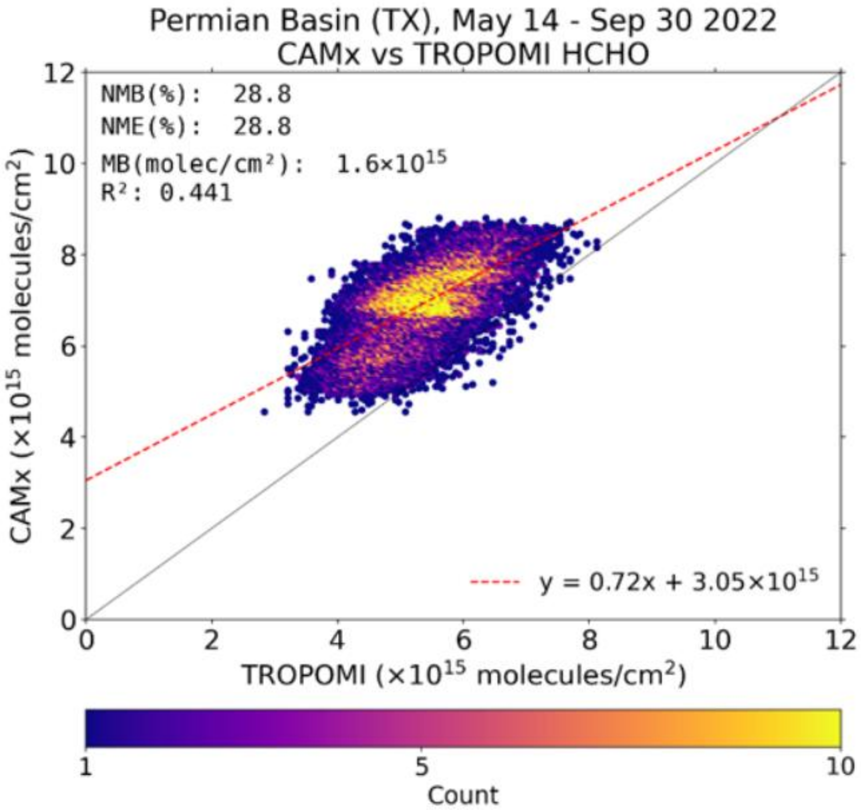




CAMx vs TROPOMI HCHO Texas Permian Basin

- CAMx formaldehyde higher than TROPOMI over Texas portion of the Permian Basin
  - More biogenic VOC emissions in Texas than New Mexico portions of the Permian Basin isoprene oxidation is a major source of atmospheric formaldehyde concentrations

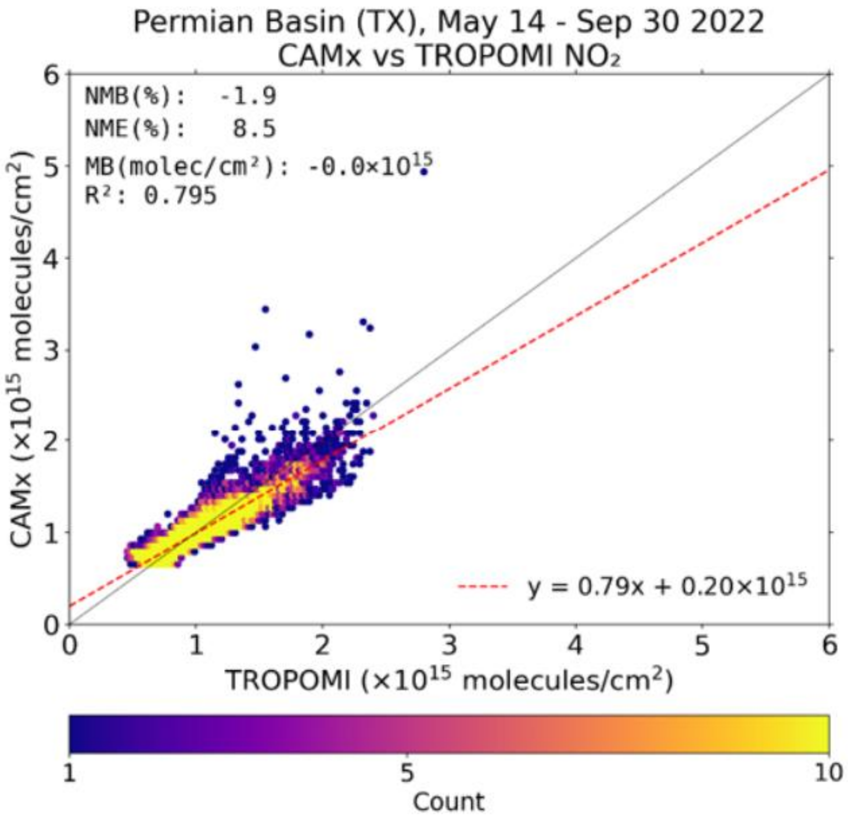




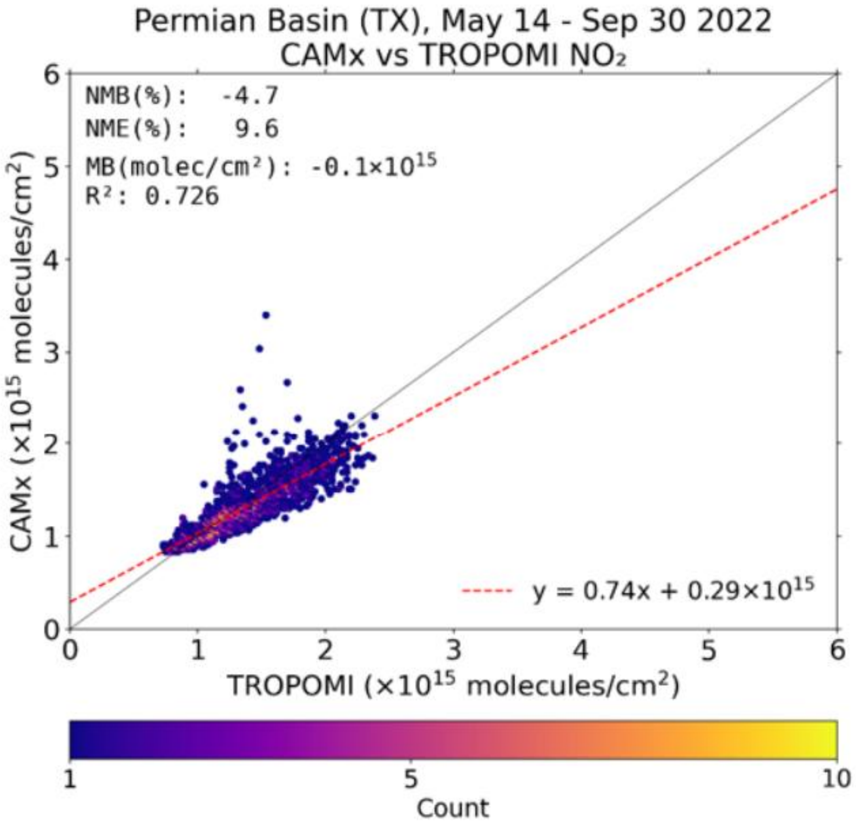
CAMx vs. TROPOMI NO_2 Texas Permian Basin

- CAMx NO_2 less than TROPOMI, especially in grid cells containing O&G emissions:
  - Underestimation bias understated due to higher resolution in CAMx producing higher NO_2 over major NO_X sources than TROPOMI

All Texas Permian Basin



TX PB when O&G NO_X > 0.02 TPD



TROPOMI Satellite Evaluation Conclusions

Overall Performance

- HCHO performance is difficult to interpret because TROPOMI are highly pixelated. CAMx tends to show higher HCHO than TROPOMI

- CAMx and TROPOMI NO_2 columns show reasonably good agreement

Ozone Formation Insights (FNR)

- TROPOMI FNR indicates more transitional, and in some areas clearly VOC-sensitive, ozone formation conditions in New Mexico Permian Basin than CAMx
  - This suggests VOC controls may be more effective at reducing ozone concentrations in the Permian Basin than estimated by the model

Implications for Emissions Evaluation

- Preliminary satellite comparisons do not show widespread systematic underestimation of Permian Basin O&G NO_X emissions; however, some local understatement may exist and may not be capture by TROPOMI

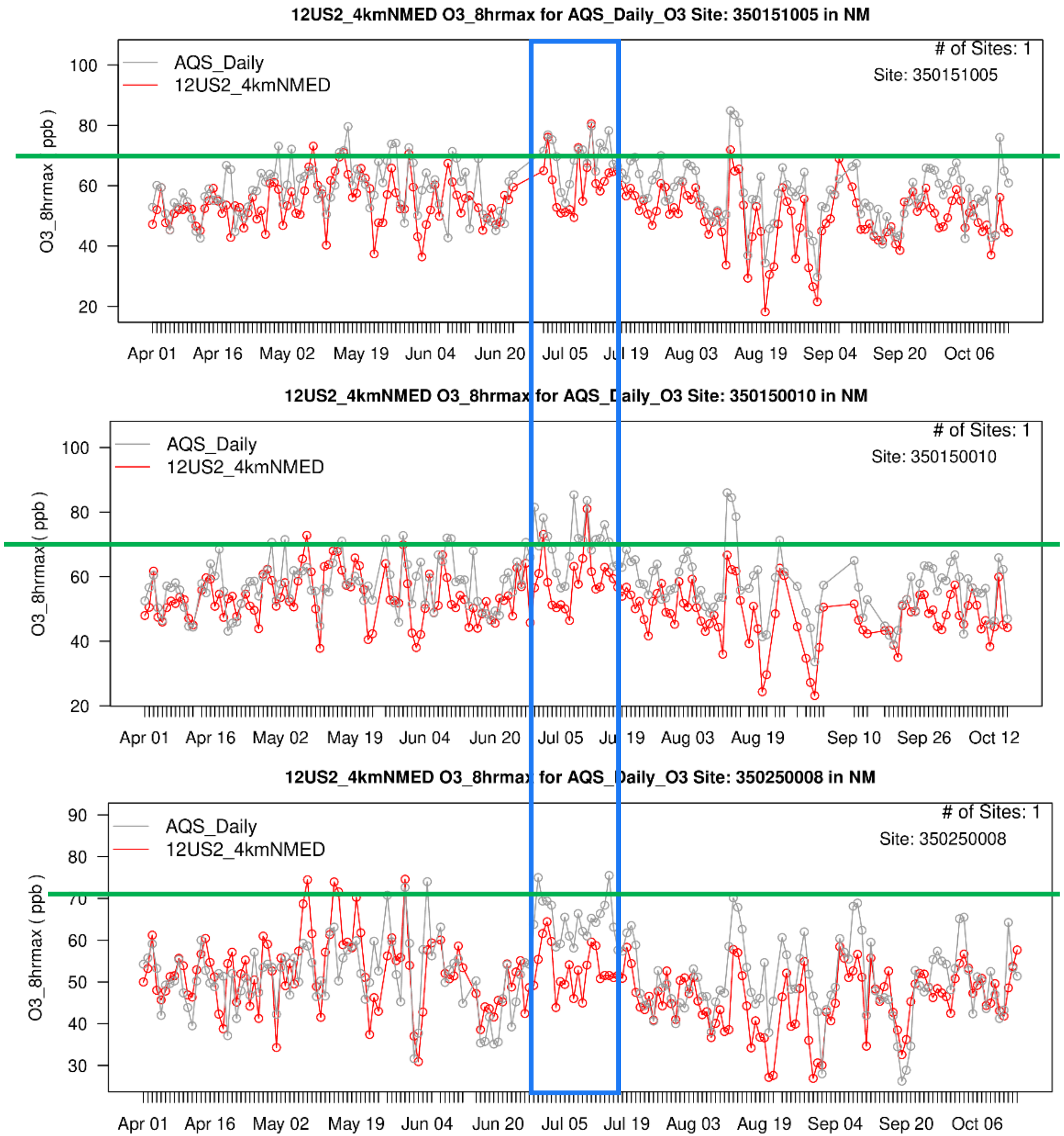
- Satellite observations carry higher uncertainties, and additional analysis with higher-resolution instruments (e.g., TEMPO) is needed

Selection of Episode Period for Sensitivity Tests

June 28 – July 17, 2022: 20 days

Blue box:
June 28 – July 17
20-day episode of high observed/modeled ozone in Permian Basin

Grey = Observed
Red = 2022_4km
Green = 70 ppb



350150010	Eddy	Carlsbad Caverns
350151005	Eddy	Carlsbad (City)
350250008	Lea	Hobbs Jefferson

Observed Ozone Exceedances in the Permian Basin

June 28 – July 17, 2022: 20-day Episode for Sensitivity Modeling (red)

- 20-days out of 157 day May 10 – Oct 14, 2022 modeling period (**13% of days**)
- Carlsbad City has 23 ozone exceedance days in 2022 (and the 157-day modeling period)
  - 20-day episode has 10 exceedance days (**43% of the exceedance days** in 2022)

Local Name:	Carlsbad Cavern	Carlsbad City	Hobbs	HMS
County:	Eddy	Eddy	Lea	Smoke
Site ID:	35-015-0010	35-015-1005	35-025-0008	Density
4/30/2022	70	73	53	Light-Medium
5/3/2022	71	72	56	None
5/14/2022	64	71	63	Light
5/15/2022	68	71	50	Light-Medium
5/16/2022	71	79	55	Light-Medium
5/26/2022	71	73	70	Light-Medium
5/27/2022	60	74	59	Medium-Heavy
5/30/2022	72	72	72	Light
6/4/2022	51	59	74	Light
6/9/2022	72	71	52	Light
6/10/2022	71	69	54	Light
6/15/2022	68	69	50	Light
6/29/2022	81	77	75	Light
6/30/2022	69	71	69	Light
7/1/2022	78	76	69	Light
7/2/2022	72	75	68	Light
7/8/2022	85	72	66	None
7/9/2022	71	71	62	Light
7/10/2022	71	67	61	Light
7/11/2022	83	79	65	Light
7/13/2022	71	74	66	Light
7/14/2022	71	71	68	Light
7/15/2022	76	78	75	Light
8/12/2022	86	84	70	Light
8/13/2022	84	83	67	Light
8/14/2022	78	80	62	Light
8/24/2022	71	66	56	None
9/8/2022	83	NA	68	Light
10/13/2022	65	76	64	None
#Exceedances	21	23	4	

Date	Obs	4kmflxnst	Bias%	12kmv1	Bias%
5/10/2022	58.8	62.5	6.5%	57.3	-2.4%
5/11/2022	50.5	43.5	-13.9%	40.3	-20.2%
5/12/2022	56.1	64.9	15.6%	61.7	10.0%
5/13/2022	60.1	59.8	-0.6%	64.8	7.8%
5/14/2022	71.0	70.6	-0.5%	69.5	-2.2%
5/15/2022	71.6	73.5	2.6%	71.0	-0.9%
5/16/2022	79.6	63.6	-20.2%	63.7	-20.0%
5/17/2022	60.1	57.8	-3.8%	56.1	-6.7%
5/18/2022	65.5	59.3	-9.4%	57.5	-12.2%
5/19/2022	62.8	68.8	9.6%	65.8	4.8%
5/20/2022	60.4	63.1	4.5%	62.5	3.5%
5/21/2022	52.6	56.6	7.5%	59.1	12.3%
5/22/2022	56.9	49.6	-12.8%	37.4	-34.2%
5/23/2022	68.0	56.0	-17.6%	47.7	-29.8%
5/24/2022	61.0	50.5	-17.2%	47.8	-21.7%
5/25/2022	68.3	57.3	-16.0%	57.0	-16.4%
5/26/2022	73.8	69.3	-6.1%	65.8	-10.8%
5/27/2022	74.1	61.3	-17.4%	57.7	-22.2%
5/28/2022	53.9	52.0	-3.6%	52.4	-2.8%
5/29/2022	47.6	50.4	5.8%	52.3	9.7%
5/30/2022	72.6	70.2	-3.4%	70.6	-2.7%
5/31/2022	67.6	59.3	-12.3%	59.5	-12.0%
6/1/2022	50.1	49.7	-0.9%	43.1	-14.0%
6/2/2022	58.5	48.1	-17.8%	36.4	-37.8%
6/3/2022	64.3	49.3	-23.2%	47.1	-26.6%
6/4/2022	59.0	53.7	-8.9%	52.0	-11.9%
6/5/2022	62.0	59.7	-3.7%	60.3	-2.8%
6/6/2022	53.9	46.6	-13.5%	49.9	-7.4%
6/8/2022	42.8	50.0	16.9%	67.4	57.7%
6/9/2022	71.4	59.8	-16.2%	61.3	-14.2%
6/10/2022	69.1	59.7	-13.7%	56.9	-17.7%
6/11/2022	61.4	56.9	-7.3%	51.0	-17.0%
6/12/2022	64.5	55.7	-13.7%	55.8	-13.4%
6/13/2022	45.8	57.4	25.5%	56.7	23.9%
6/15/2022	69.0	59.5	-13.8%	52.7	-23.6%

Date	Obs	4kmflxnst	Bias%	12kmv1	Bias%
6/16/2022	50.5	49.6	-1.9%	45.2	-10.5%
6/17/2022	48.9	52.1	6.6%	49.3	0.9%
6/18/2022	48.0	51.5	7.2%	52.5	9.4%
6/19/2022	45.1	44.7	-0.9%	47.1	4.4%
6/20/2022	51.6	40.7	-21.1%	47.9	-7.1%
6/21/2022	47.4	46.7	-1.5%	56.8	20.0%
6/22/2022	61.4	55.1	-10.2%	55.4	-9.8%
6/23/2022	63.6	56.9	-10.6%	59.5	-6.5%
6/30/2022	71.5	70.2	-1.8%	65.0	-9.2%
7/1/2022	76.9	74.0	-3.8%	76.1	-1.0%
7/2/2022	75.3	71.5	-5.0%	61.9	-17.7%
7/3/2022	69.6	57.1	-18.0%	52.8	-24.2%
7/4/2022	57.8	54.3	-6.1%	50.9	-11.8%
7/5/2022	54.3	51.6	-4.8%	51.2	-5.6%
7/6/2022	60.5	54.8	-9.4%	52.1	-13.9%
7/7/2022	68.4	59.4	-13.1%	49.4	-27.7%
7/8/2022	72.1	59.1	-18.1%	72.7	0.7%
7/9/2022	71.9	64.2	-10.7%	54.9	-23.7%
7/10/2022	67.4	66.9	-0.7%	66.0	-2.0%
7/11/2022	79.8	74.1	-7.1%	80.6	1.0%
7/12/2022	64.8	62.3	-3.8%	60.7	-6.3%
7/13/2022	74.1	68.0	-8.2%	58.2	-21.5%
7/14/2022	71.4	64.4	-9.8%	61.4	-13.9%
7/15/2022	78.3	65.1	-16.8%	64.2	-17.9%
7/16/2022	67.1	67.4	0.4%	64.7	-3.6%
7/17/2022	66.5	68.6	3.2%	65.2	-1.9%
7/18/2022	64.3	62.6	-2.5%	60.1	-6.4%
7/19/2022	62.1	59.5	-4.3%	56.6	-8.9%
7/20/2022	68.3	65.2	-4.4%	59.2	-13.3%
7/21/2022	69.4	66.0	-4.8%	56.7	-18.3%
7/22/2022	63.9	61.2	-4.3%	51.7	-19.0%
7/23/2022	55.6	54.1	-2.7%	55.0	-1.1%
7/24/2022	55.9	56.7	1.4%	50.6	-9.4%
7/25/2022	61.9	52.3	-15.4%	46.9	-24.2%
7/26/2022	63.6	54.3	-14.7%	51.6	-18.9%
7/27/2022	70.0	54.0	-22.9%	60.8	-13.2%
7/28/2022	54.9	57.9	5.5%	59.5	8.4%
7/29/2022	55.5	52.2	-5.9%	50.5	-8.9%
7/30/2022	59.6	50.1	-15.9%	52.7	-11.5%
7/31/2022	61.6	53.9	-12.5%	50.7	-17.7%

Date	Obs	4kmflxnst	Bias%	12kmv1	Bias%
8/1/2022	61.5	54.9	-10.7%	61.3	-0.3%
8/2/2022	67.3	61.9	-8.0%	56.7	-15.7%
8/3/2022	66.5	60.7	-8.8%	55.4	-16.6%
8/4/2022	65.0	55.3	-14.9%	59.3	-8.7%
8/5/2022	55.5	56.9	2.5%	53.6	-3.5%
8/6/2022	53.1	51.9	-2.3%	48.1	-9.4%
8/7/2022	50.4	50.8	0.8%	43.9	-12.9%
8/8/2022	48.1	54.9	14.0%	47.9	-0.4%
8/9/2022	51.8	56.0	8.2%	51.1	-1.2%
8/10/2022	47.8	53.7	12.5%	44.7	-6.4%
8/11/2022	50.5	54.7	8.3%	33.7	-33.3%
8/12/2022	84.9	66.8	-21.3%	71.9	-15.3%
8/13/2022	83.5	73.0	-12.5%	64.9	-22.3%
8/14/2022	80.9	68.9	-14.9%	65.5	-19.0%
8/15/2022	57.6	53.4	-7.4%	53.6	-7.0%
8/16/2022	36.9	47.0	27.4%	29.4	-20.4%
8/17/2022	55.5	38.8	-30.1%	43.1	-22.4%
8/18/2022	55.4	51.1	-7.7%	53.1	-4.1%
8/19/2022	63.0	57.3	-9.0%	44.8	-28.8%
8/20/2022	34.4	40.6	18.2%	18.2	-47.1%
8/21/2022	45.8	39.2	-14.3%	30.6	-33.2%
8/22/2022	47.5	42.2	-11.1%	33.2	-30.1%
8/23/2022	57.5	53.0	-7.8%	47.3	-17.7%
8/24/2022	66.0	65.6	-0.6%	59.4	-10.1%
8/25/2022	60.4	58.2	-3.7%	54.8	-9.3%
8/26/2022	58.0	61.8	6.5%	51.6	-11.0%
8/27/2022	56.5	46.4	-17.8%	35.8	-36.7%
8/28/2022	58.6	53.0	-9.6%	46.0	-21.5%
8/29/2022	64.5	57.4	-11.0%	55.6	-13.8%
8/30/2022	43.8	46.4	6.0%	32.8	-25.0%
8/31/2022	41.6	46.3	11.2%	26.5	-36.3%
9/1/2022	29.8	51.2	72.2%	21.6	-27.6%
9/2/2022	53.1	57.0	7.2%	45.0	-15.3%
9/3/2022	52.6	55.2	4.8%	47.5	-9.7%
9/4/2022	58.6	57.8	-1.4%	49.0	-16.3%
9/5/2022	56.9	57.5	1.0%	57.1	0.4%
9/6/2022	62.3	66.4	6.7%	68.9	10.7%
9/9/2022	66.4	63.2	-4.8%	59.7	-10.1%
9/10/2022	67.4	59.9	-11.1%	54.3	-19.4%
9/11/2022	50.6	58.4	15.3%	45.5	-10.1%
9/12/2022	54.3	53.7	-1.1%	45.5	-16.1%
9/13/2022	53.1	49.3	-7.3%	47.4	-10.7%
9/14/2022	43.6	54.0	23.7%	43.2	-0.9%
9/15/2022	52.3	48.3	-7.6%	42.0	-19.7%

Sensitivity Tests

June 28 – July 17, 2022: 20 days

Vertical Mixing Sensitivity Tests for 20-day Episode

Is the modeled too low afternoon NO_2 concentrations due to excessive vertical mixing?

Vertical Mixing in CAMx

- CAMx vertical mixing algorithm uses vertical turbulent coefficient (diffusivities or Kv) that are defined in WRFCAMx using two options: YSU or CMAQ
- A minimum Kv is imposed of 0.1 m^2/s
- To account for urban heat island effect, a "KvPatch100" program is used to set a minimum Kv in the lowest 100 m of the atmosphere from 0.1 to 2.0 m^2/s depending on fraction of urban landuse in the grid cell (100% urban = 2.0 m^2/s)

Vertical Mixing Sensitivity Tests

4km20202v2 = Base Case: Kv(YSU) with KvPatch100

4km2022v2_sens1 = Kv(YSU) no KvPatch100

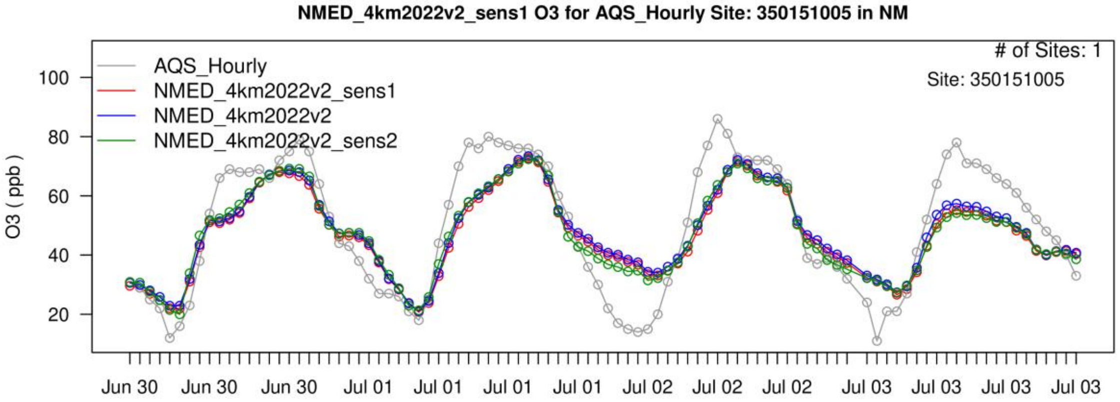
4km2022v2_sens2 = Kv(CMAQ) no KvPatch100

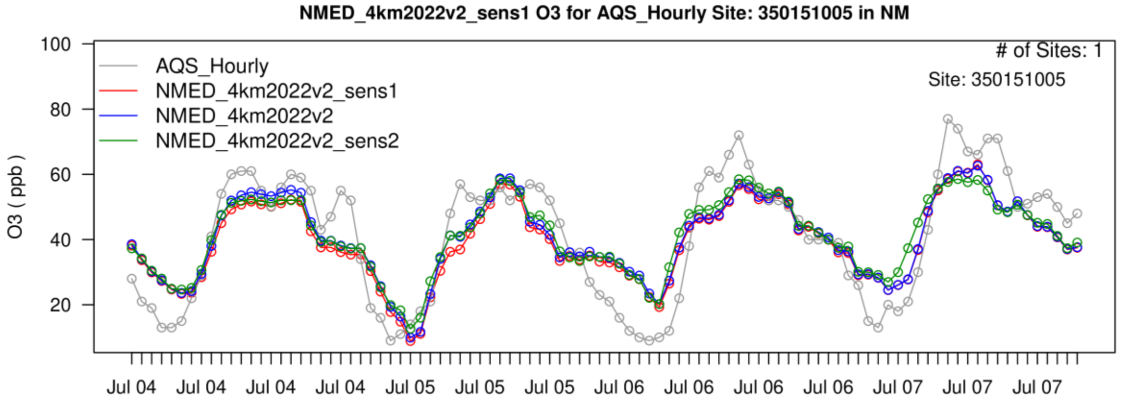
- All tests use CAMx 2022v2 12/4 km base case configuration (4km2022v2) with only **different Kv profiles** in sens1 and sens2
- Examine hourly ozone and NO_2 time series at Carlsbad City site for several 4-day periods

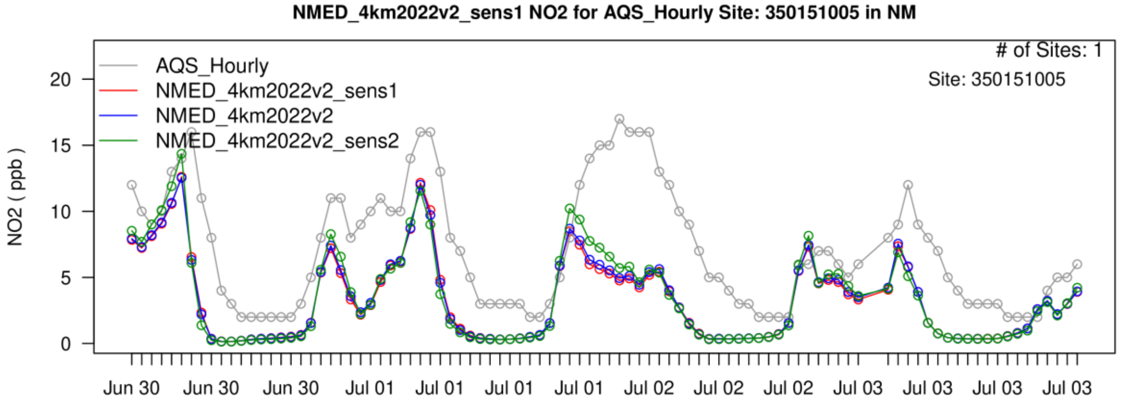
Vertical Mixing Sensitivity Ozone and NO_2 @ Carlsbad City

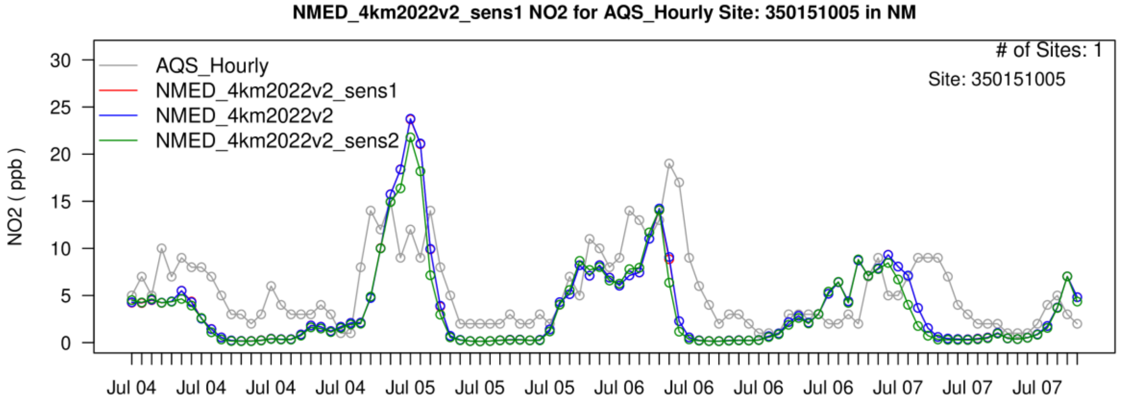
Base Kv(YSU) KvPatch100; Sens1 Kv(YSU) No KvPatch; Sens2 Kv(CMAQ) No KvPatch

- Small differences in CAMx 2022v2 4 km ozone/NO_2 at Carlsbad City due to alternative vertical mixing approaches – not significant amount of urban landuse so KvPatch has little effect







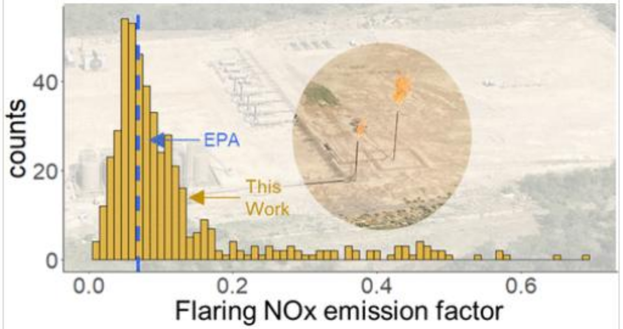


Permian Basin Emissions are Likely Underestimated in 2022 Platform

ENERGY AND CLIMATE | January 8, 2024

In Situ Sampling of NOx Emissions from United States Natural Gas Flares Reveals Heavy-Tail Emission Characteristic

Genevieve Plant*, Eric A. Kort*, Alan M. Gorchov Negron, Yuanlei Chen, Graham Fordice, and Colin Harkins



ELSEVIER

Remote Sensing of Environment

Volume 334, 1 March 2026, 115229

Space-based assessment of NO_x emissions from global oil and gas fields: Bridging the gap in current emission inventories

Piyushkumar N. Patel [a 1], Ritesh Gautam [a b], Mark Omara [a b]

- Top-down satellite-based analysis reveals current bottom-up inventories underestimate NOx emissions from Oil & Gas basins by 61-92%.

Numerous reported excess emissions leading to potential fines that represent a fraction of the actual excess emissions

Recent Major Penalties and Settlements (2023–2025):

- **Targa Northern Delaware, LLC (Dec 2024):** $47.8 million penalty for excessive emissions in Lea County, NM.
- **Ameredev II LLC (April 2024):** $24.5 million settlement for state air regulation violations.
- **Apache Corporation (Feb 2024):** $4 million in penalties with $5.5 million for compliance, totaling $9.5M.
- **Mewbourne Oil Company (Aug 2023):** $5.5 million penalty and $4.6 million in compliance costs.
- **Callon Permian LLC (July 2023):** $1.285 million penalty for violations involving tank pressure and emissions.
- **Permian Resources (March 2023):** $610,000 penalty for air pollution violations.
- **Matador Production Company (March 2023):** $1.15 million penalty. U.S. Environmental Protection Agency (.... +4

Satellite-based Quantification of NOx Emissions from Global Oil and Gas Fields

ATMOSPHERIC SCIENCES | CLIMATOLOGY (GLOBAL CHANGE) | EMISSIONS | ENVIRONMENTAL SCIENCES | NOX | OIL AND GAS | REMOTE SENSING | SATELLITE DATA

Piyushkumar Patel, Ritesh Gautam, Mark Omara

December 26, 2024 – ESS Open Archive

Delaware Basin NO_X emissions underestimated by 91-95% based on TROPOMI

Targa Red Hills Processing Plant ~50 km SE of Carlsbad Site

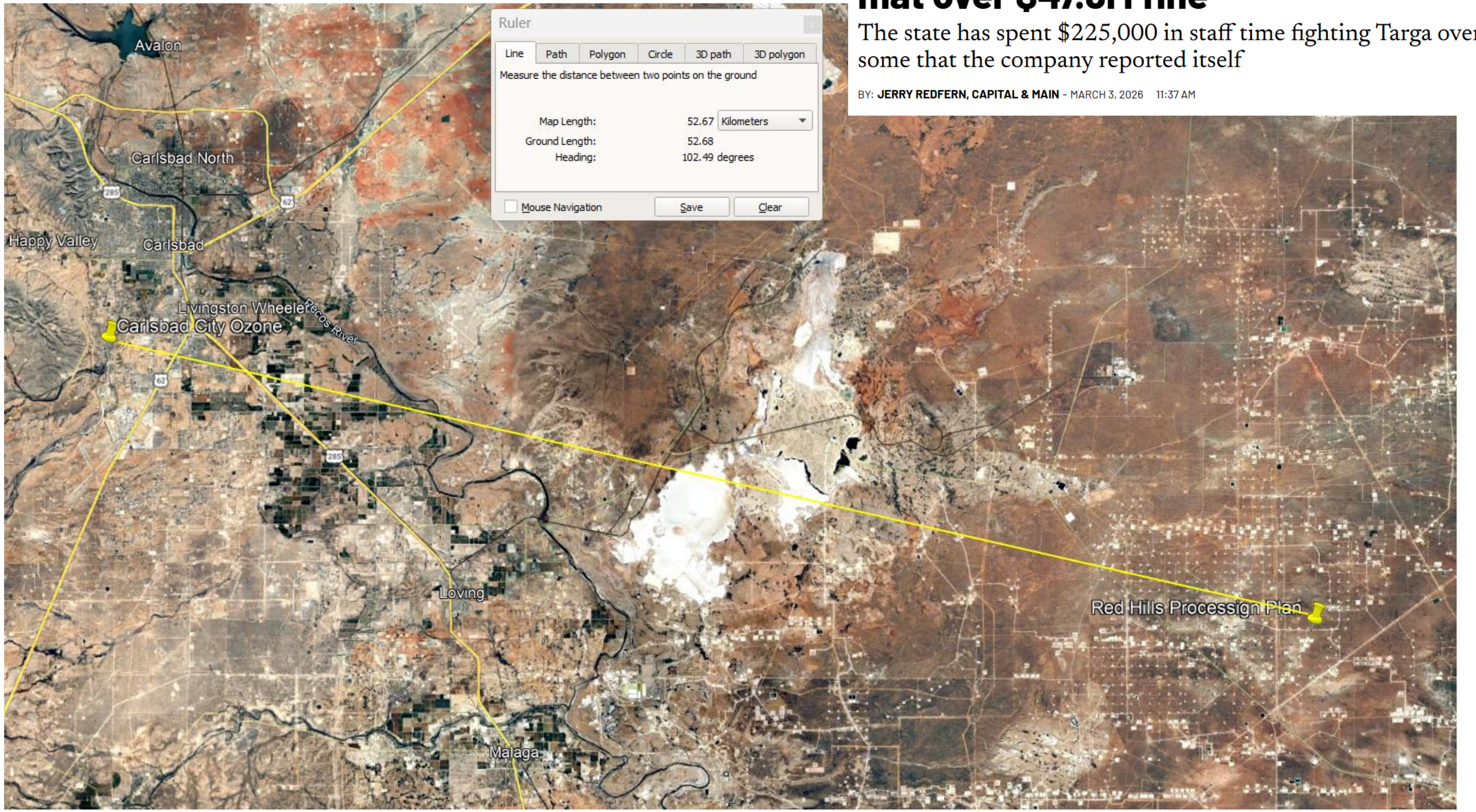
- Targa Red Hills Natural Gas Processing Plant has reported known excess emissions > million pounds
- These excess emissions occurred in several years, including 2022
- Red Hills Plant ~50 km SE of Carlsbad City Site

ENVIRONMENT & CLIMATE CHANGE

In New Mexico, natural gas transporter goes to the mat over $47.8M fine

The state has spent $225,000 in staff time fighting Targa over emission infractions, some that the company reported itself

BY: JERRY REDFERN, CAPITAL & MAIN - MARCH 3, 2026 11:37 AM



Emission Sensitivity Tests

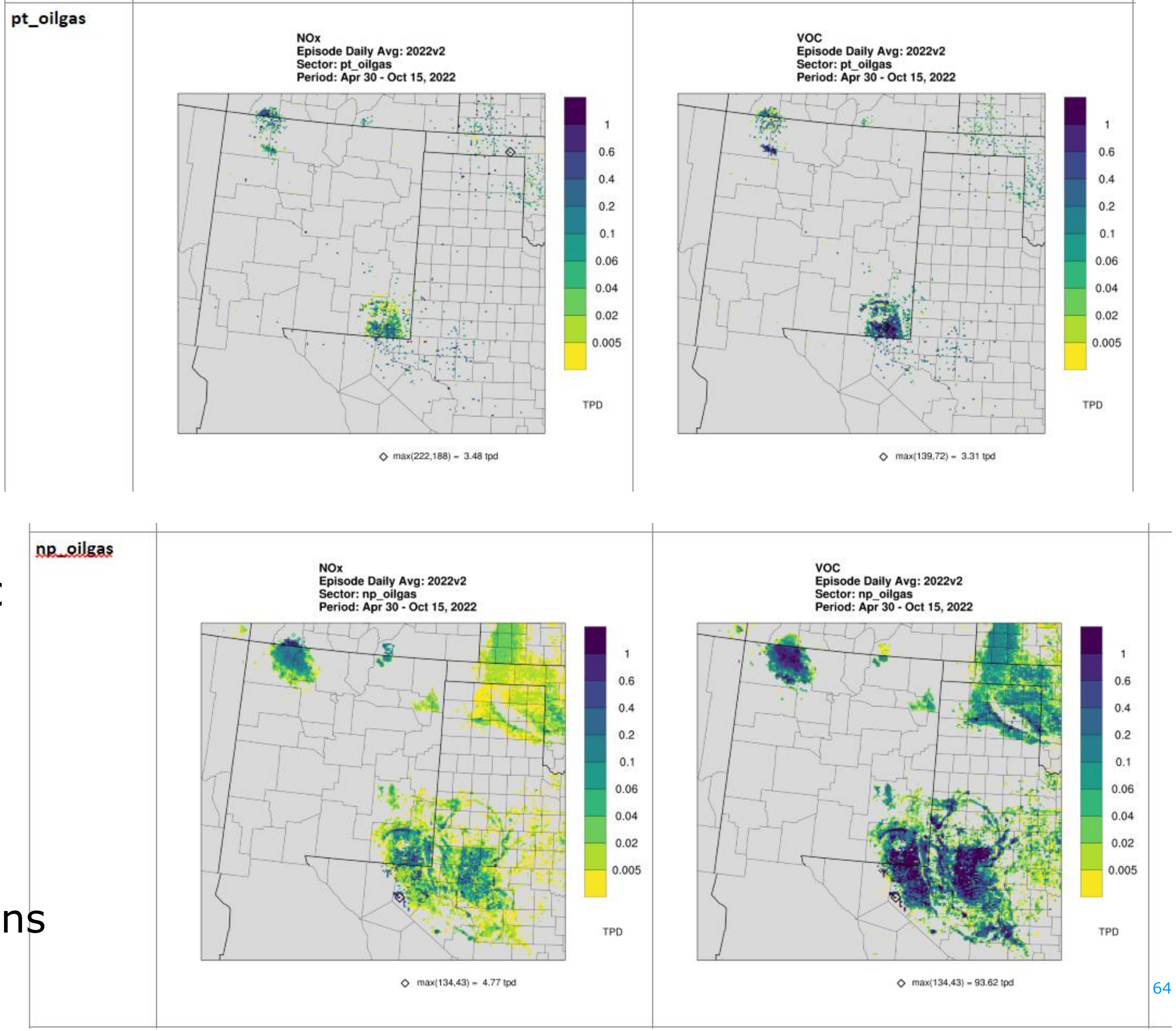
Permian Basin (PB) O&G Emissions Sensitivity Tests

Increase New Mexico (NM) or Texas (TX) portions of Permian Basin (PB) O&G emissions by a factor of 3

- 4km2022v2 = Base Case 2022v2 PB O&G
- Sens3 = 3 x 2022v2 NM PB O&G NO_X
- Sens4 = 3 x 2022v2 NM PB O&G VOC
- Sens5 = 3 x 2022v2 NM PB O&G NO_X & VOC
- Sens7 = 3 x 2022v2 TX PB O&G NO_X & VOC

- The factor of 3 is arbitrary and the locations of the missing O&G emissions likely don't align with the spatial distribution of the 2022v2 O&G emissions

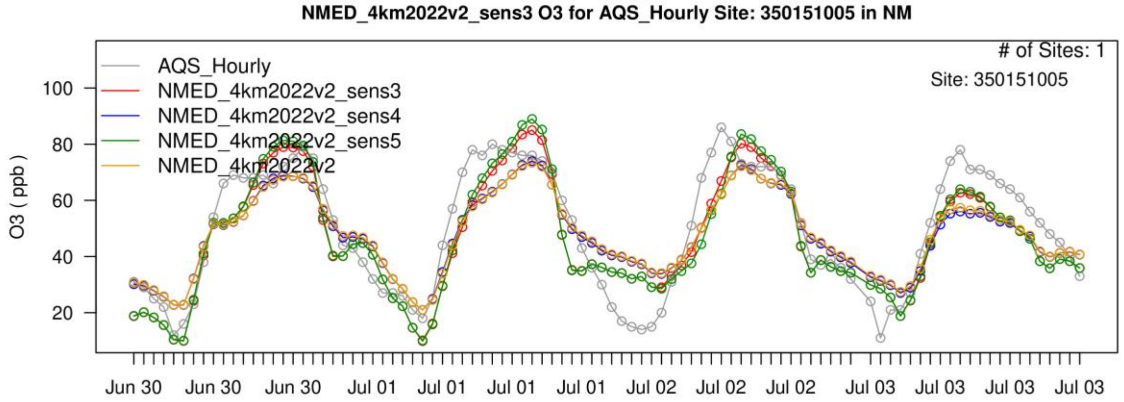
2022v2 O&G NO_X | VOC

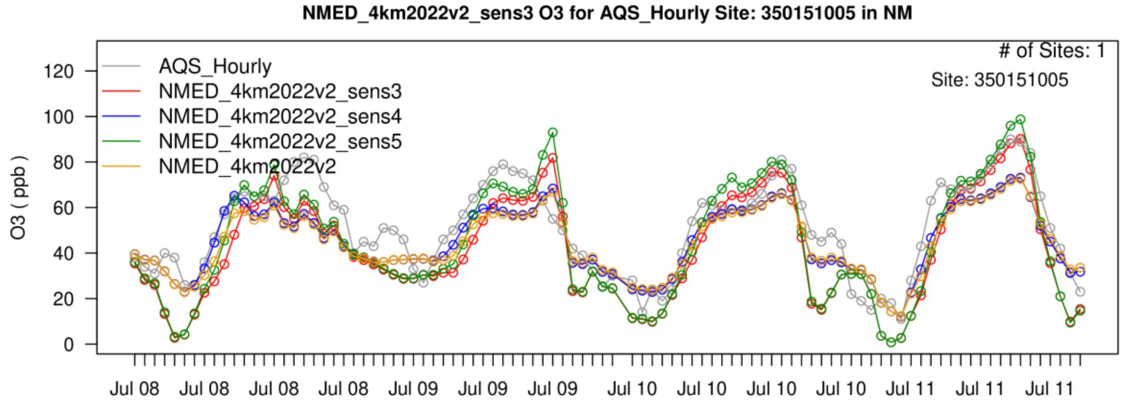


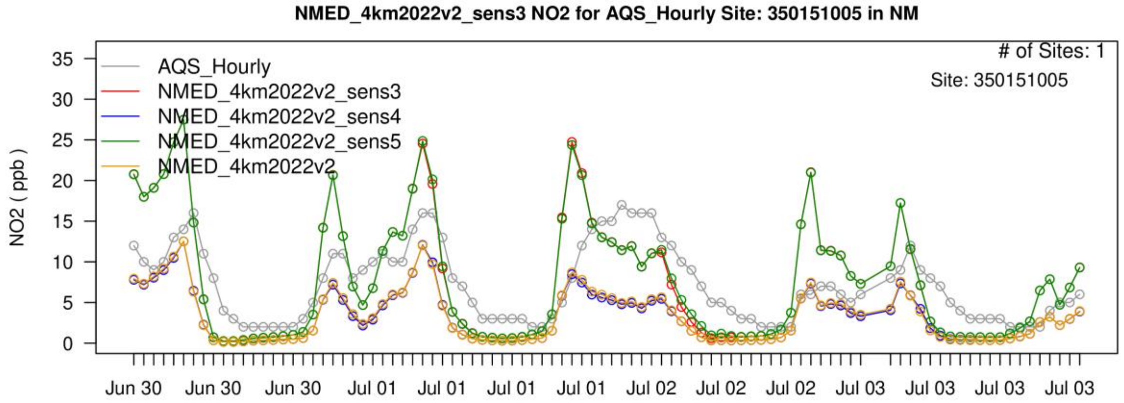
Carlsbad City NM PB O&G Sensitivities O_3 and NO_2

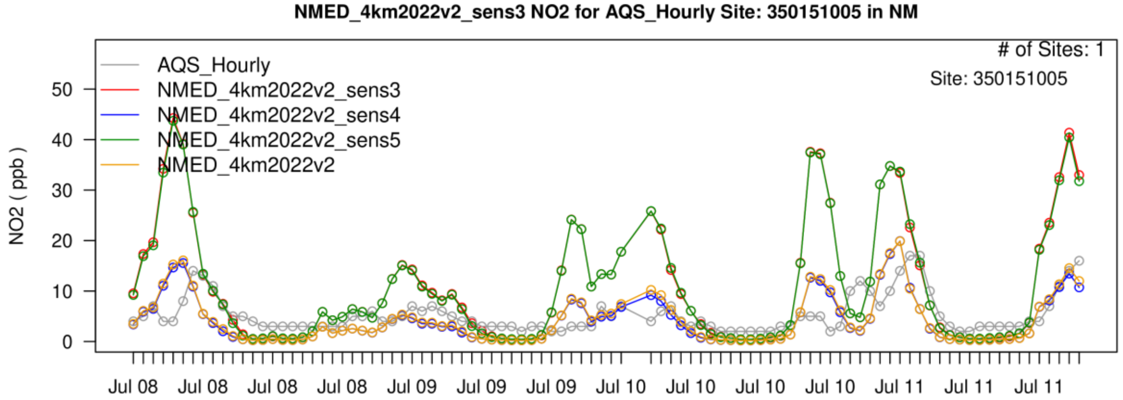
2022v2 Base Case; Sens3 3 x NO_X; Sens4 3 x VOC; Sens5 3 x NO_X & VOC

- Better ozone performance with 3 x NO_X O&G (**Sens3** and **Sens5**), but some NO_2 overestimation (3x to high?)
- **Sens5** produces lower nighttime ozone than the other tests. Ozone performance improves across the full concentration range, not just at the high end. Modeled afternoon NO_2 still lower than observed.
- 3 x VOC O&G (**Sens4**) has small effect on ozone (will show later that model understates VOC-sensitivity)



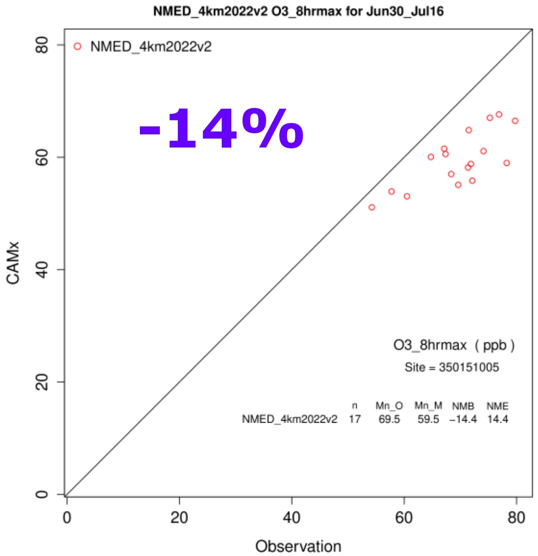


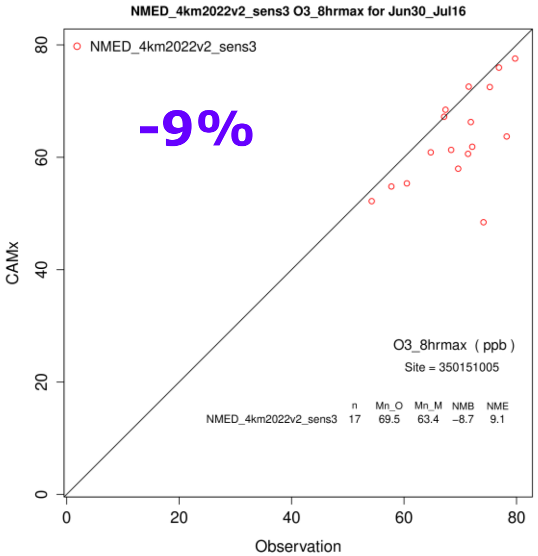


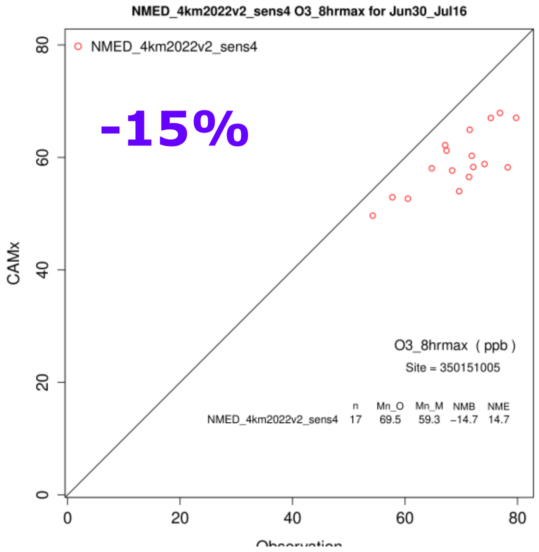


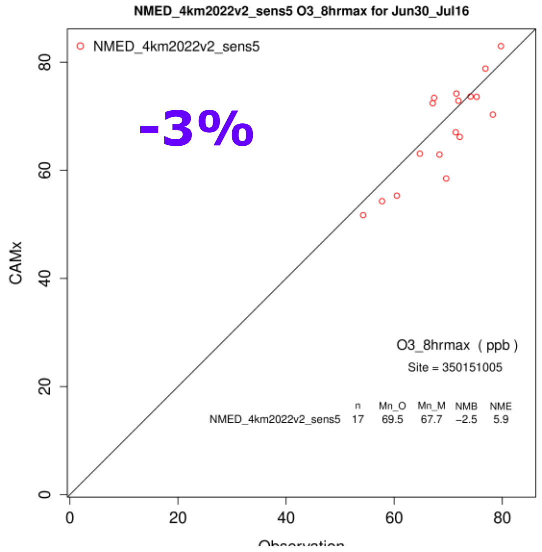
NM PB O&G: Carlsbad City MDA8 (Top) & Hourly (Bottom) O_3

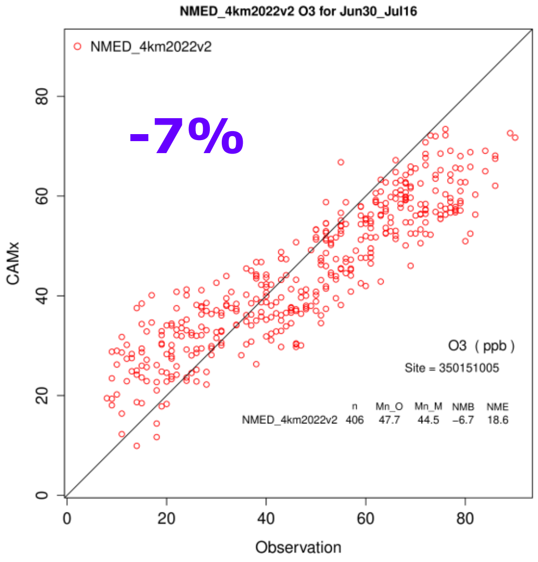
4km2022v2	3 x NO_x O&G	3 x VOC O&G	3 x NO_x & VOC O&G

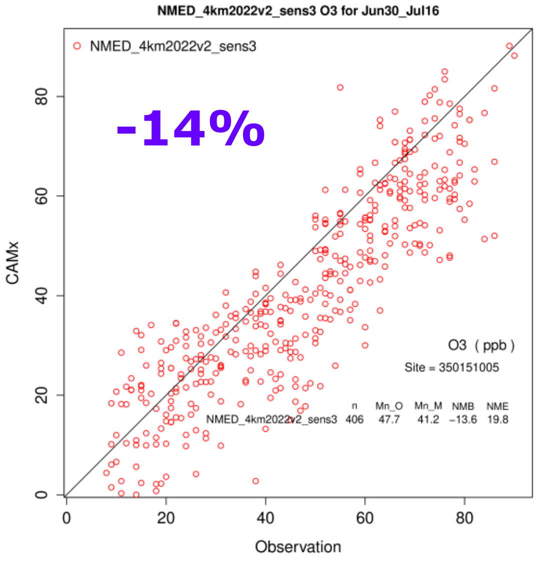


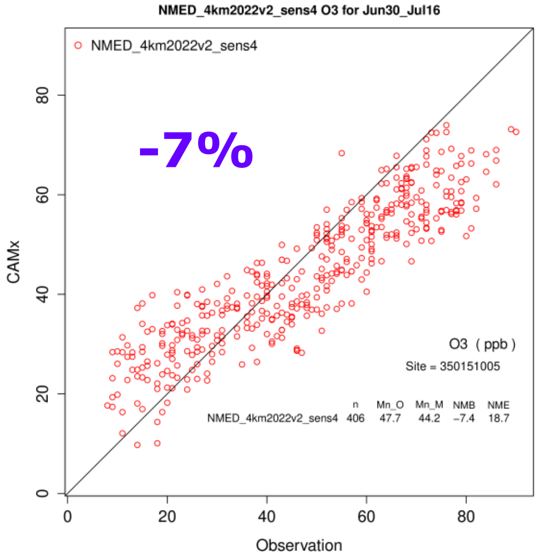


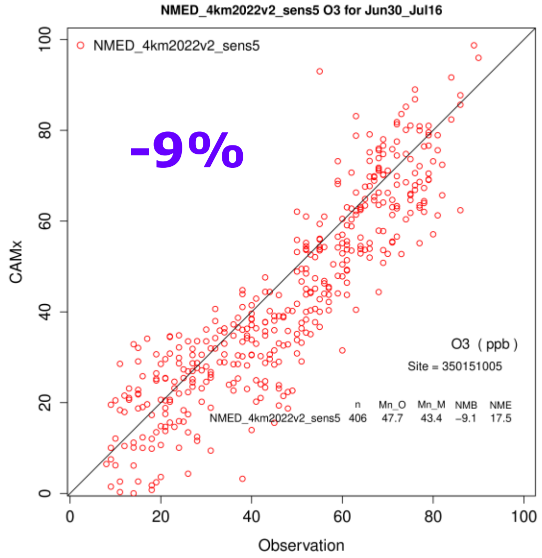












LNM Oil and Gas Tracers – 2022v2 Base & Sens5 vs. Obs

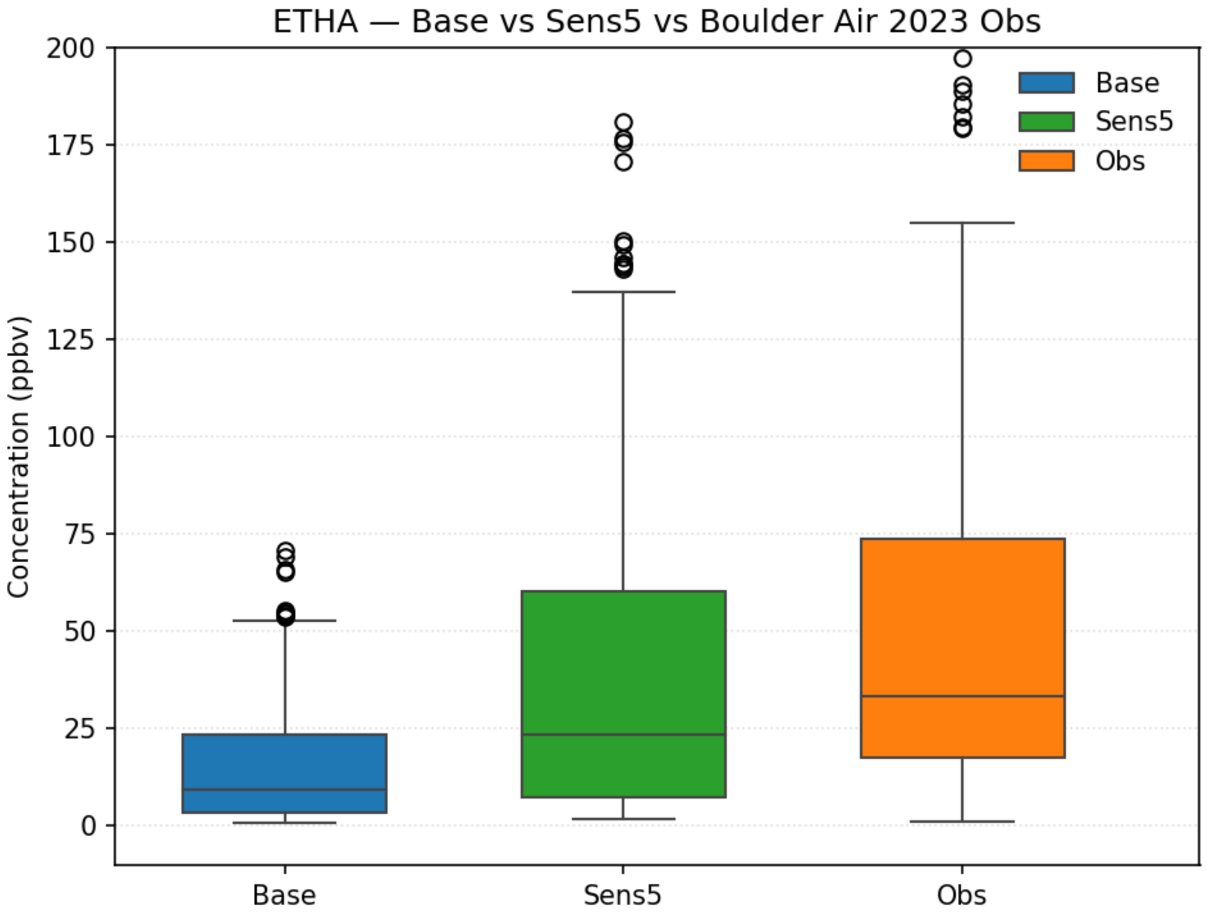
Even with 3 x NM Permian Basin O&G VOC emissions, model still underestimates ethane and propane

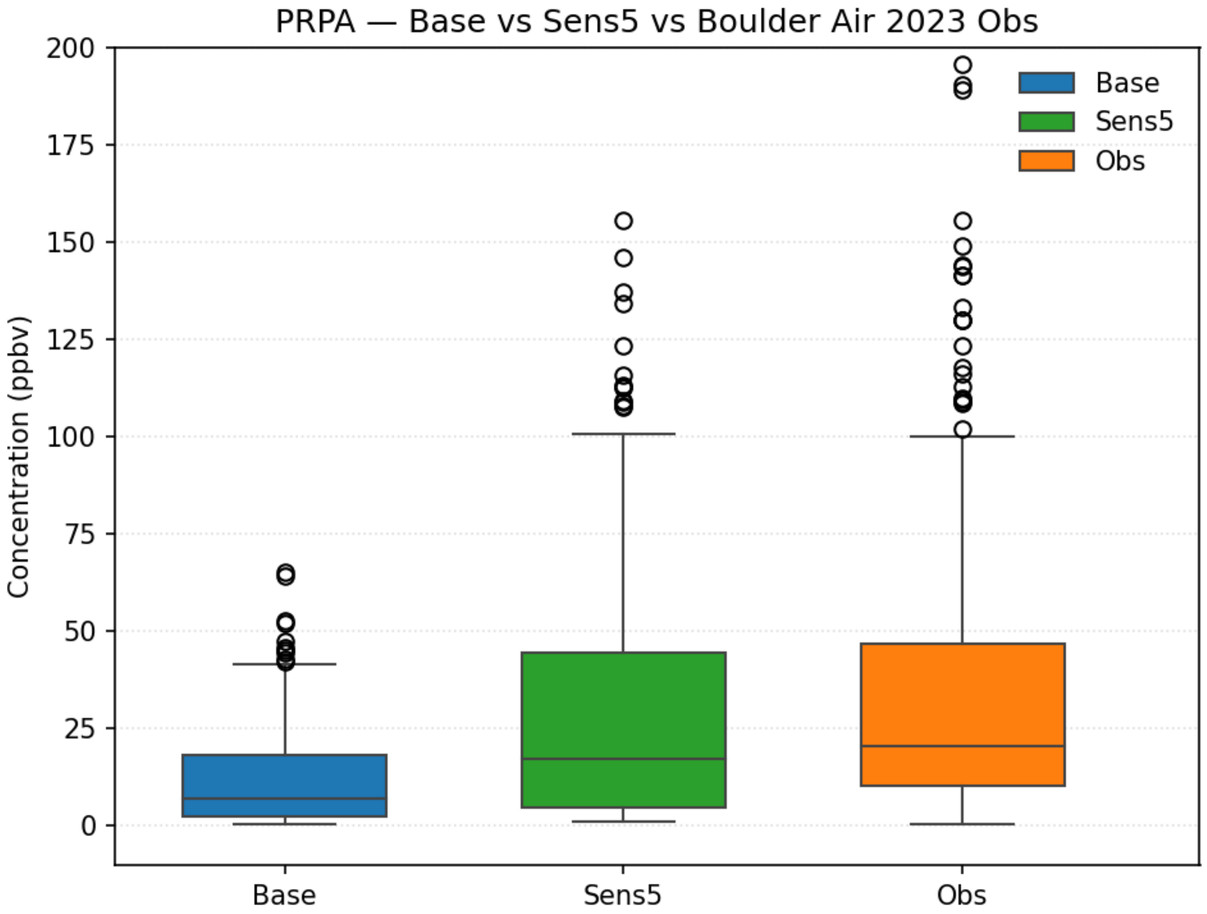
Ethane

- Median Underprediction: **1.4** times (33 vs 24 ppb)
- Mean Underprediction: **1.5** times (58 vs 39 ppb)

Propane

- Median Underprediction: **1.2** times (20 vs 17 ppb)
- Mean Underprediction: **1.2** times (36 vs 29 ppb)



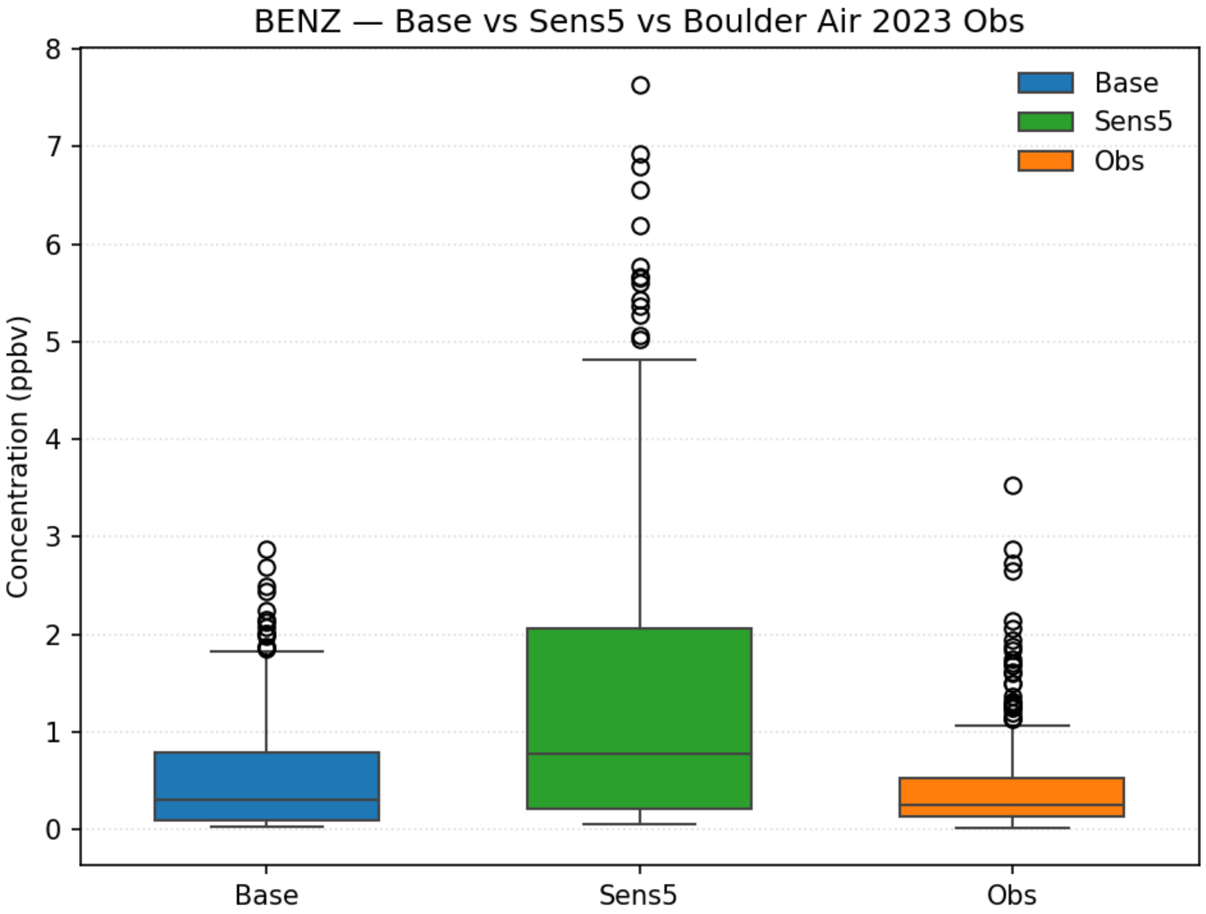


LNM Benzene (Gasoline Combustion) and Ethene

3 x NM Permian Basin O&G VOC results in overstated BENZ and ETH

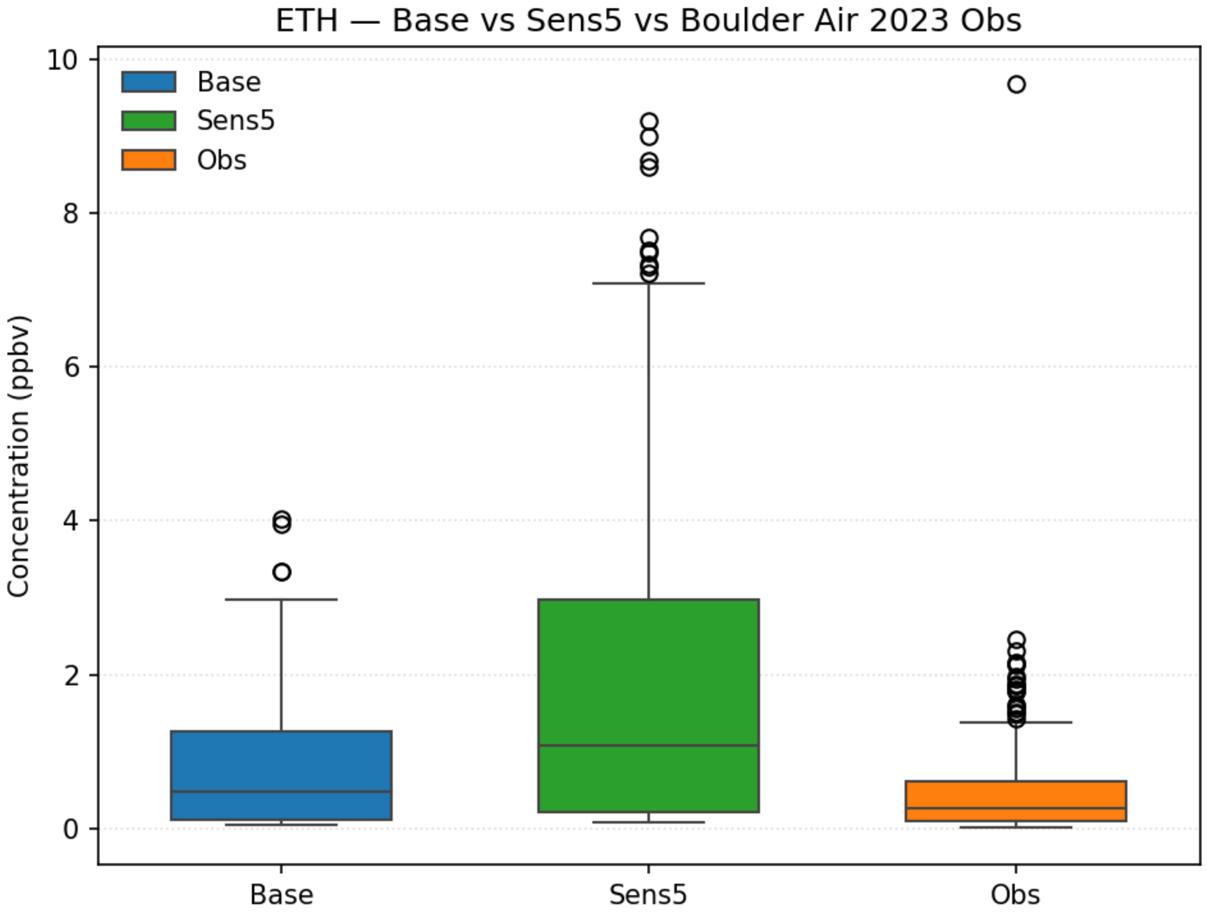
Benzene

- Model overestimates by factor of ~3



Ethene

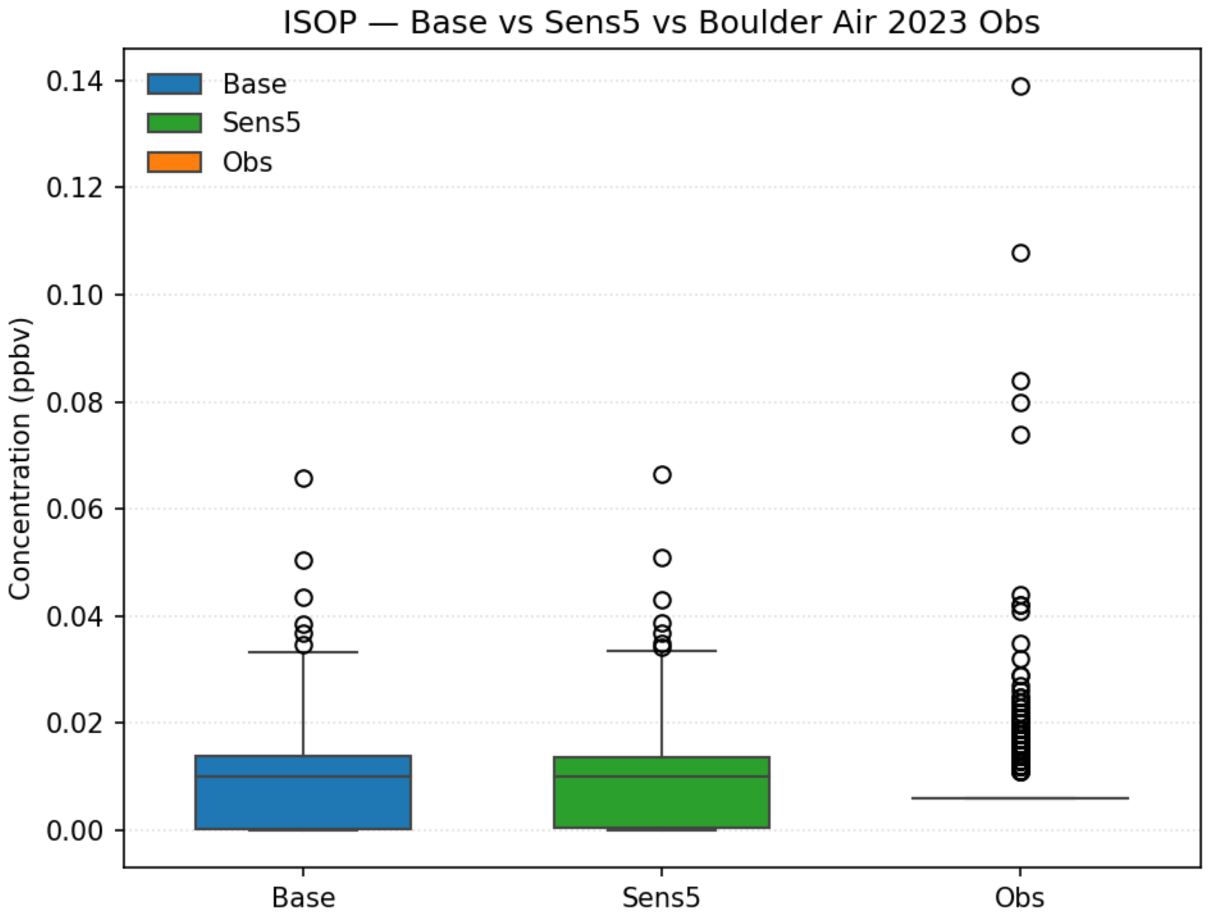
- Model overestimates by factor of ~4



LNM Isoprene (Biogenic) and Nitric Oxide (NO)

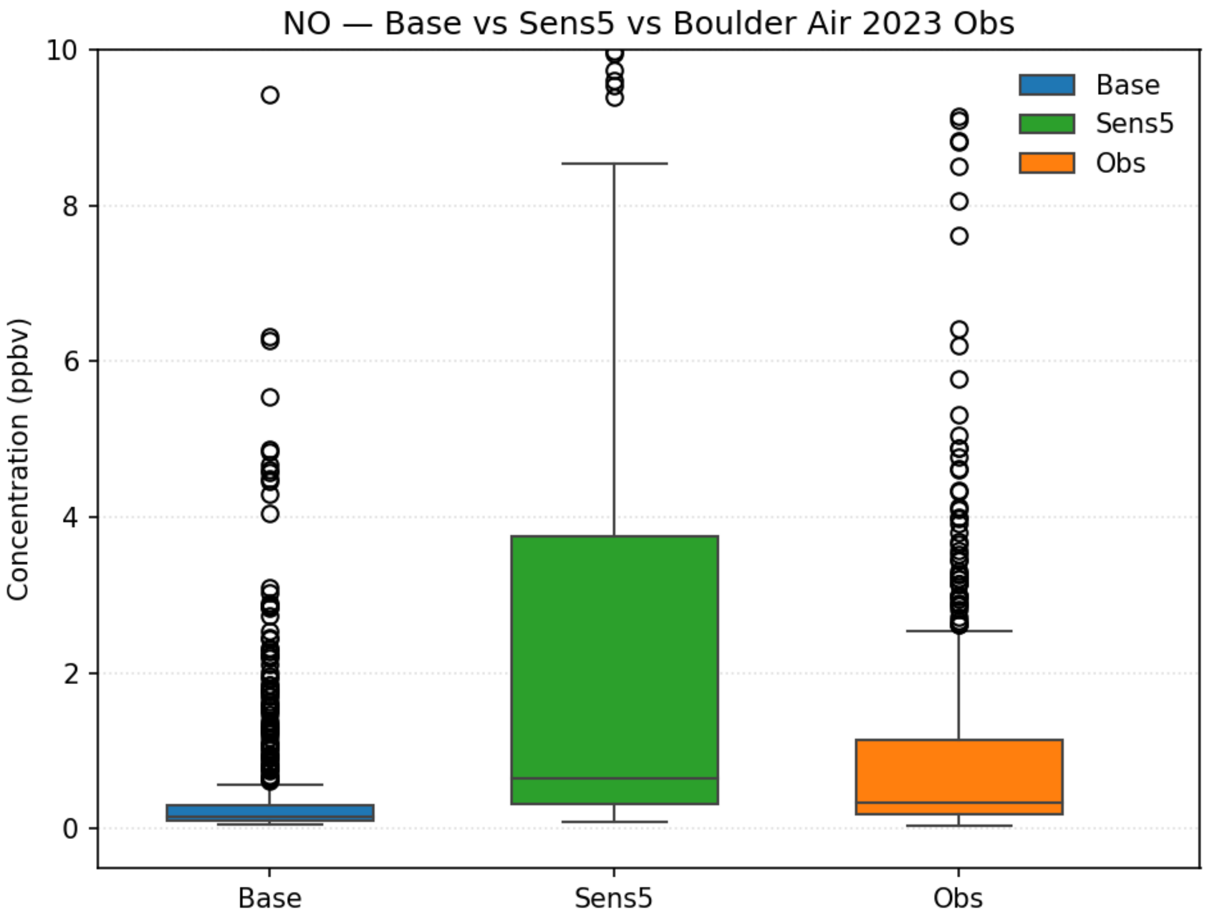
Isoprene

- 3 x NM PB O&G VOC has little effects on ISOP



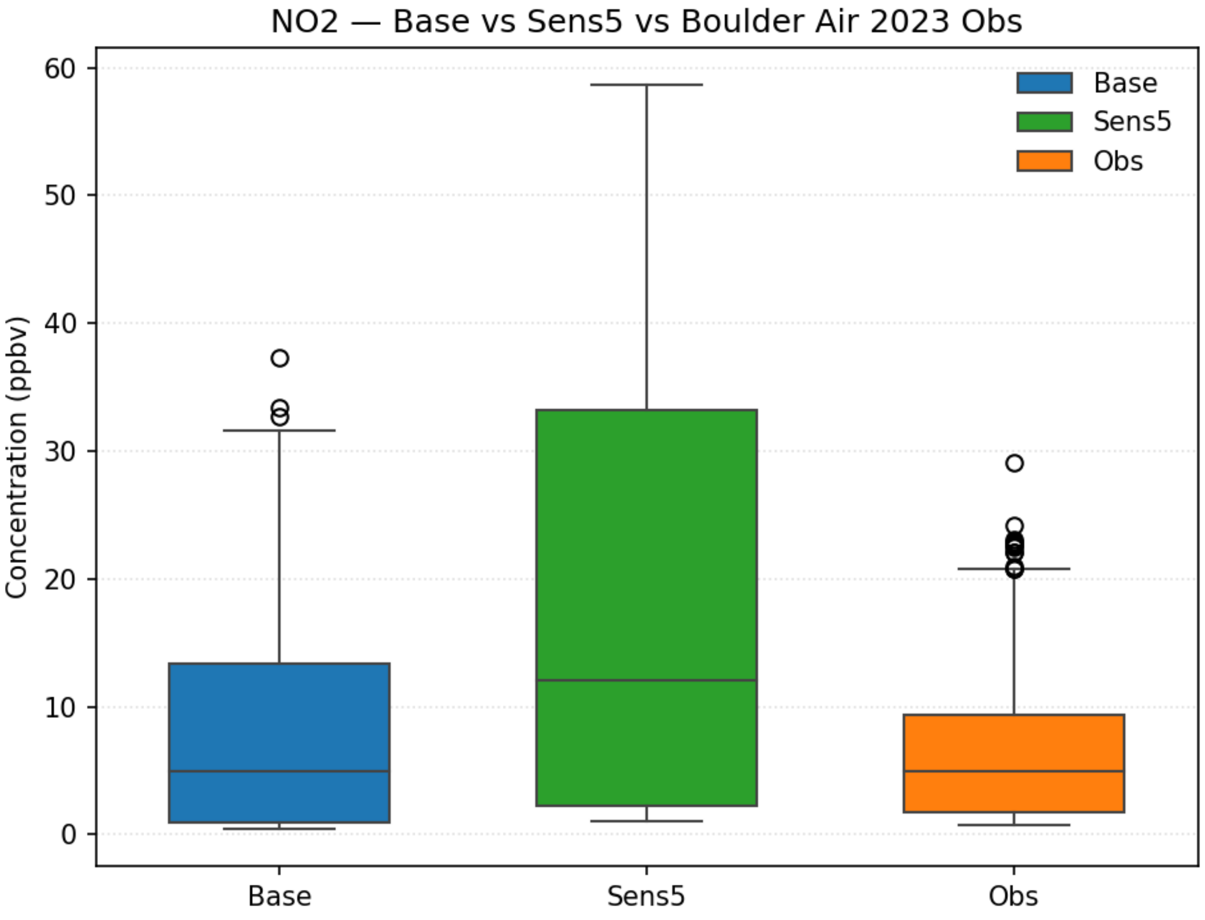
Nitric Oxide

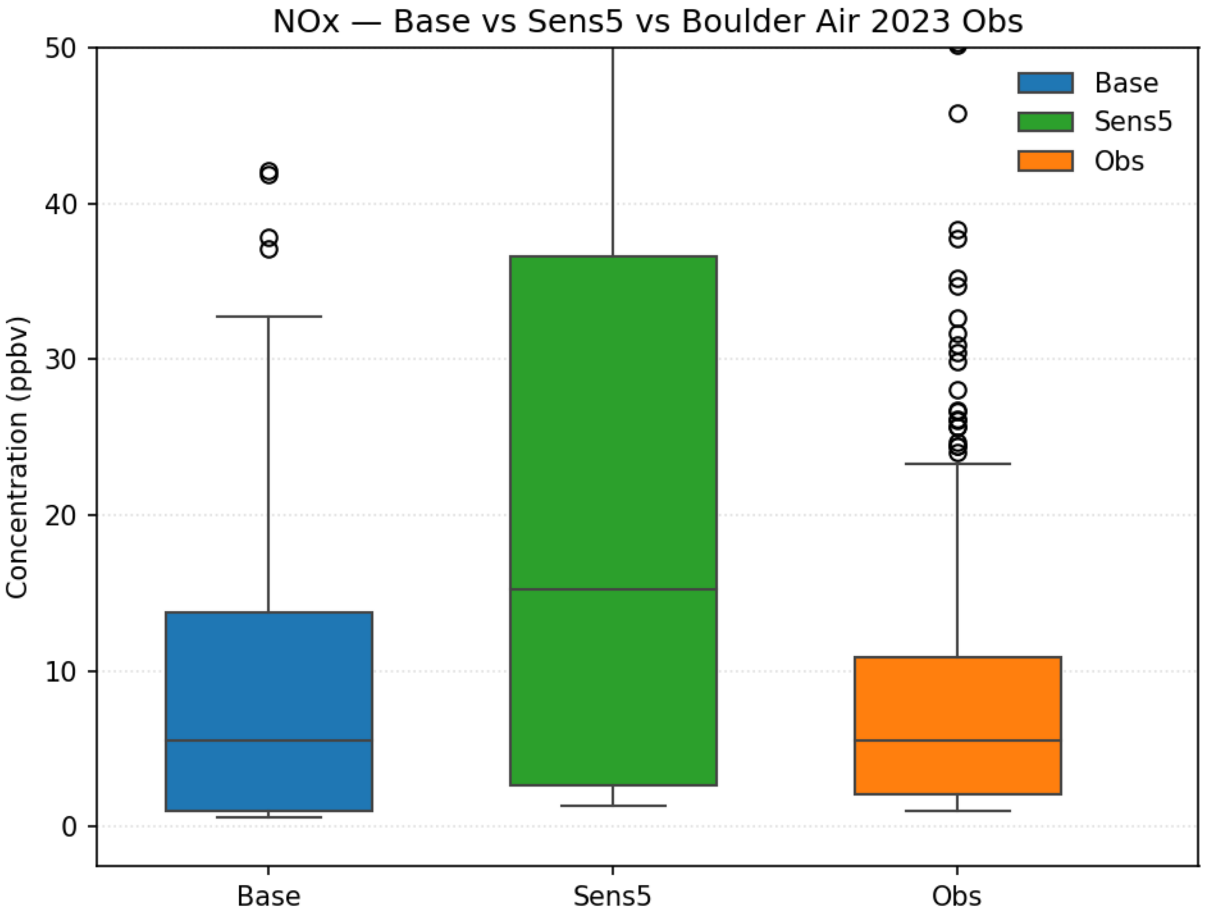
- 3 x NM PB O&G NO_X results in overstated NO by factor of 2 (median) to 3.5 (mean)



LNM NO_2 and NO_x – 3 x NM PB O&G NO_x and VOC

3 x NM PB O&G NO_x overstates observed NO_x



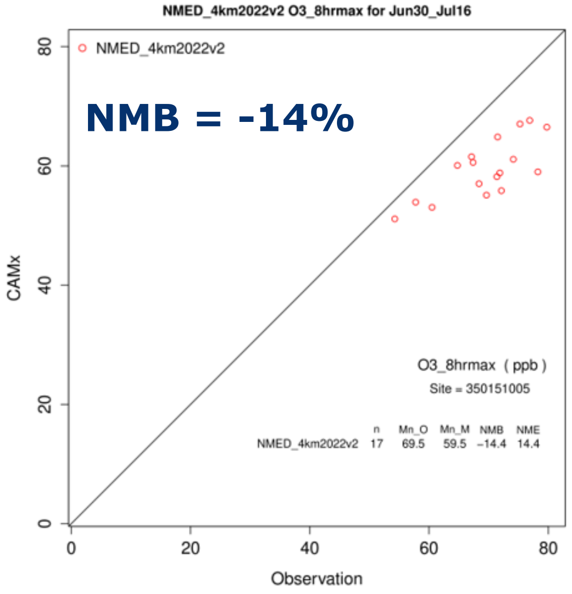


Sens7: 3 x Texas Permian Basin O&G NO_X and VOC

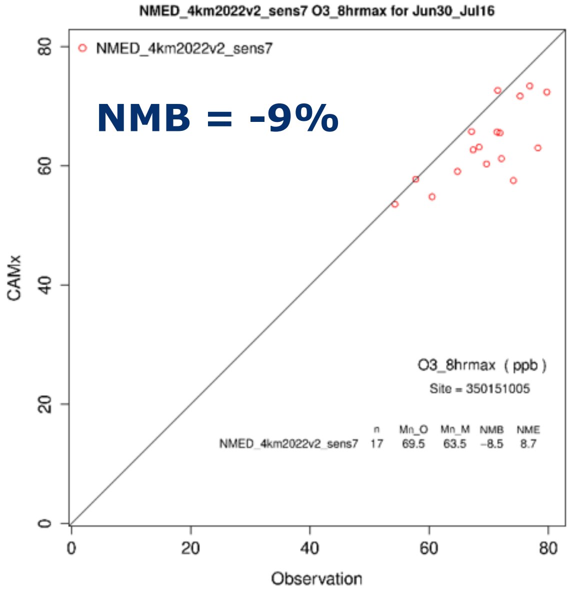
- Increase O&G NO_X and VOC in Texas Permian Basin improves ozone model performance
- Carlsbad City NMB from -14% to -9%; Hobbs NMB from -14% to -7%
- Missing O&G emissions from TX PB in 2022v2 platform may be part of the CAMx 2022v2 ozone underestimation issue

Carlsbad City, NM

2022v2 12/4 Base Case

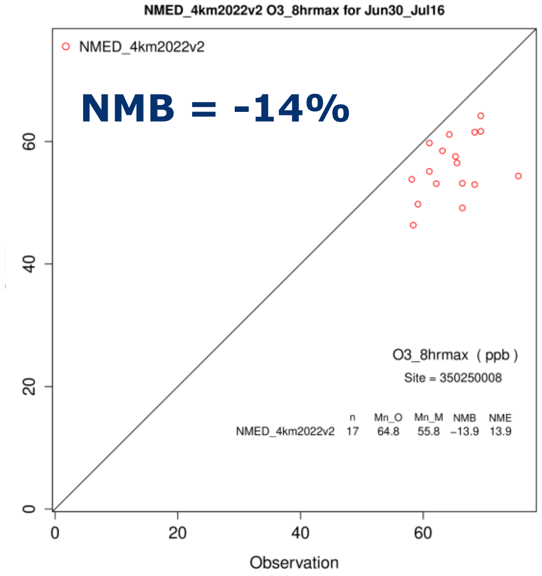


Sens7: 3 x TX PB O&G NO_X/VOC

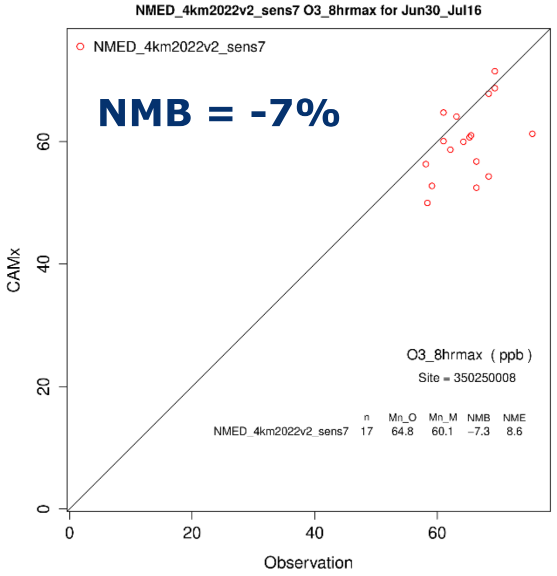


Hobbs, NM

2022v2 12/4 Base Case

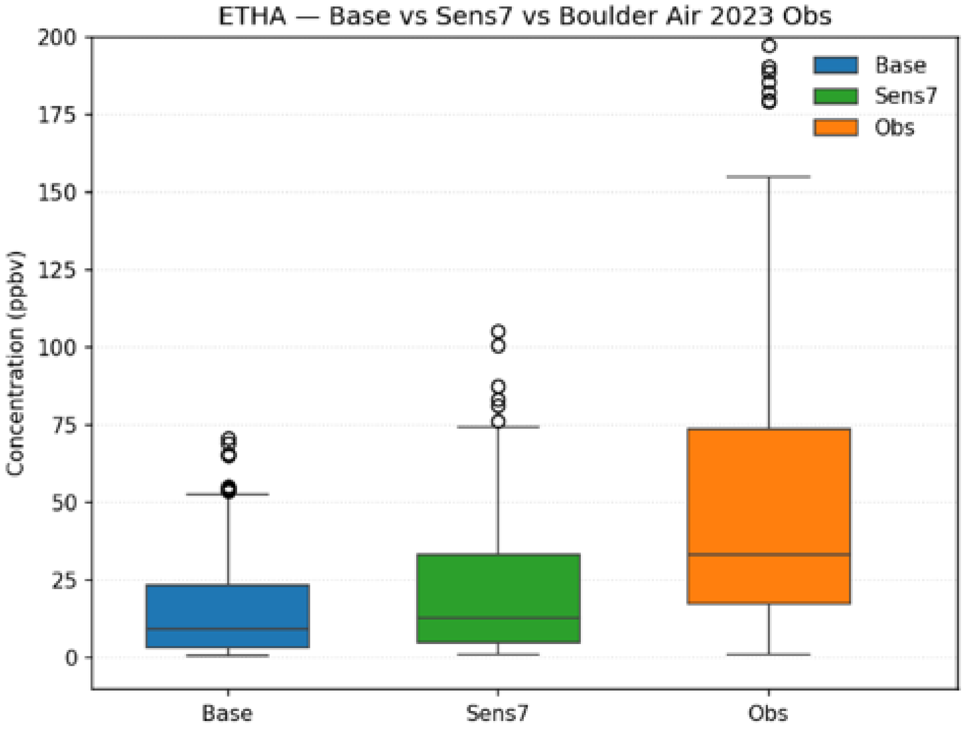


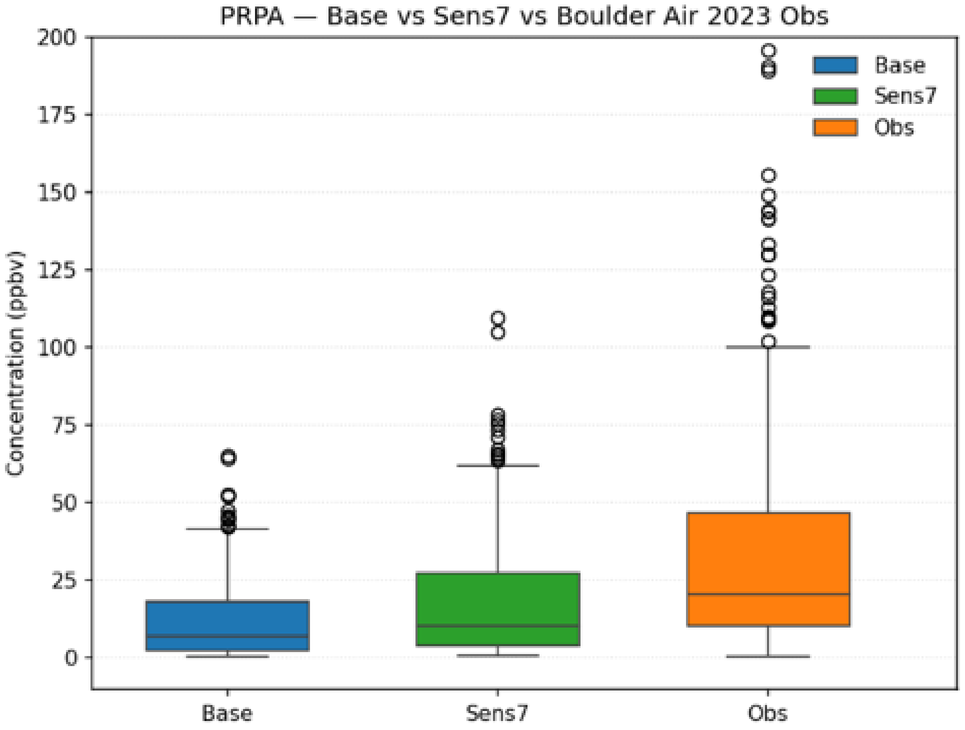
Sens7: 3 x TX PB O&G NO_X/VOC



Sens7: 3 x Texas Permian Basin O&G NO_X and VOC

- During June 30 – July 17, 2022 20-day sensitivity test episode period, the Sens7 3 x TX PB O&G NO_X and VOC sensitivity test reduced the Ethane and Propane underestimation bias:
  - Ethane underestimation bias reduced from factor of 4 to 3
  - Propane underestimation bias reduced from factor of 3 to 2





Assessment of NM and TX 3 x PB O&G NO_X and VOC

- Sens5 with 3 x NM PB O&G NO_X and VOC Emissions:
  - Much improved ozone performance
  - Reduced Ethane and Propane underestimation bias
    - Still have underestimation
  - Results in Benzene overestimation
  - Results in NO_X overestimation
- O&G sources of ethane and propane (and methane) different than primary sources of benzene and NO_X
  - HEI study conducted Receptor Modeling of Boulder AIR VOC measurements from Loving, New Mexico:
    - Ethane and Propane mainly from from Venting
    - A majority of Benzene from Produced Water, Combustion and Traffic
    - NO_X from Combustion and Traffic
- Sens7 3 x TX PB O&G NO_X and VOC Emissions:
  - Improves Ozone, Ethane and Propane Performance

- VOC Receptor Modeling (NMF) Source Apportionment Modeling at Loving, New Mexico
- (Source: Franklin, et. al., 2025; HEI Report No., 231, December 2025)

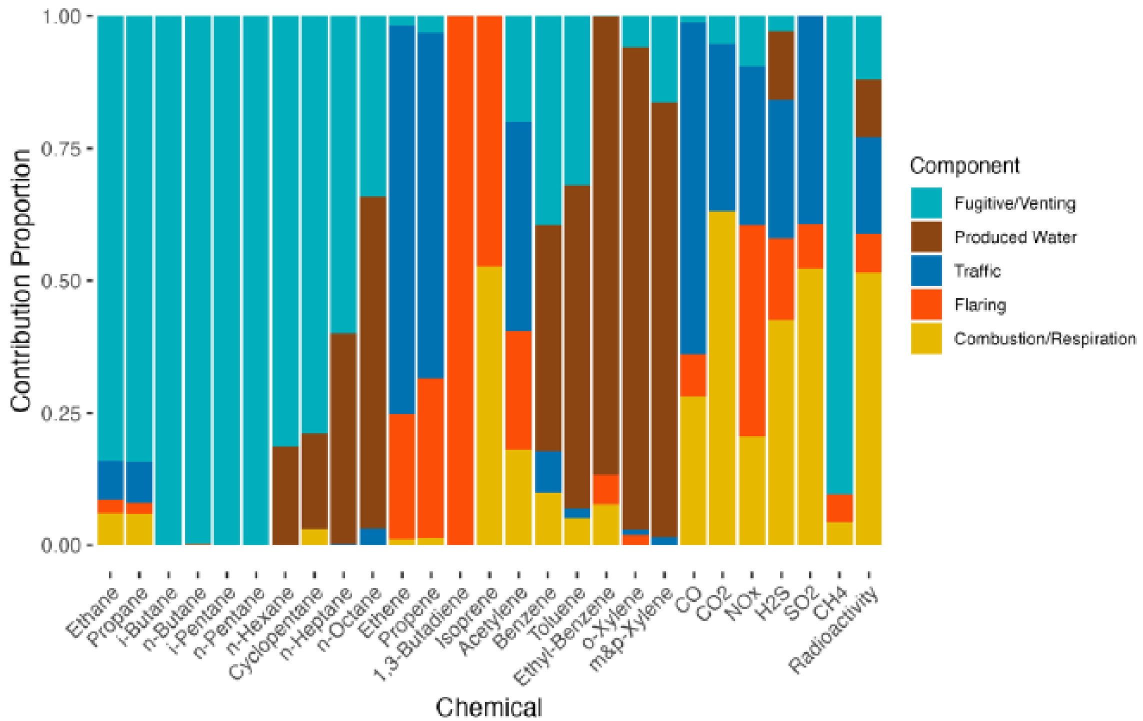


Figure 32. Contribution proportions of each compound to the five NMF-derived source factors at LNM.

Permian Basin O&G NO_X/VOC Sensitivity Tests

What we know about the emissions

Permian Basin O&G emissions in the 2022v2 are understated

- Reported and not reported excess emissions are not included in the 2022v2 emissions inventory
- This is a bigger issue for VOC than NO_X emissions

What sensitivity tests show

- The 3 x NM PB Basin O&G NO_X emissions produced better ozone model performance at the New Mexico Permian Basin ozone monitoring sites whether alone (Sens3) or with 3 x VOC (Sens5)
- 3 x NM PB O&G NO_X produced some NO_2 overestimation, but 3 x TX PB O&G NO_X does not
- 3 x NM PB O&G VOC much better performance for O&G tracers (ETHA and PRPA)
- 3 x NM or TX O&G NOX and VOC produce better ozone and ethane/propane model performance

Implications for future modeling

- Unclear how to use this information to improve the Permian Basin O&G emissions inventory
  - Could try and include the reported excess emissions in the emissions inventory, but that would be resource intensive and just a snapshot, and it only represents part of the missing excess emissions
  - When interpreting the CAMx 2022v2 12/4 km modeling results, need to recognize that the Permian Basin O&G emission are understated

Next Steps

Next Steps (April 6, 2026)

- Prepare draft report on the CAMx 2022v2 4 km base case modeling and model performance evaluation
- Post results to date on WESTAR website:
  - WESTAR suggested either the ADMS or Regional Ozone Analysis (where NMED OAI resides) webpages
- Develop 2032 emission inputs for the 12 km CONUS and 4 km New Mexico domains
- Conduct CAMx **2022 and 2032 Local Source** ozone source apportionment modeling
- Conduct CAMx **2022 State-Specific and International Emissions** ozone source apportionment modeling
- Prepare displays and dashboards of ozone source apportionment modeling results
- Prepare draft report on CAMx ozone source apportionment modeling results

Develop 2032 Emissions for 12/4 km Domains

- 2032 Oil and Gas (O&G) On-the-Book (OTB) projections in the New Mexico 4 km domain
  - Similar approach as used for the BLM Carlsbad FO RMP Modeling only applied to entire New Mexico 4 km domain
  - Currently treating OOOOb/c O&G controls as OTB even though current Administration trying to rescind them (doesn't affect NM Permian Basin O&G due to OAI but does affect TX PB O&G)
- Project 2022v2 mobile source emission to 2032 using MOVES5
  - SMOKE-MOVES used with 2032 MOVES5 Emissions Factors and 2022 4 km Meteorology
- Prepare remainder 2032 emissions for 4 km domain (some based on 2026v1)
  - Process 2032 emissions for 4 km New Mexico domain using SMOKE

2032 Emissions for 12/4 km Domains

- Slight reductions in New Mexico anthropogenic NO_X (-8%) and VOC (-6%) emissions between 2022 and 2032
  - NM NO_X and VOC reductions driven mainly by On-Road (-68% and -45%) and Non-Road (-33% and -6%)
  - Total O&G NO_X increases 8% and O&G VOC decreases -26% between 2022 and 2032
- Documentation of 2032 emissions developed under development

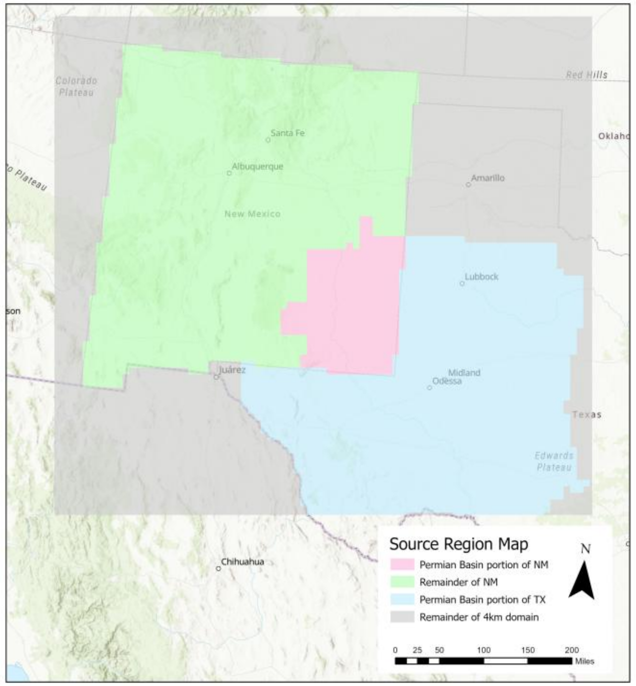
Sectors	2022v2		2032		Difference	
	NO_x	VOC	NO_x	VOC	NO_x	VOC
	(tpd)		(tpd)		(%)	
Airports	1.7	1.0	1.8	1.1	6.0%	5.6%
Biogenic	58.8	1,567.6	58.8	1,567.6	0.0%	0.0%
Livestock#	0.0	9.1	0.0	9.1	0.0%	0.0%
Non-Point	10.2	42.0	9.8	44.8	-4.1%	6.8%
Non-Road Mobile	12.0	14.1	8.1	13.3	-32.6%	-6.0%
O&G Pre-Production	36.0	36.8	33.5	35.4	-7.0%	-3.8%
O&G Production	134.3	748.2	148.3	548.8	10.4%	-26.6%
Solvents	0.0	50.7	0.0	53.2	0.0%	4.8%
On-Road Mobile	79.7	35.6	25.7	19.7	-67.7%	-44.6%
Open Burning#	0.7	1.2	0.7	1.2	0.0%	0.0%
O&G Midstream	95.8	174.8	105.4	129.2	10.0%	-26.1%
Ag Fire*	0.2	0.9	0.2	0.9	0.0%	0.0%
EGU Point	19.1	0.6	14.5	0.7	-23.9%	18.7%
Rx Fire*	0.1	2.2	0.1	2.2	0.0%	0.0%
Wildfire*	64.0	1,871.6	64.0	1,871.6	0.0%	0.0%
Non-EGU Point	7.0	5.5	6.7	5.5	-4.4%	0.7%
Rail	44.0	1.8	43.7	1.8	-0.8%	-0.8%
RWC#	0.4	5.0	0.4	5.0	0.0%	0.0%
Total	**564**	**4,569**	**522**	**4,311**	**-7.5%**	**-5.6%**

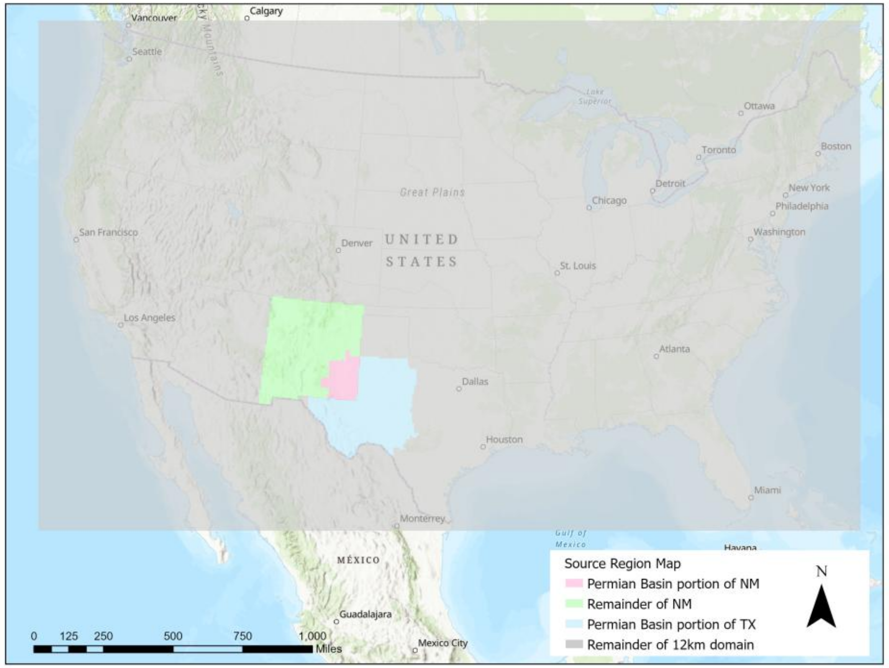
* Remains unchanged between 2022 and 2032

Task E: Local Source Ozone Source App. Modeling

- **June 1 – August 15, 2022** Modeling Period and **2022 and 2032** Emission Years (2 Runs)
  - Although some high ozone in May 2022, Phase I CAMx 2026v1 12 km ozone source apportionment modeling showed it was mainly due to international emissions (i.e., BCs)
- **Four Source Regions** focusing on Permian Basin and New Mexico: (1) New Mexico Permian Basin; (2) Remainder New Mexico; (3) Texas Permian Basin; and (4) Remainder 12/4 km domain
- **Ten Source Categories**:

  1. Natural (Biogenic + LNOx)
  2. Fires
  3. O&G Pre-Production
  4. O&G Production
  5. O&G Midstream
  6. EGU Point
  7. Non-EGU Point
  8. On-Road Mobile
  9. Non-Road Mobile
  10. Remainder Anthropogenic

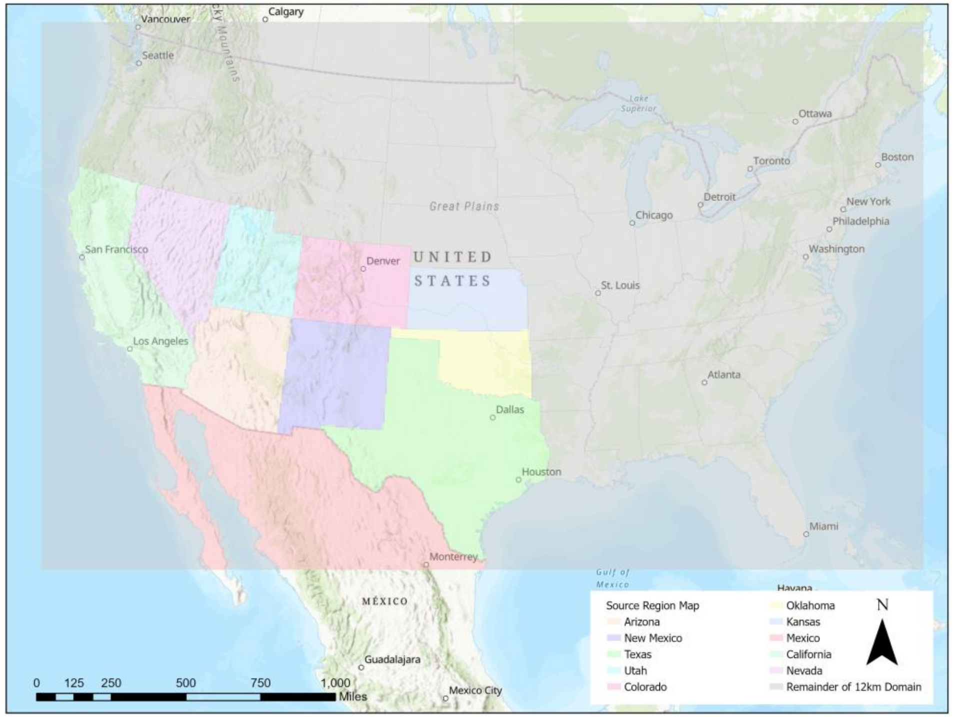




- Results in separate ozone contributions from 42 Source Groups (= 4 x 10 + 2) (simulation takes ~2 weeks elapsed time)

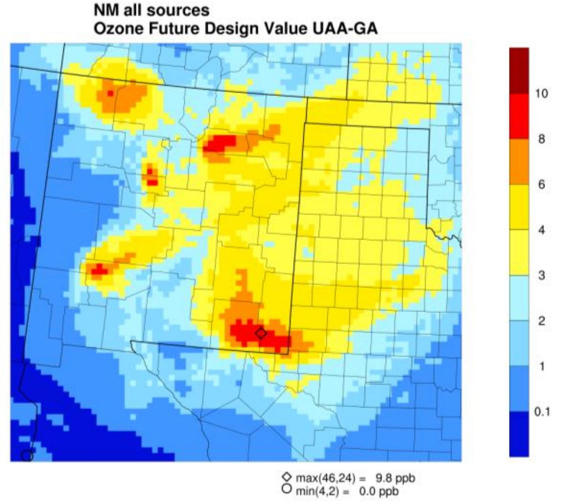
Task F: State & International Ozone SA Modeling

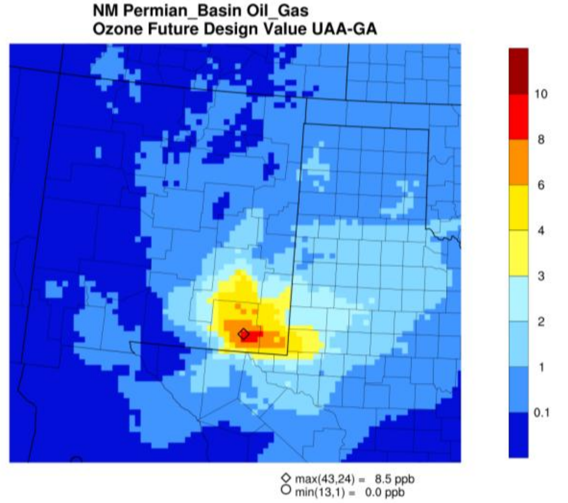
- Run CAMx in a similar fashion as EPA's Good Neighbor Plan modeling
- Emissions Year: **2022**
- **May 1 – August 15, 2026** Modeling Period
- **3 Source Categories**: (1) Biogenic; (3) Fires+LNOx; (3) Anthropogenic
- **10 Source Regions**: 9 Western States, Mexico and Remainder 12 km Domain
- 35 Source Groups (3 x 10 + 2)
- EPA has run 2022 HCMAQ with no international anthropogenic emissions (for Intl Anthro in BCs) but it is being reviewed by EPA upper management and likely won't be released in time for NMED Phase II

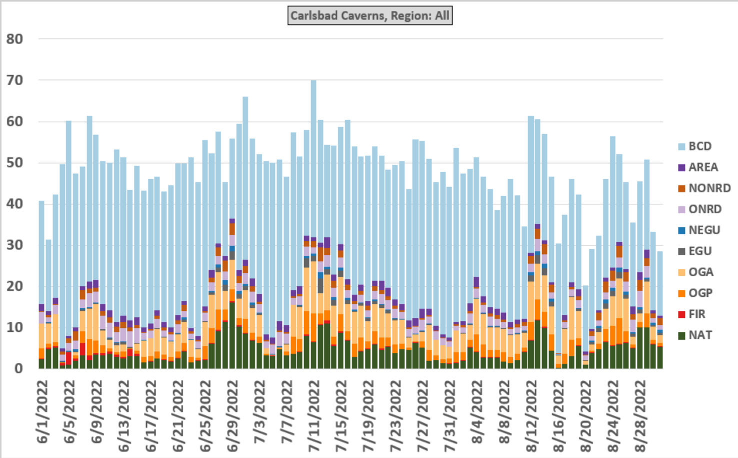


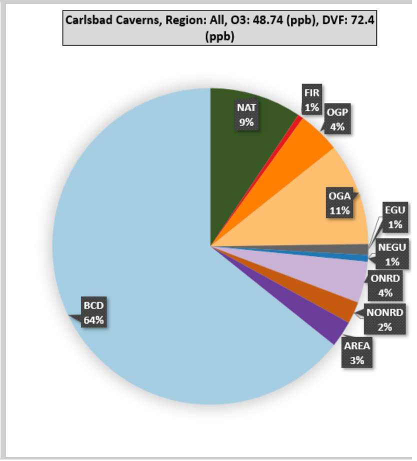
Post-Processing Local Source 2022/2032 O_3 SA Modeling

- Software for Modeled Attainment Test (SMAT)
  - EPA ozone DV Projection Tools
  - Unmonitored Area Analysis (UAA)
  - Contributions to base year 2020-2024 ozone DVB
  - Contributions to projected 2032 ozone DVF
- Contributions at the Monitoring sites
  - Excel Dashboards
  - 2022 and 2032
- Pseudo-Receptors in Permian Basin
  - Extract 2022 and 2032 ozone SA results at receptors across Permian Basin (Eddy & Lea Counties)
  - Make Dashboard for displays at pseudo receptors



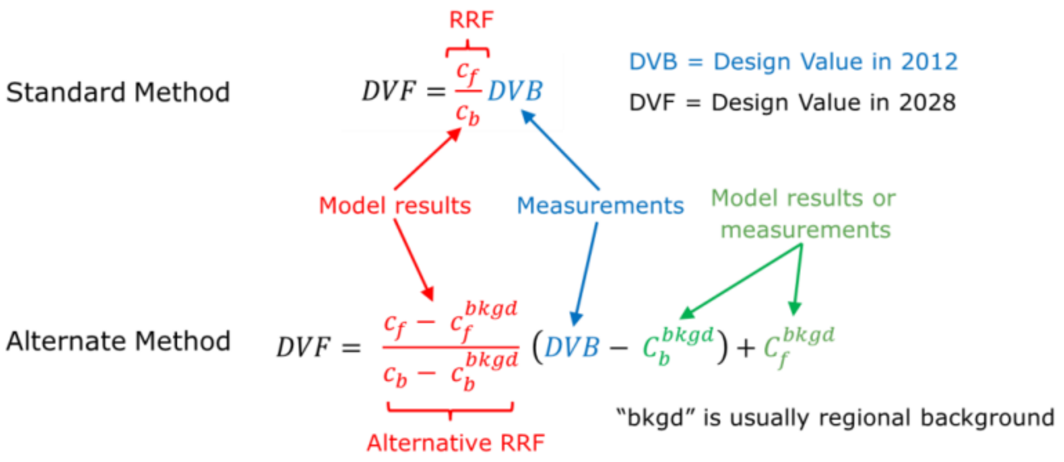






Post-Processing Local Source 2022/2032 O_3 SA Modeling

- Alternative 2032 Ozone DVF projection approach
  - Similar approach to that used CRC A-112 Study
    - https://crcao.org/wp-content/uploads/2019/05/CRC_A-112_Executive-Summary_22Oct18-1.pdf
    - https://www.sciencedirect.com/science/article/pii/S2590162119300322?via%3Dihub
  - Decompose 2020-2024 ozone DVB into local and background (regional) components
    - 2020-2024 DVB = DVB_{Local} + $DVB_{Regional}$
  - Use CAMx 2022 and 2032 4 km ozone source apportionment results to develop separate RRFs for projecting the DVB_{Local} (anthropogenic from NM PB, TX PB and Remainder NM regions) and $DVB_{Regional}$ (natural, remainder domain region and BCs) to develop separate RRFs for local and regional



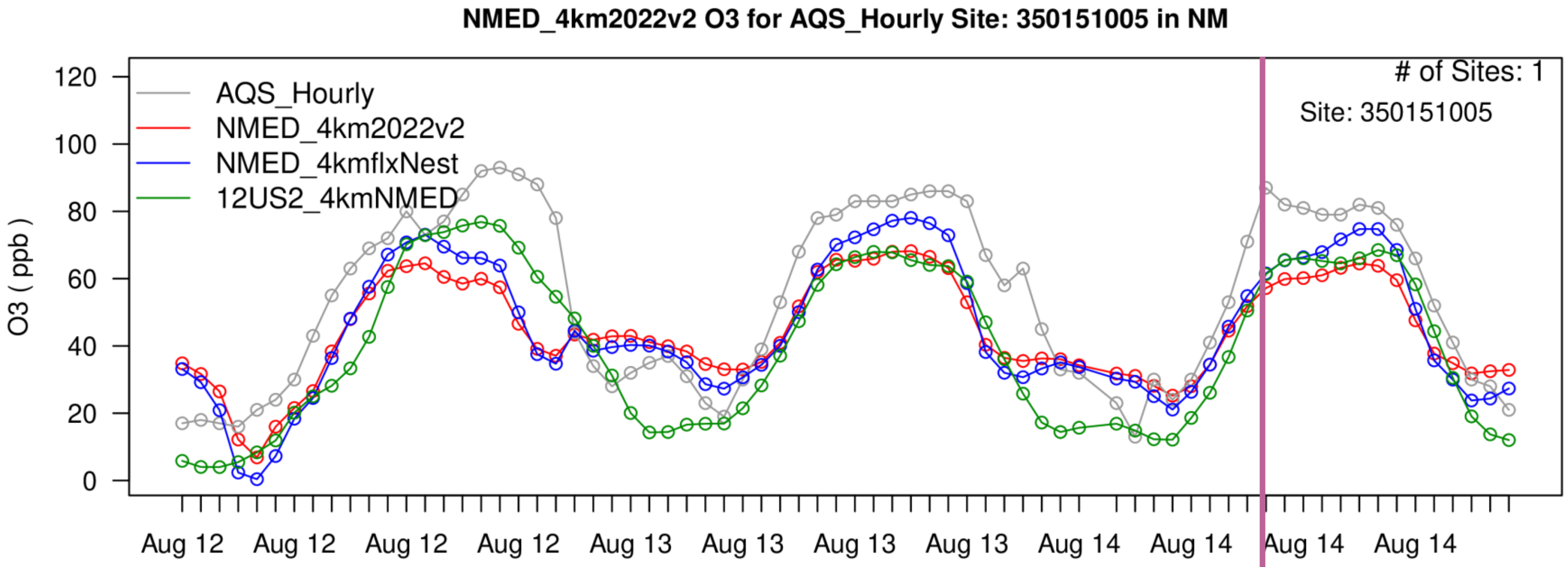
Post-Processing State-Specific/Intl 2022 O_3 SA Modeling

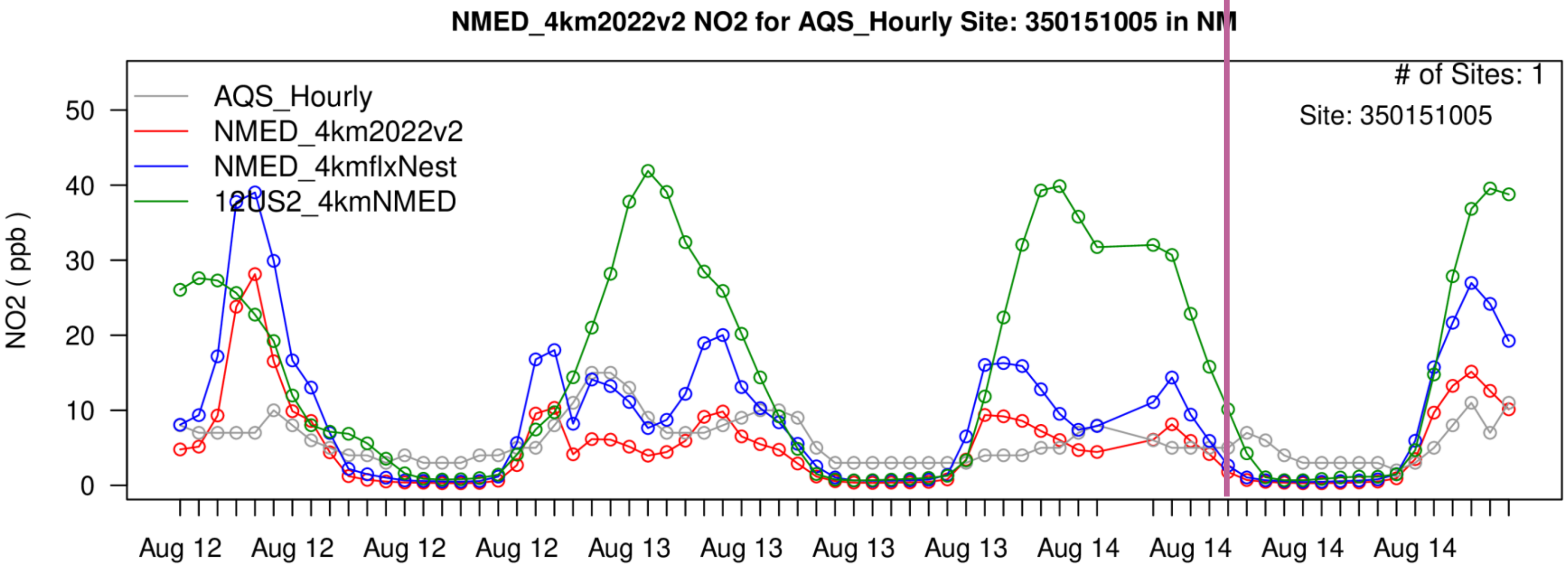
- Process results into Dashboards for monitoring in the New Mexico 4 km domain
- Use Contribution Factor (CF) to obtain upwind state anthropogenic emissions contributions to 2020-2024 ozone DVB at ozone monitoring sites within and outside of New Mexico
  - Compare with 2024 Good Neighbor Plan 2023 state contributions
- Obtain contribution of Mexico anthropogenic emissions to 2020-2024 ozone DVB in New Mexico 4 km domain

Additional Slides

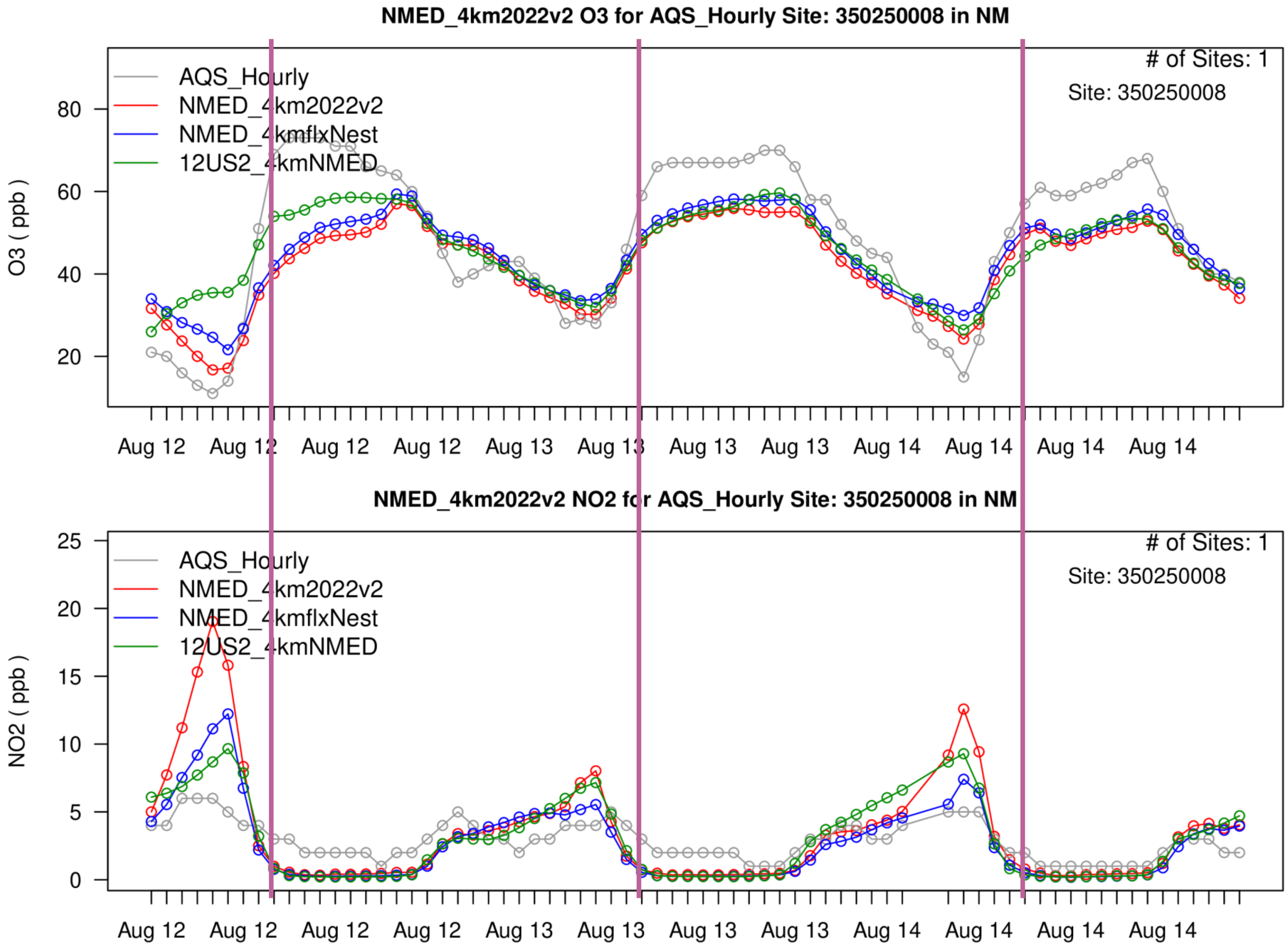
CAMx 2022v2 12/4 km base case ozone and NO_2 hourly ozone time series at PB sites

August 12-13, 2022: Carlsbad City

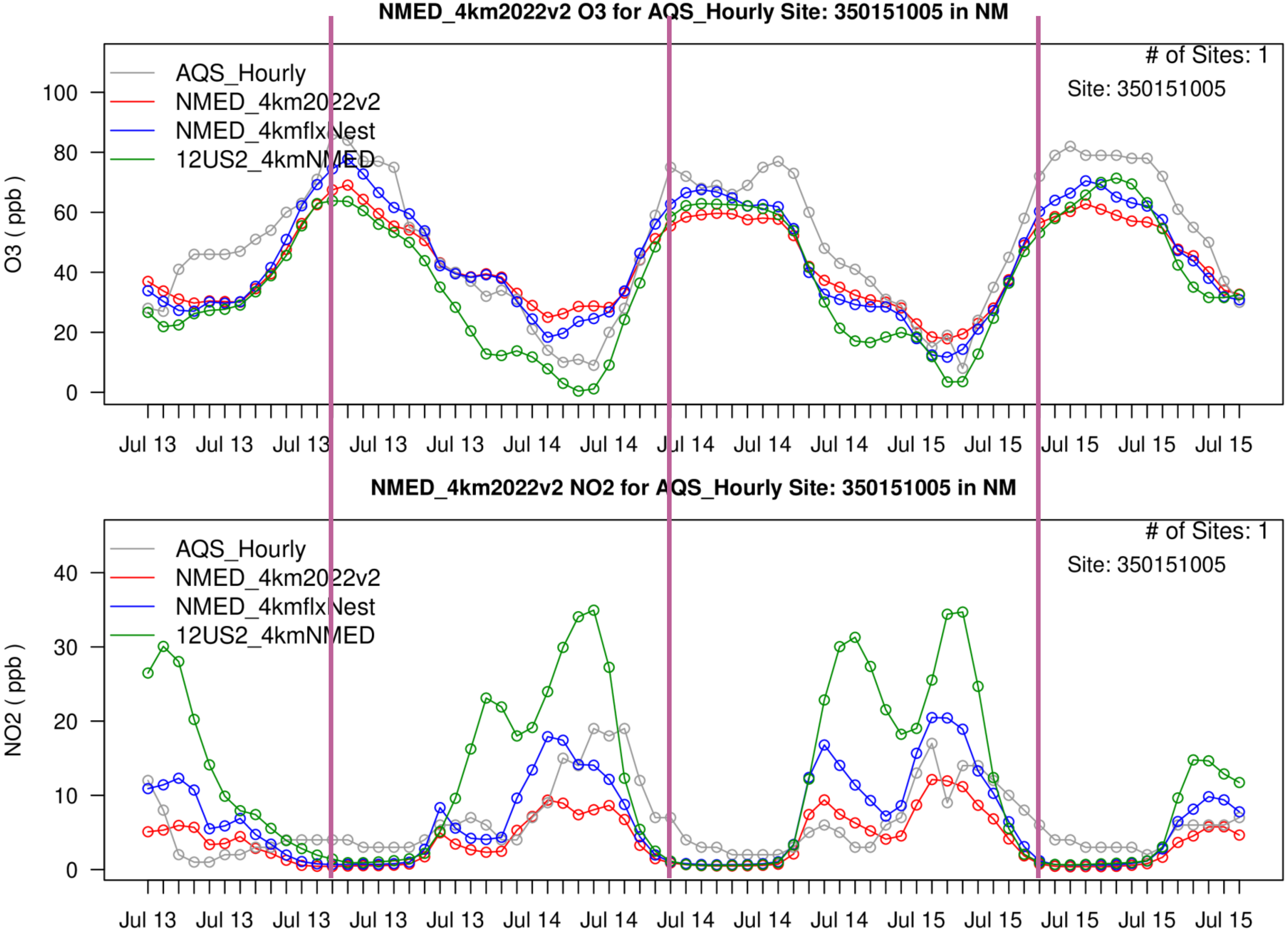




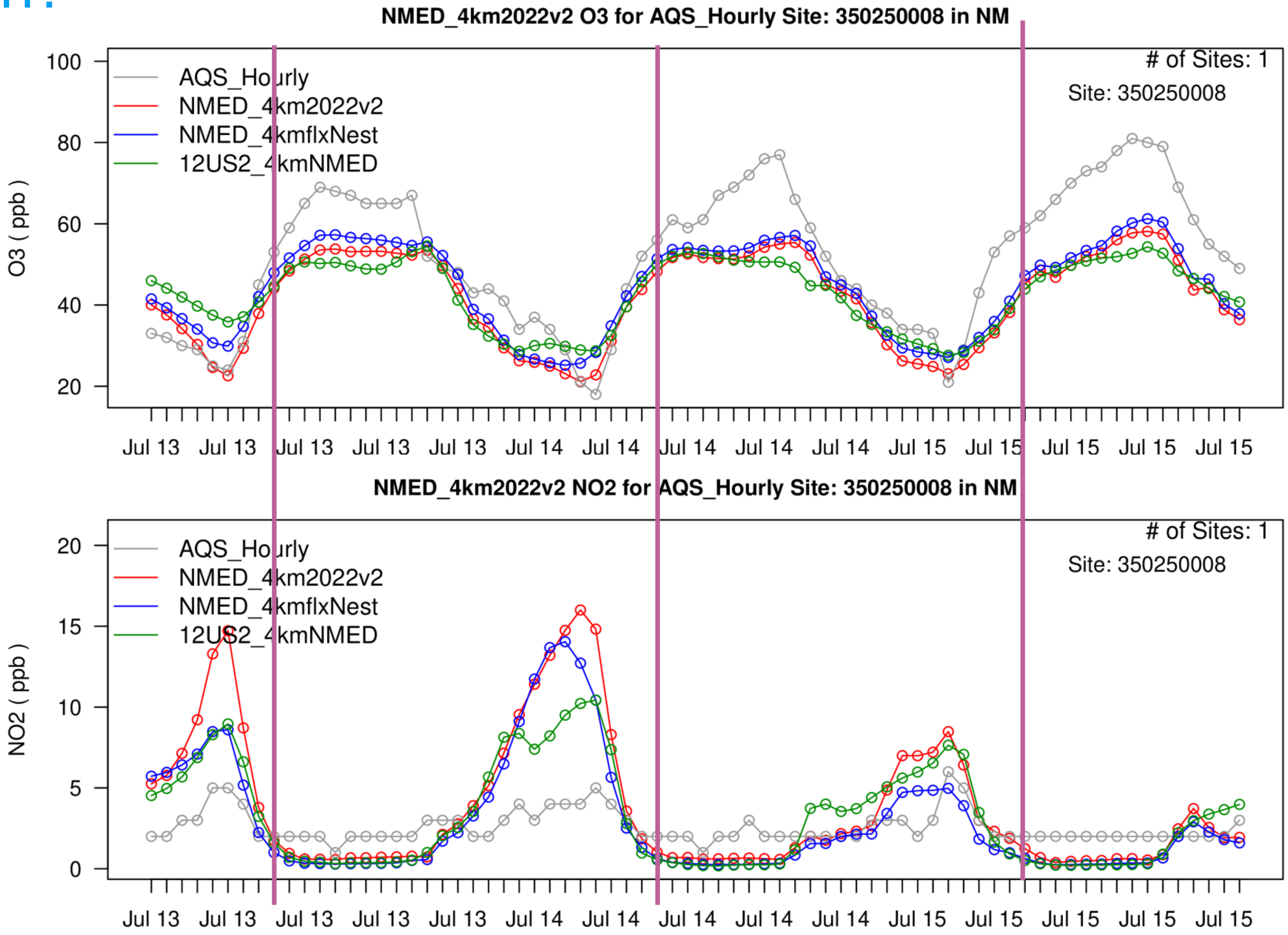
August 12-13, 2022: Hobbs

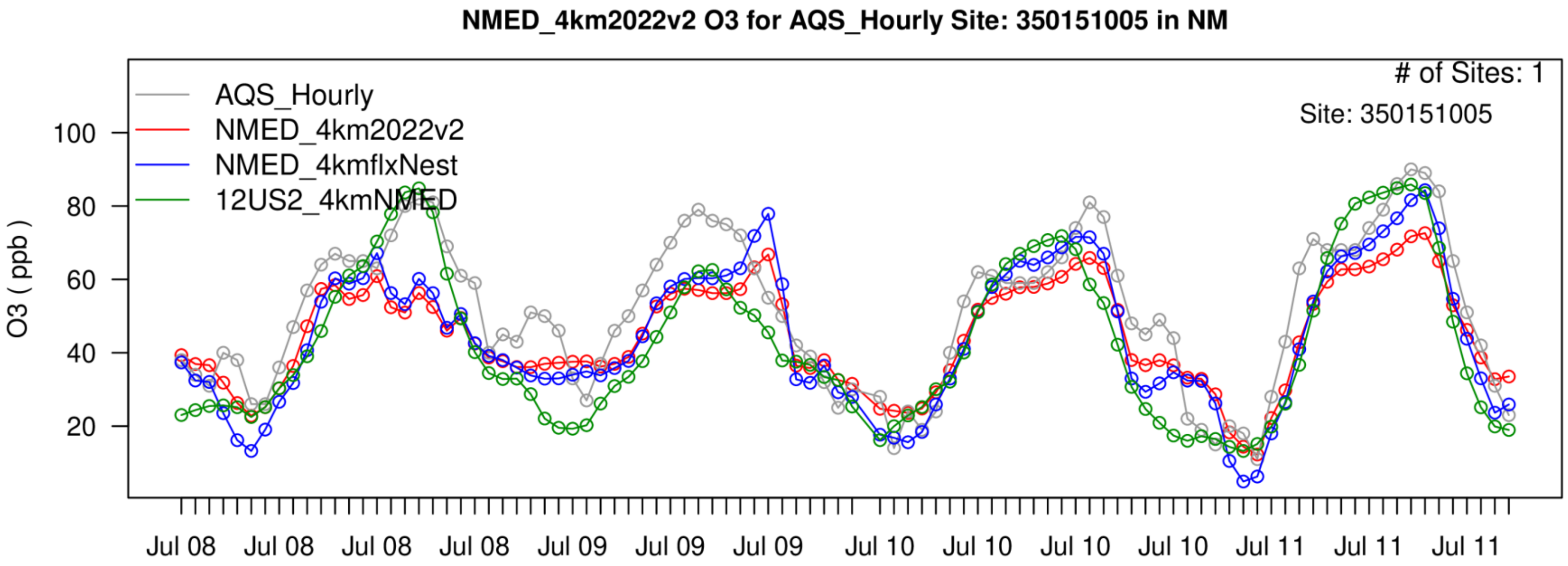


July 13-15, 2022: Carlsbad City



July 13-15, 2022: Hobbs – Obs NO2 at 2 ppb near detection?

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Site: 350151005
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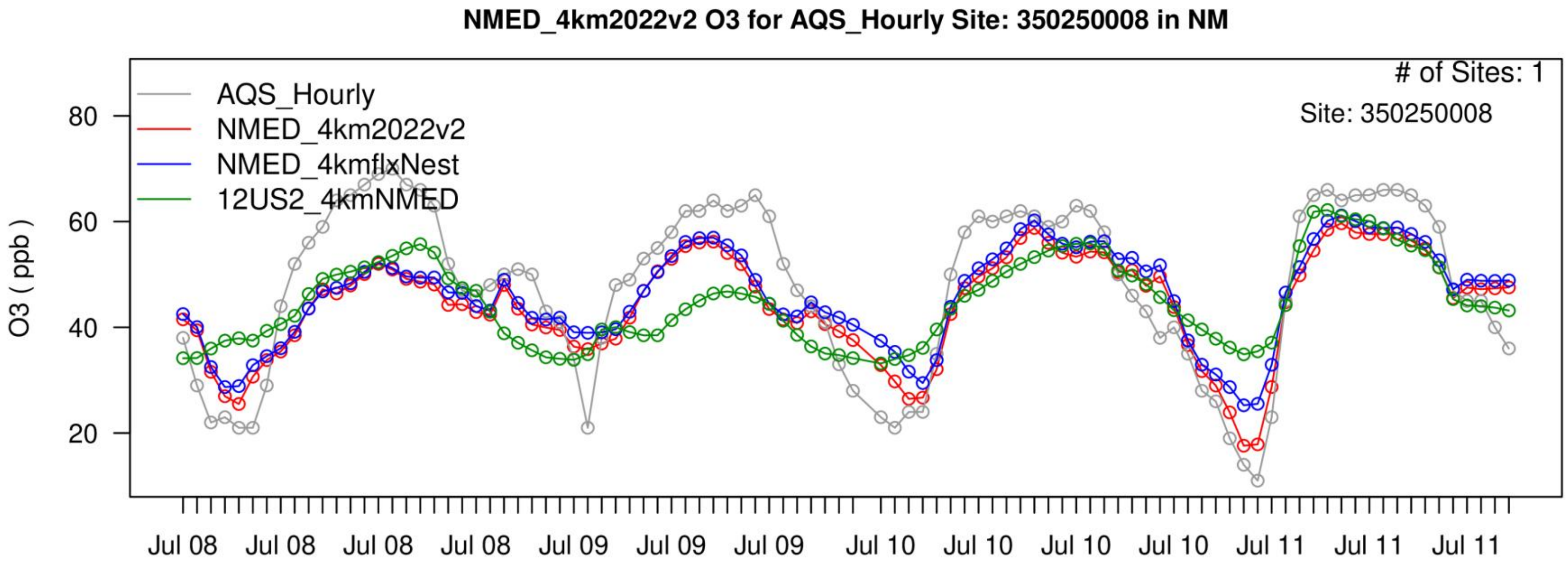
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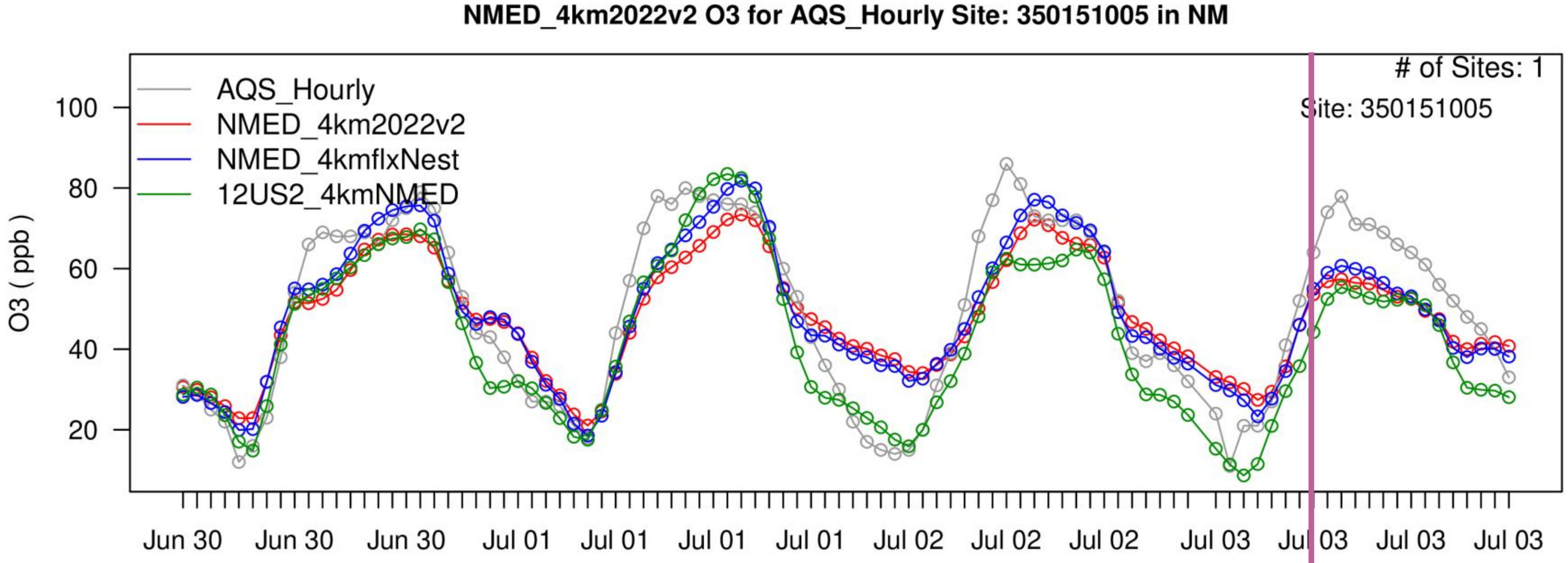

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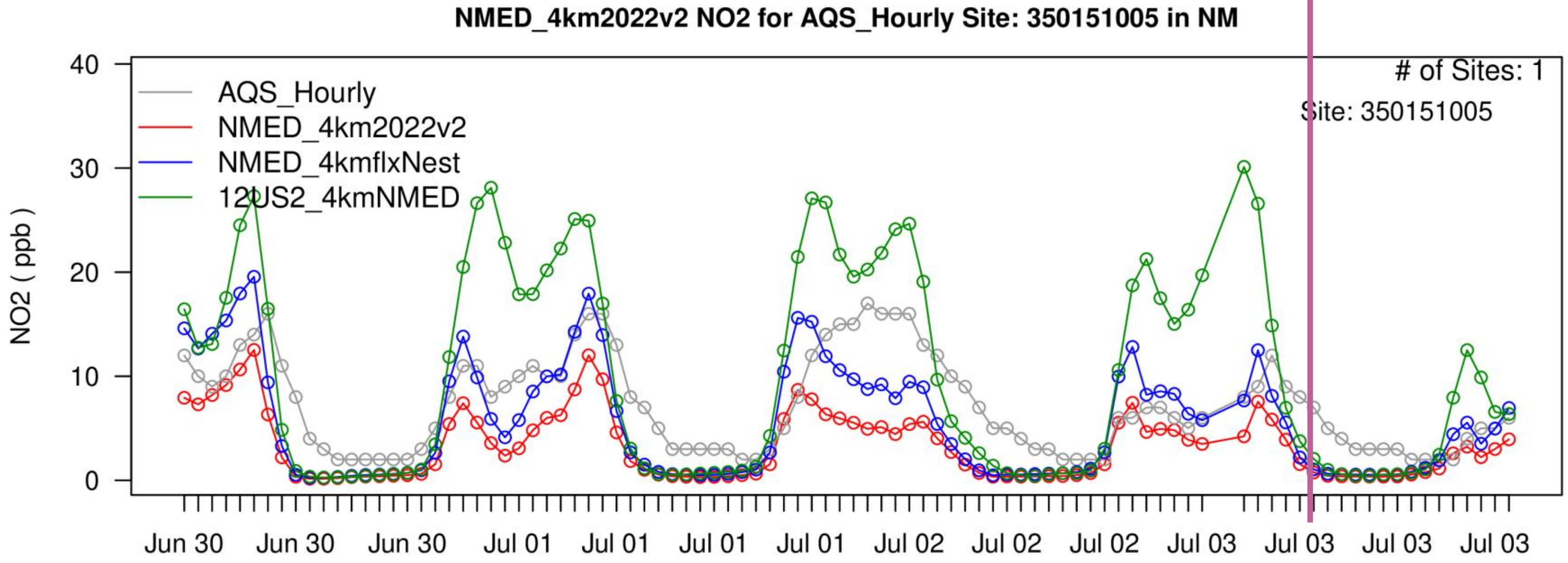

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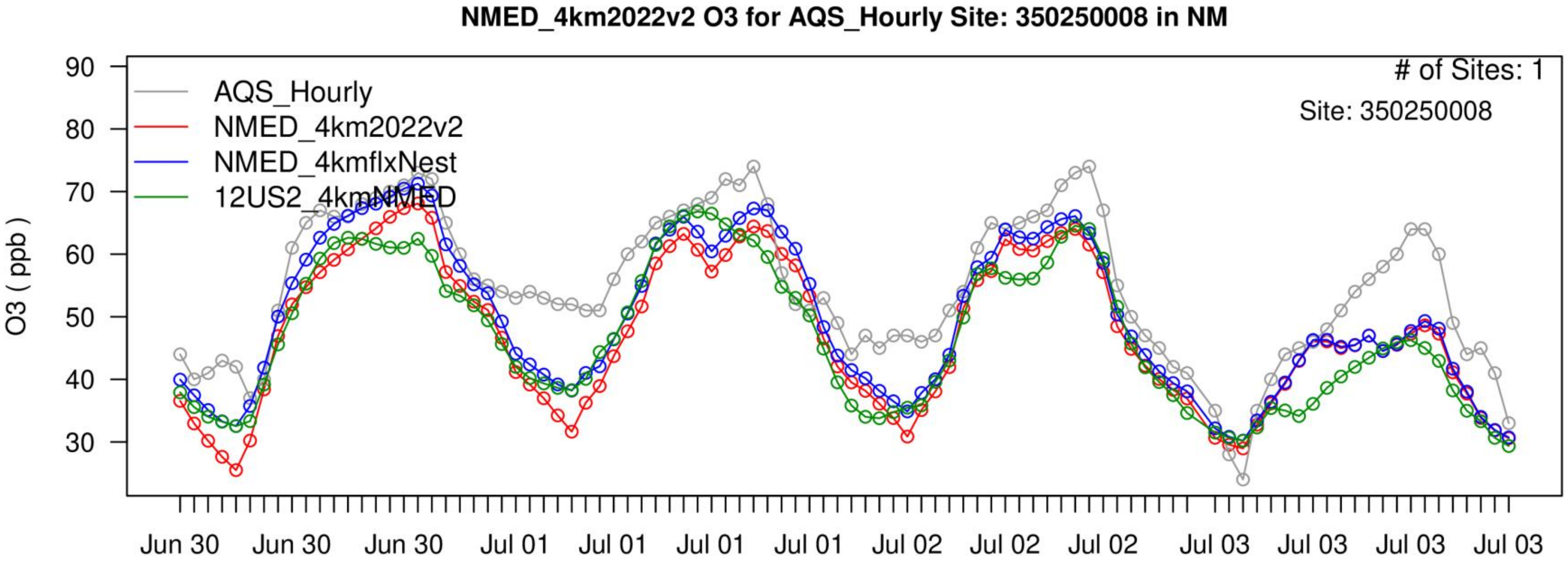
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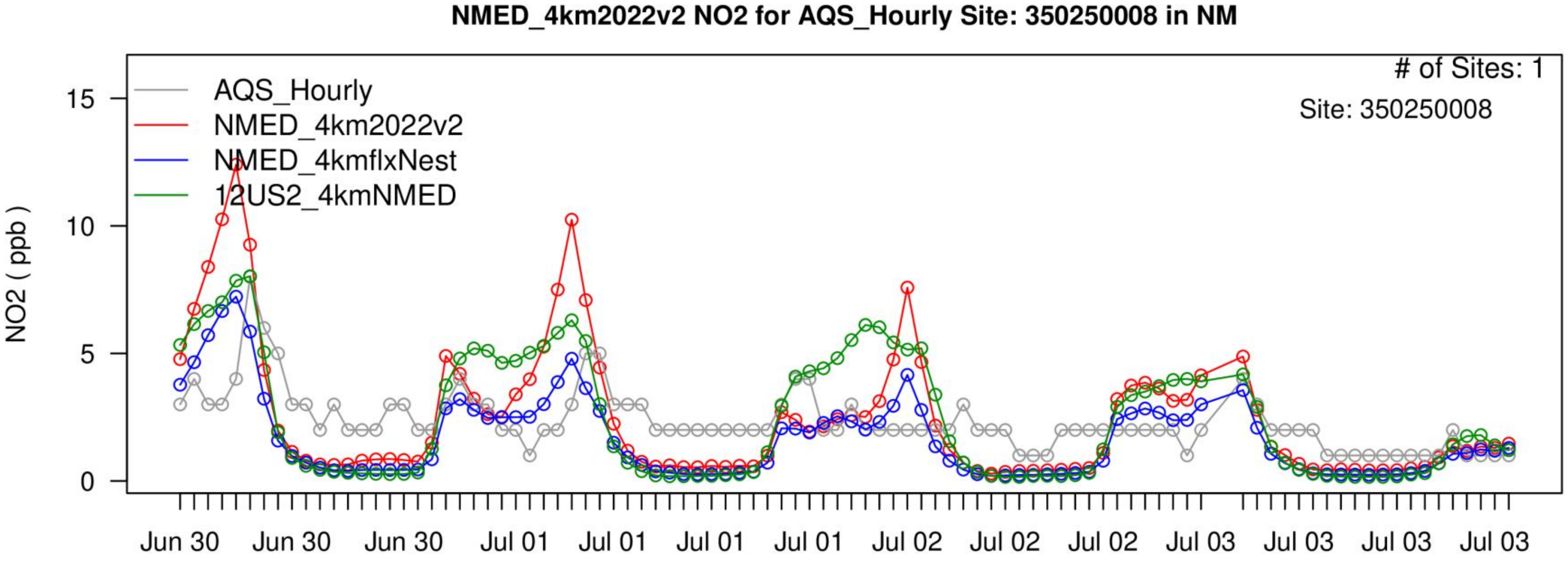
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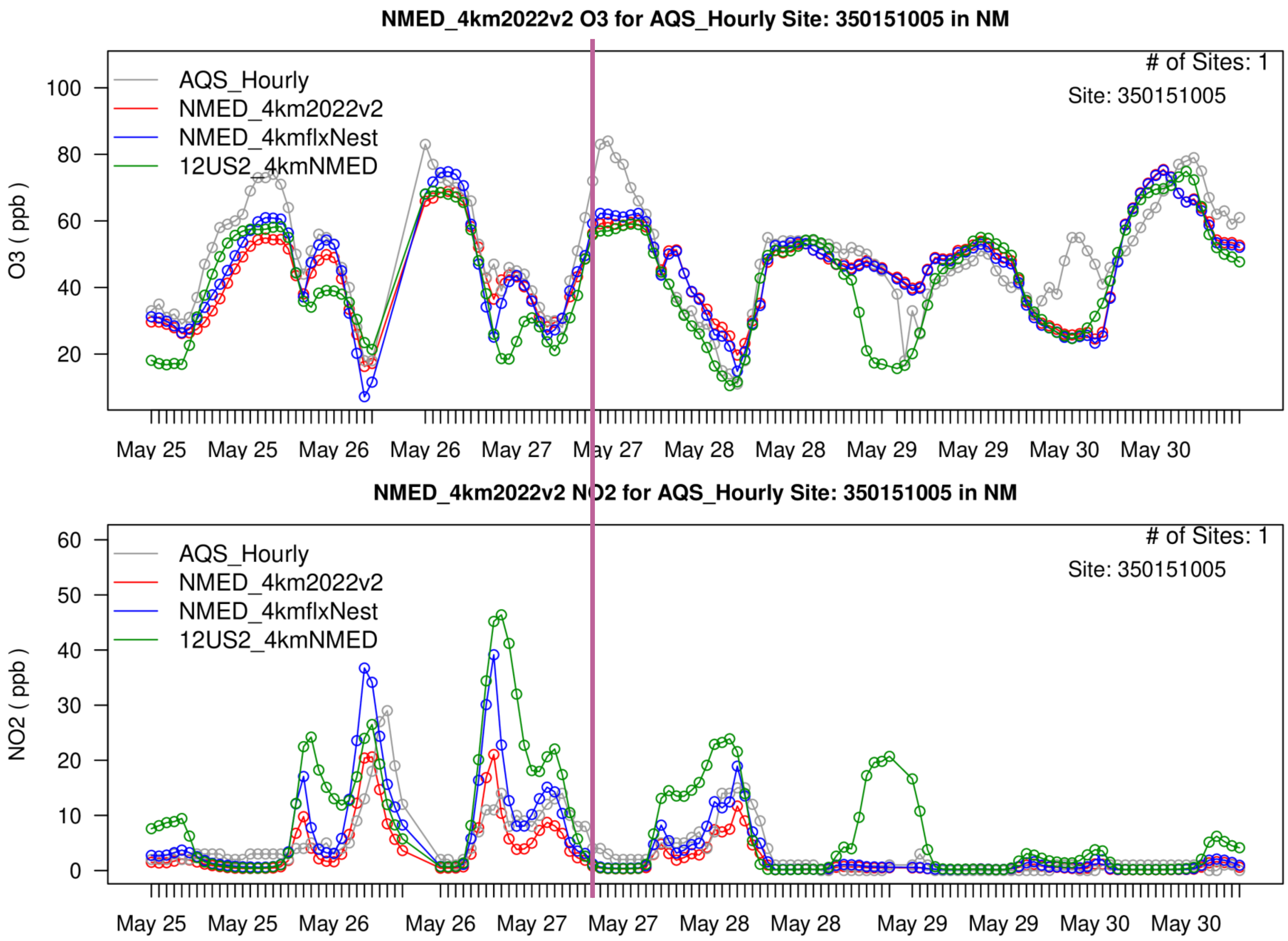
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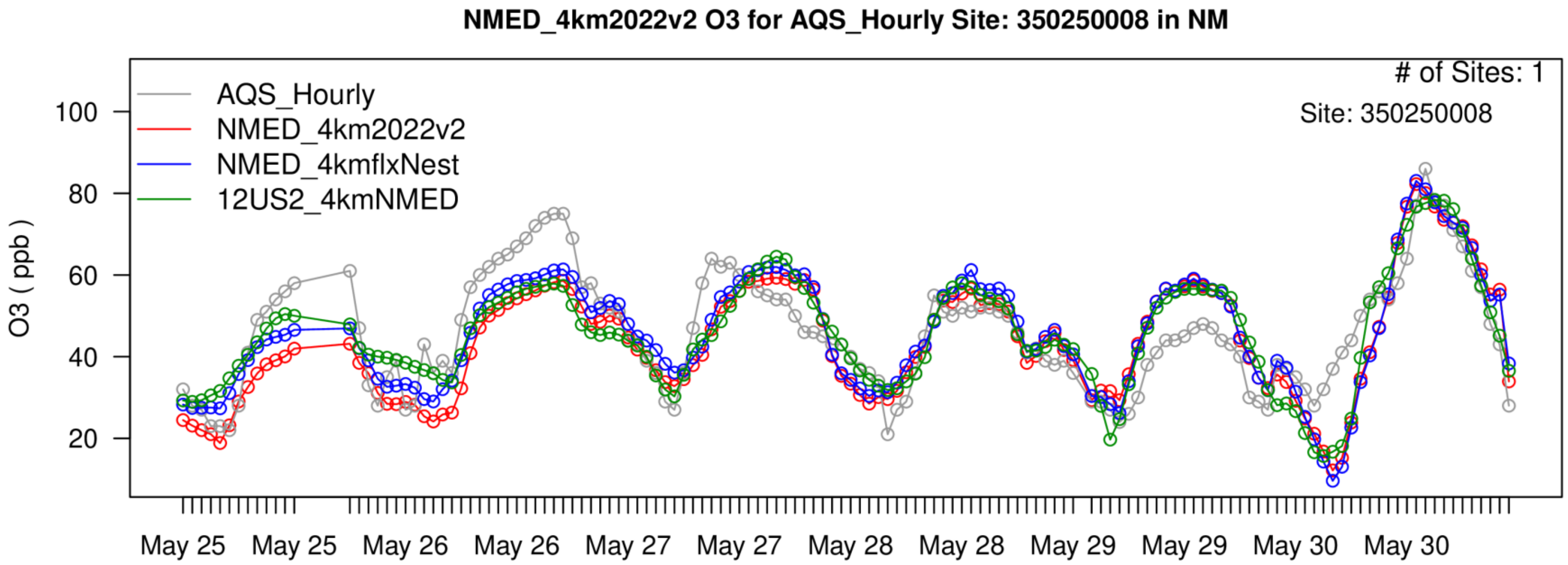
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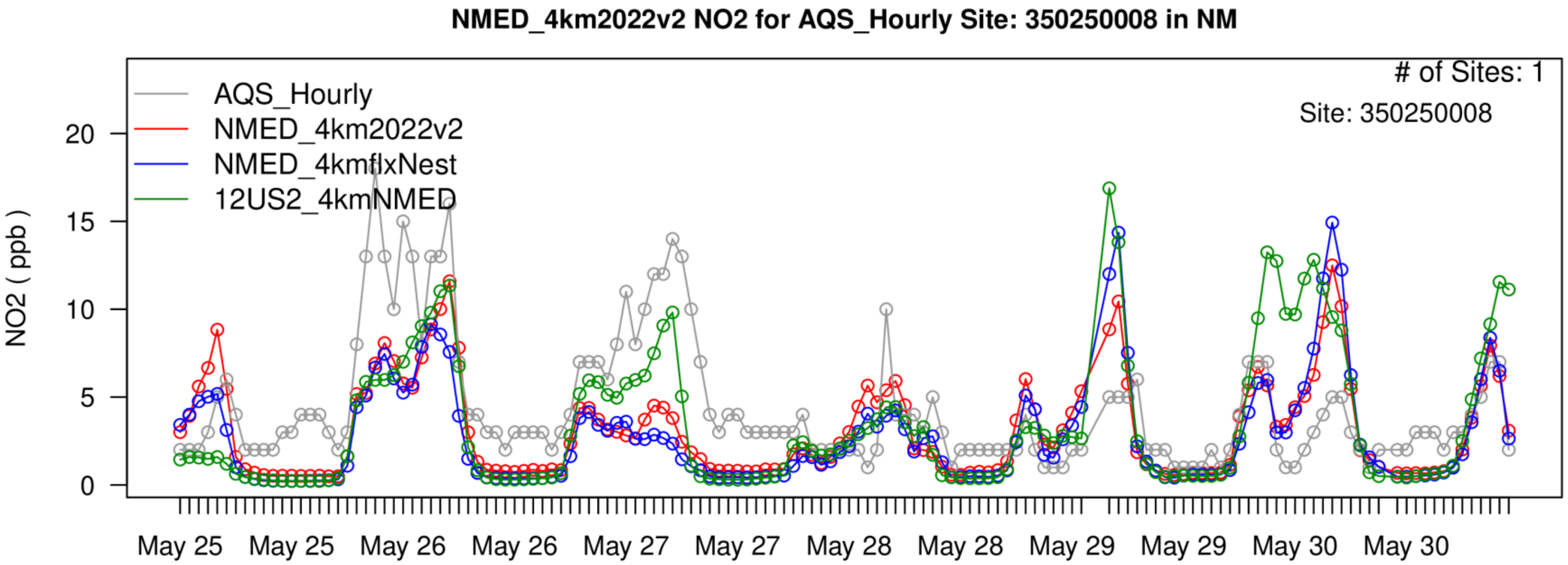
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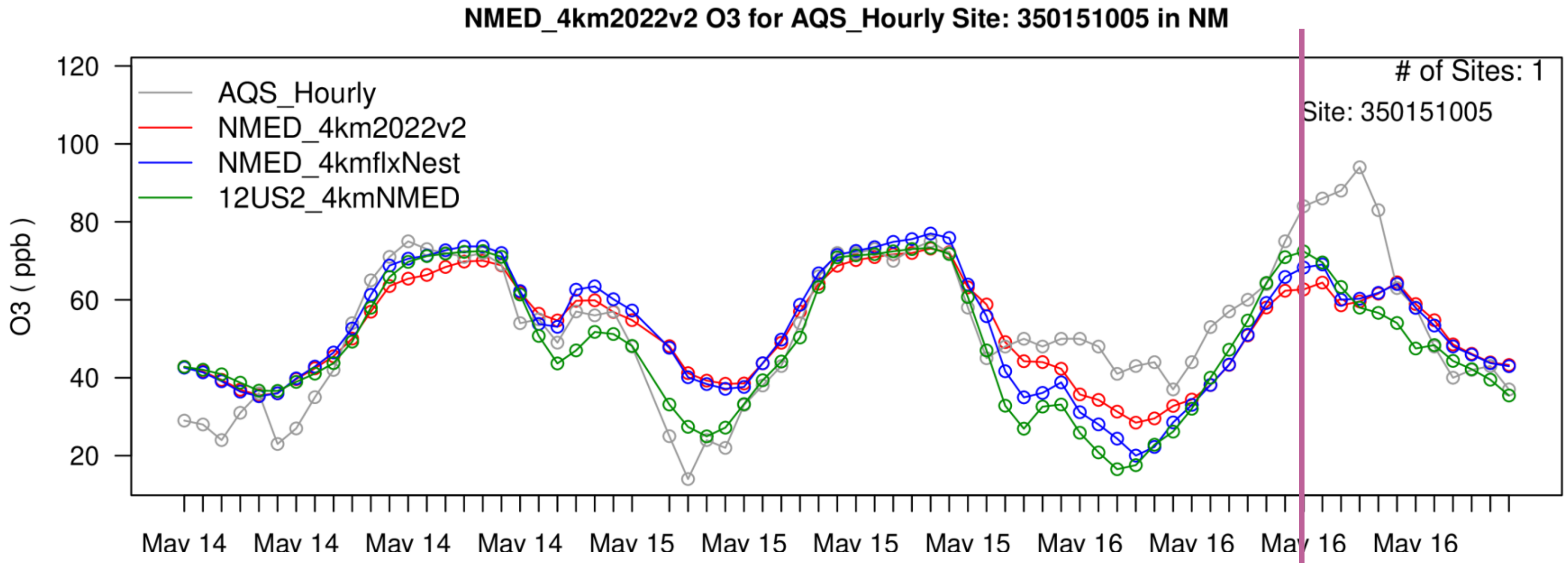
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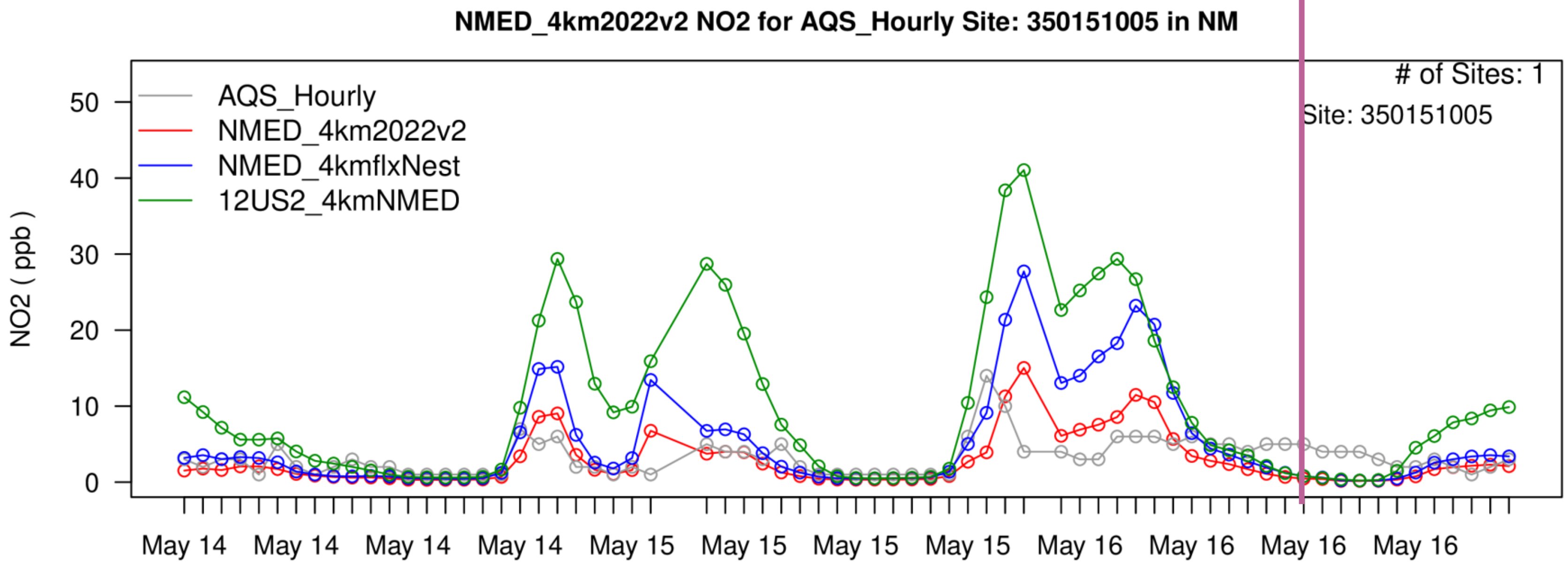
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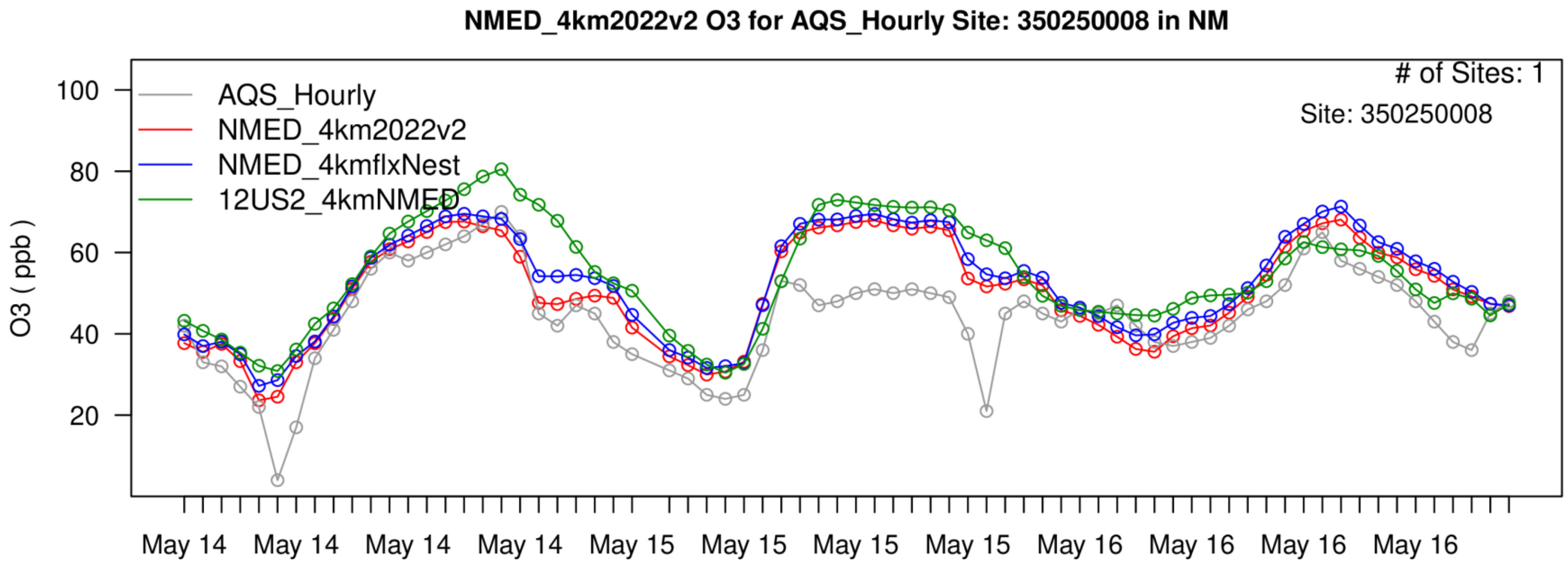
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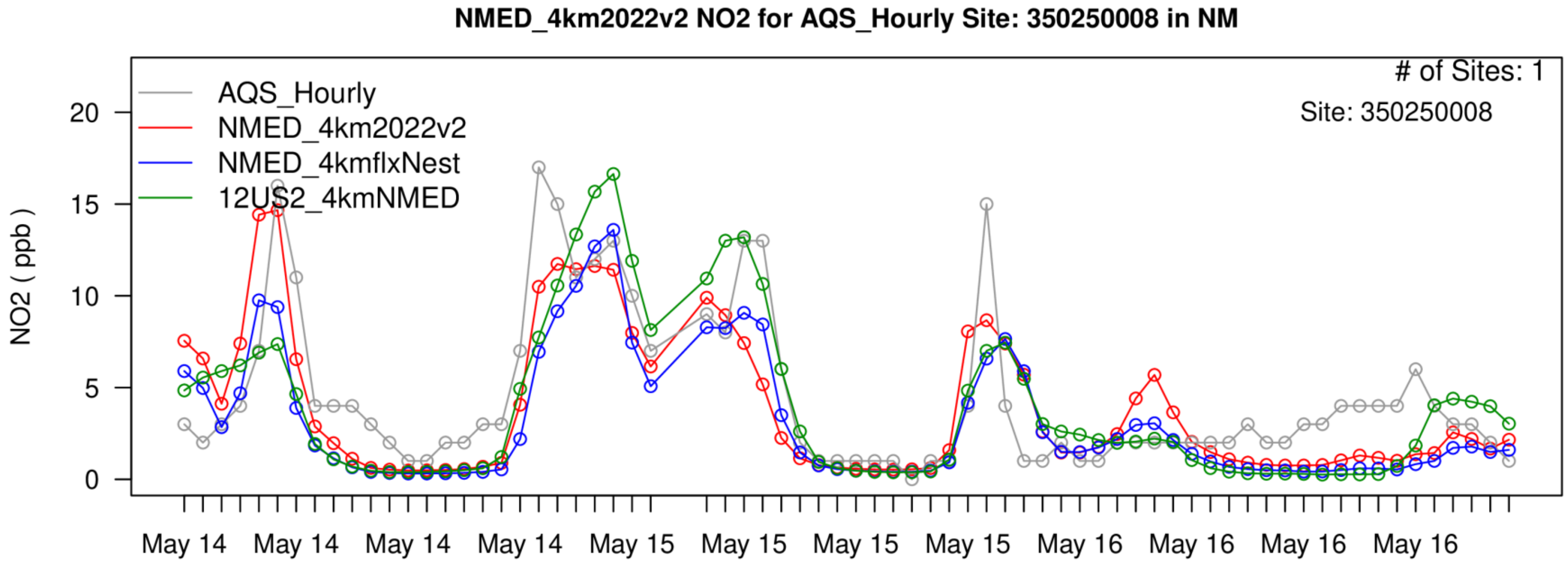
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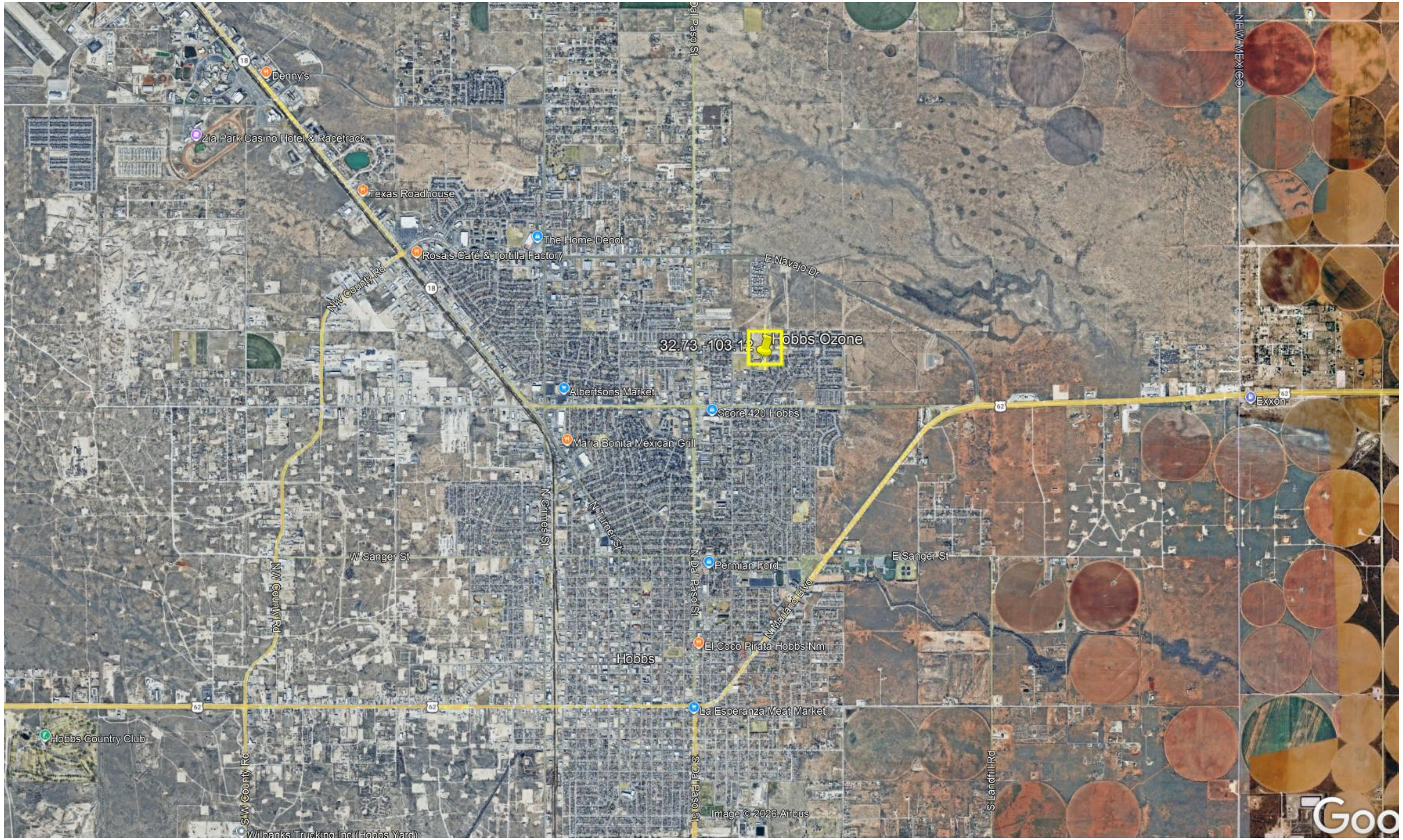
Hobbs Ozone Site



Evaluation for 8 Explicit VOC Species in CB6r5

- **Ethane – ETHA** (C_2H_6) is a major component of natural gas and is a tracer for the oil and gas (O&G) Source Sector
- **Propane – PRPA** (C_3H_8) is a by product of natural gas processing and oil refining and is a tracer for the oil and gas (O&G) Source Sector
- **Benzene – BENZ** (C_6H_6) is a natural component of crude oil and gasoline and is a tracer for gasoline combustion.
- **Ethyne or Acetylene – ETHY** (C_2H_4) is widely used as a fuel and Fresno can be a combustion tracer.
- **Isoprene – ISOP** (C_5H_8) is primarily emitted from plants (broad leaf trees and shrubs) in the afternoon and is a biogenic tracer
- **Ethene or Ethylene – ETH** (C_2H_4) is widely used in the chemical industry and is the most produced organic compound in the world.
- **Acetone – ACET** [$(CH_3)_2CO$] is primarily used as a solvent
- **Acetaldehyde – ALD2** (CH_3CHO) is one of the most important aldehydes that occurs naturally in nature and secondary product of many VOCS (e.g., Alkanes)