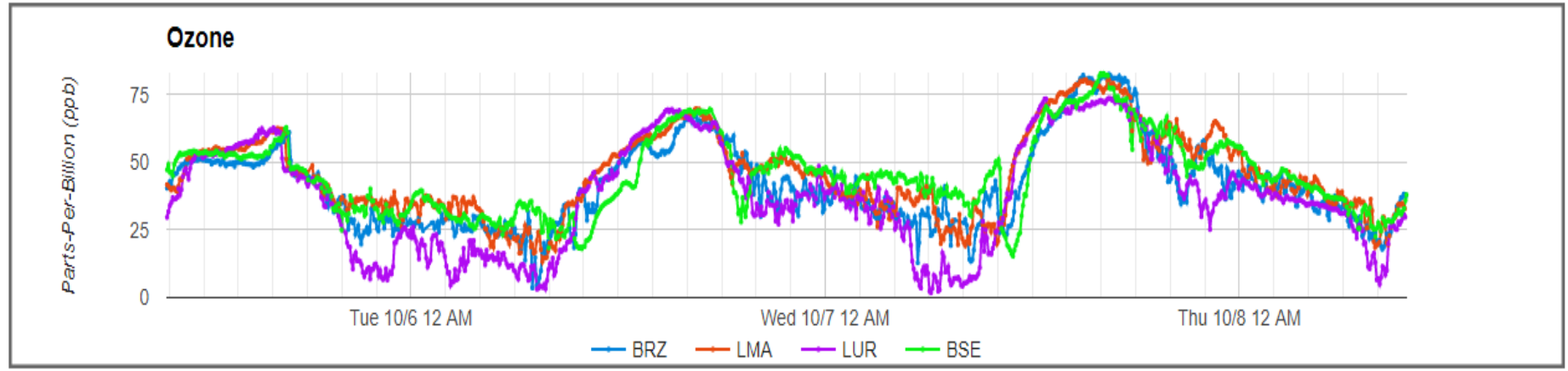
Yesterday's Ozone



October 7, 2020, ozone maxima:

Boulder Reservoir: 82.1 ppb
Longmont Airport: 80.5 ppb
Longmont Union Reservoir: 73.7 ppb
Broomfield Soaring Eagle: 82.9 ppb

Boulder Atmosphere Innovation Research

Air Quality Monitoring at the Boulder Reservoir

Detlev Helmig

- *Review of the Monitoring Program*
- *What's New?*
- *Remarkable 2020:*
  - *Ozone*
  - *COVID*
  - *Fires*
- *Concentration Changes (Trends)*

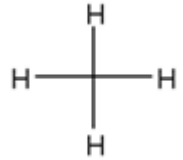
Note: All 2020 data and analyses in this presentation are preliminary!
Please direct any questions to dh.bouldair@gmail.com

Air Quality Impacts of Oil and Gas Development (Fracking, Wells, Storage, Distribution, Pipelines, Flaring, ……)

- Fracking Fluid
- Silica
- Diesel Exhaust
- **Nitrogen Oxides**
- Dust
- **Particulate Matter**
- ***Fugitive Emissions of Oil and Gas***
  - **Methane**
  - **Volatile Organic Compounds**
  - Polycyclic Aromatic Hydrocarbons
- **Hydrogen Sulfide, H_2S**

Ozone

O&NG Emissions - Methane and Volatile Organic Compounds (VOCs)



Methane (CH_4)

Ethane (C_2H_6)

Propane (C_3H_8)

n-Butane (C_4H_{10})

iso-Butane (C_4H_{10})

Natural Gas

Oil

n-Pentane (C_5H_{12})

iso-Pentane (C_5H_{12})

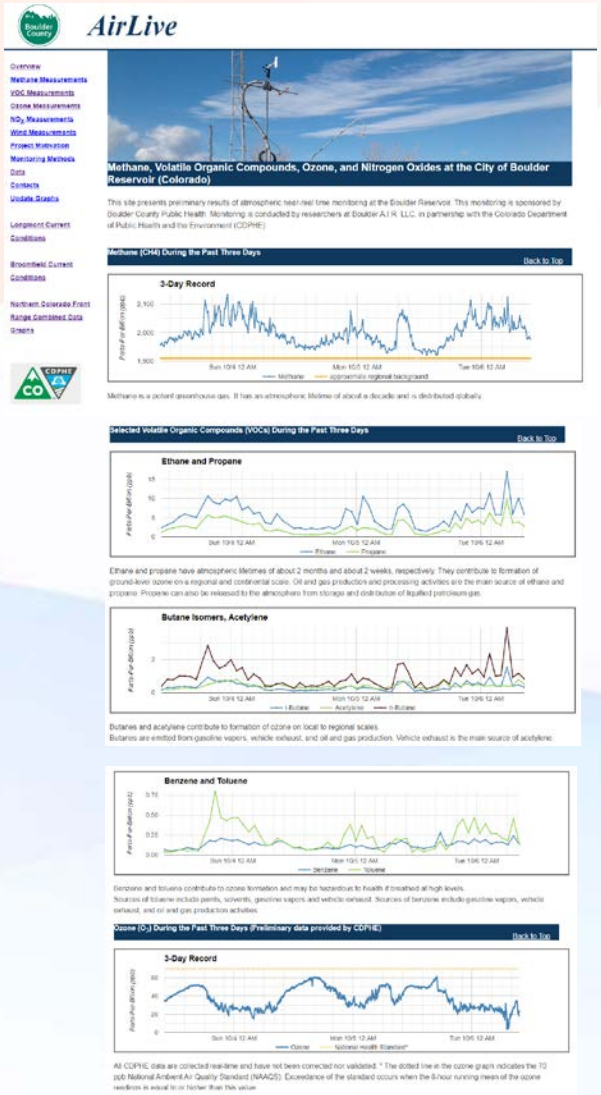
Benzene (C_6H_6)

Toluene (C_7H_8)

Xylenes (C_8H_{10})

Boulder Reservoir Air Monitoring Shelter (CDPHE)

Real Time Monitoring and Real Time Reporting of Air Quality and Oil and Gas Emissions

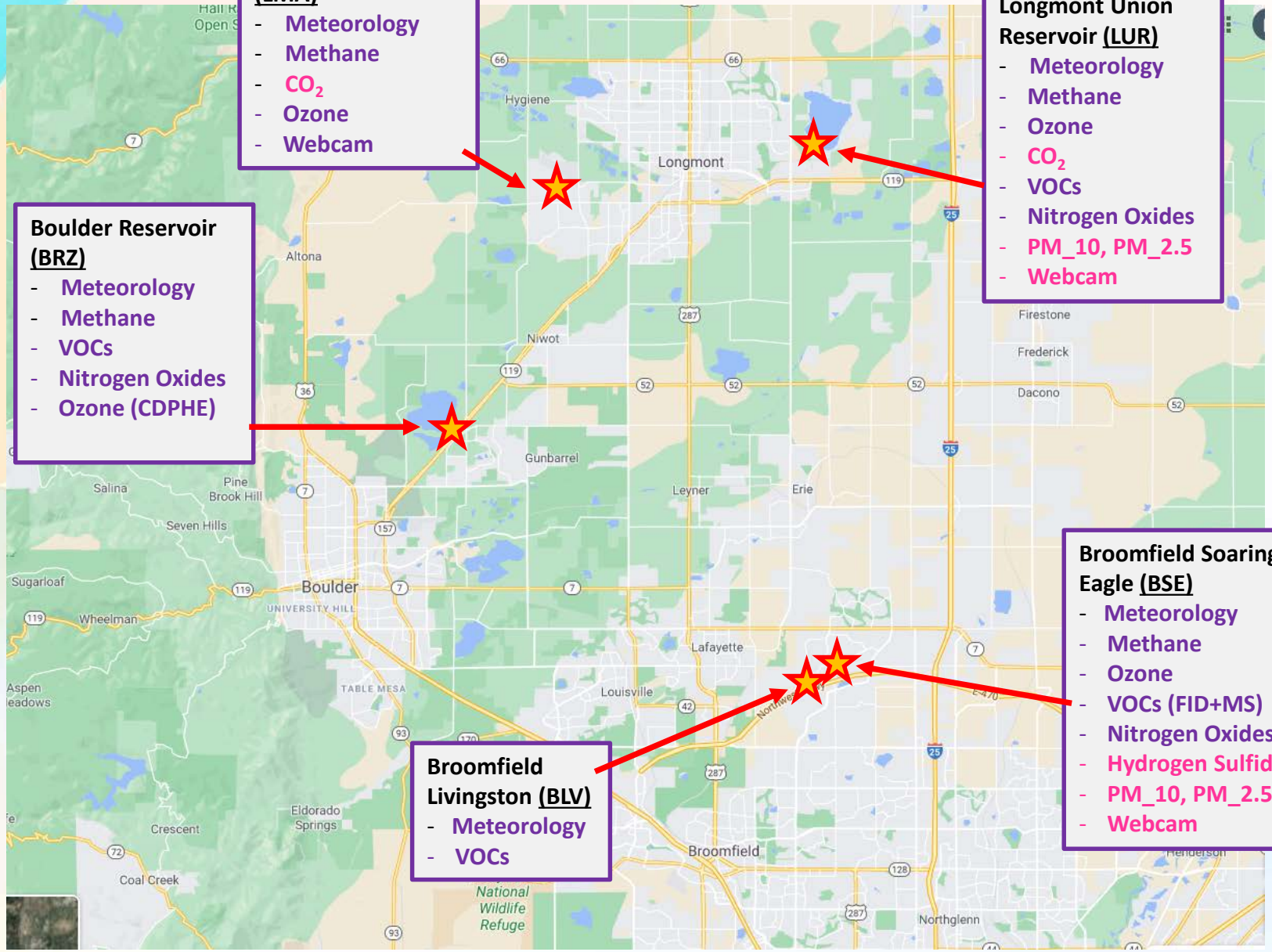


Monitoring Methods

* Fully automated
* 24/7, 365 days per year
* Sensitivity well sufficient to capture full range of atmospheric concentrations
* Regulatory/research-grade instrumentation (NASA, NSF, NOAA, (EPA, CDPHE)
* Calibrations referenced to EPA, CDPHE, NOAA, Global Atmospheric Watch
* Working with CDPHE and EPA on audits, quality control
* Peer-review research quality
* Legally defensible

What's New?

Front Range Air Monitoring Network



Broomfield Soaring Eagle (BSE)

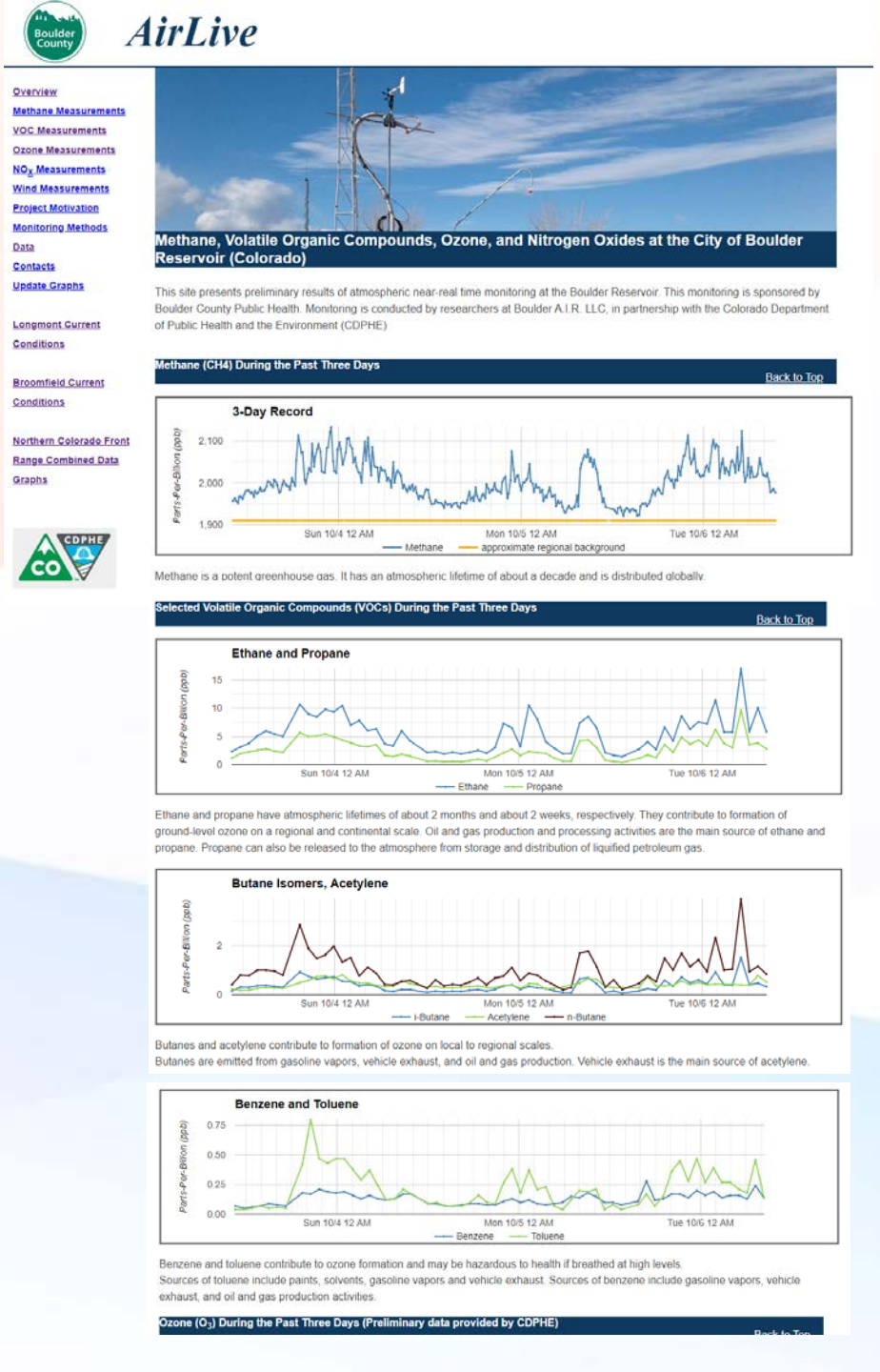
Longmont Union Reservoir (LUR)

Broomfield Livingston (BLV)

Longmont Municipal Airport (LMA)

New Website, New URL

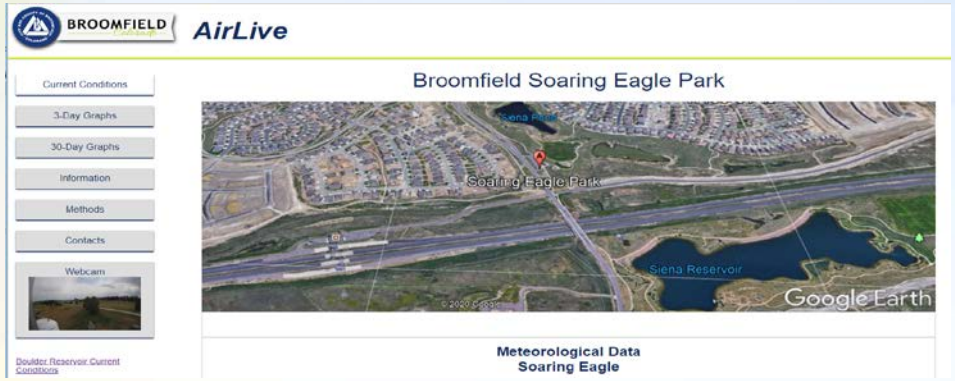
https://www.bouldair.com/boulder



Two Partner Websites

https://www.bouldair.com/boulder.htm

https://www.bouldair.com/longmont.htm



https://www.bouldair.com/broomfield.htm

Website Visits since May 24, 2020

(~ 30-50 per day each per site)

2684

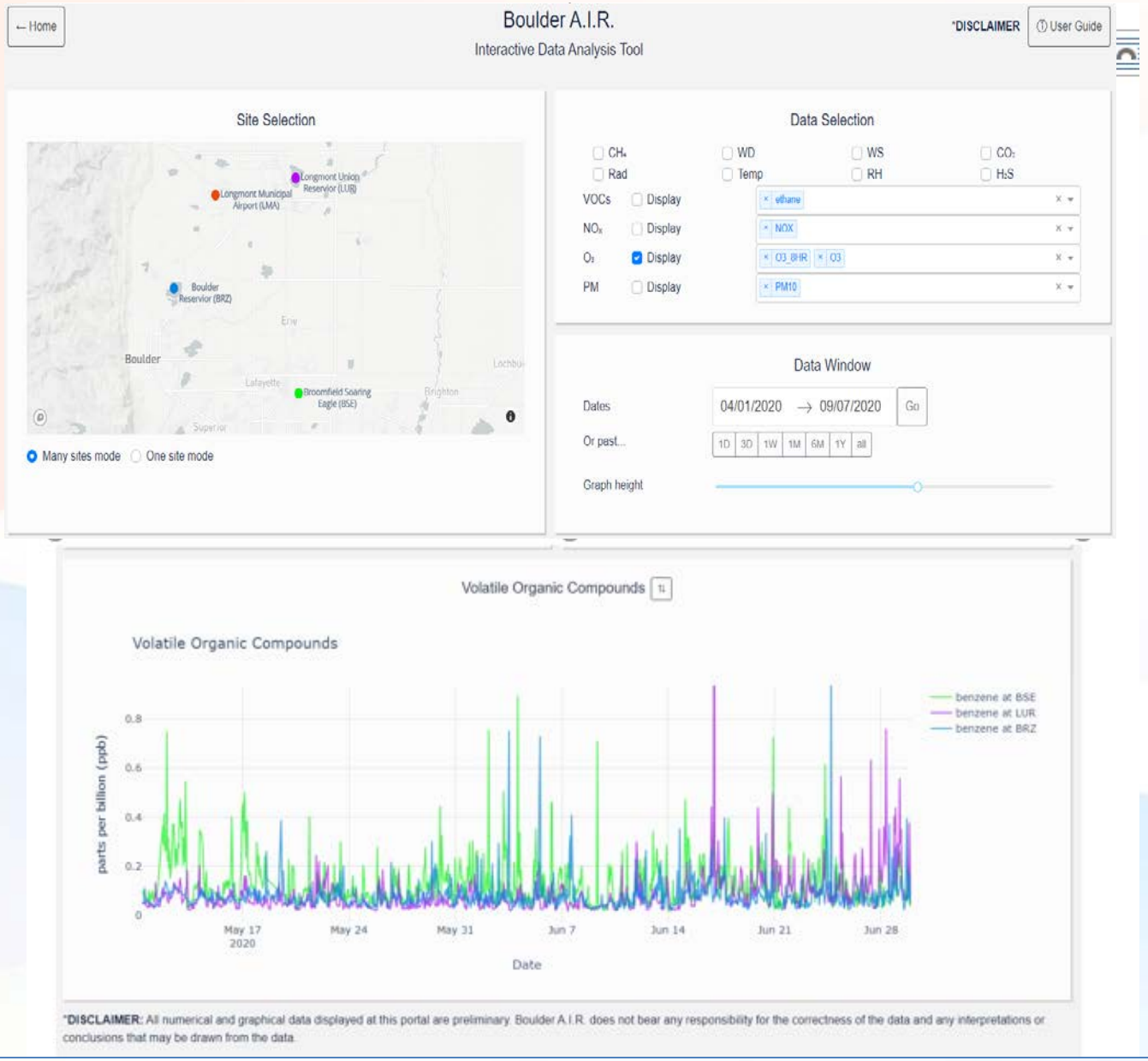
6370

3647

New Website with direct comparison of monitoring data within network in real time:

https://www.bouldair.com/NoCoFrontRange.htm

Interactive Data Analysis Tool



Automated E-Mails with Air Quality Alerts (Sept. 6-7)

Current Air Quality Alert Thresholds for Broomfield:

Ozone > 70.9 ppb
Benzene > 0.9 ppb
PM2.5 > 35 µg m^{-3}

alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 1	
alert.bouldair	Inbox	** AIRLive ALERT ** High Ozone Values at Broomfield Soaring Eagle - At 1	
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 1	
alert.bouldair	Inbox	** AIRLive ALERT ** High Ozone Values at Broomfield Soaring Eagle - At 1	
alert.bouldair	Inbox	** AIRLive ALERT ** High Ozone Values at Broomfield Soaring Eagle - At 15	
alert.bouldair	Inbox	** AIRLive ALERT ** High Ozone Values at Broomfield Soaring Eagle - At 14	
alert.bouldair	Inbox	** AIRLive ALERT ** High Ozone Values at Broomfield Soaring Eagle - At 13:03 MDT on 09/07/2020, a 5-minute averaged Ozone value o...	1:20 PM
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 11:47 MDT on 09/07/2020, a 5-minute averaged PM2.5 value of ...	12:00 PM
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 01:07 MDT on 09/07/2020, a 5-minute averaged PM2.5 value o...	1:20 AM
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 00:07 MDT on 09/07/2020, a 5-minute averaged PM2.5 value o...	12:20 AM
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 23:07 MDT on 09/06/2020, a 5-minute averaged PM2.5 value o...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 20:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value of ...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 19:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value o...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 18:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value of ...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High Benzene Values at Broomfield Soaring Eagle - At 16:40 MDT on 09/06/2020, a 5-minute averaged Benzene valu...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 17:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value of ...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 16:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value o...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High Benzene Values at Broomfield Soaring Eagle - At 15:37 MDT on 09/06/2020, a 5-minute averaged Benzene val...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 15:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value of ...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 14:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value of ...	Sep 6
alert.bouldair	Inbox	** AIRLive ALERT ** High PM2.5 Values at Broomfield Soaring Eagle - At 13:37 MDT on 09/06/2020, a 5-minute averaged PM2.5 value o...	Sep 6

Remarkable Year 2020 !

Ozone

EPA United States Environmental Protection Agency

Environmental Topics | Laws & Regulations | About EPA | Search EPA.gov

CONTACT US SHARE

News Releases

News Releases from Region 08

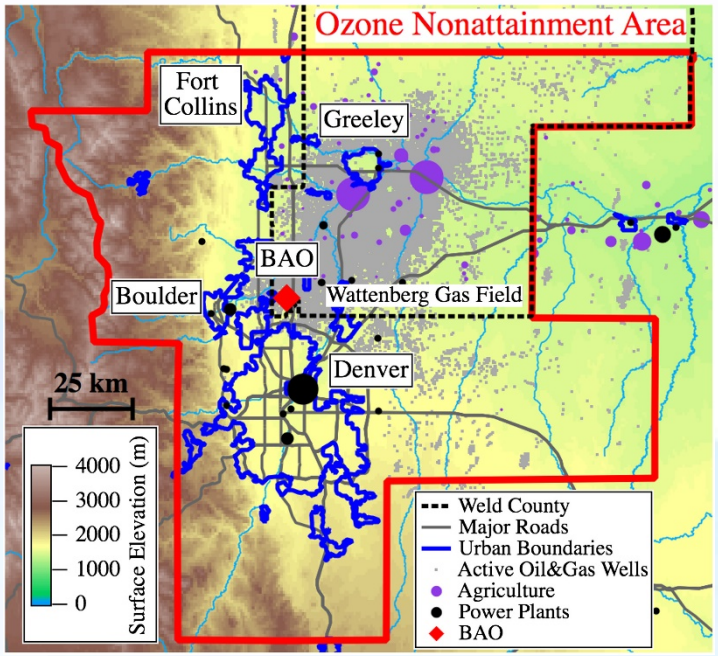
EPA reclassifies Denver area to "Serious" nonattainment for ozone

Reclassification requires additional control measures to reduce emissions

12/16/2019

Contact Information:
Richard Mylott (mylott.richard@epa.gov)
303-312-6654

DENVER—The U.S. Environmental Protection Agency (EPA) today announced the agency is finalizing a determination to reclassify the Denver Metro/North Front Range ozone nonattainment area from Moderate to Serious nonattainment under the Clean Air Act.



Elevated Levels of Surface **Ozone** can cause:

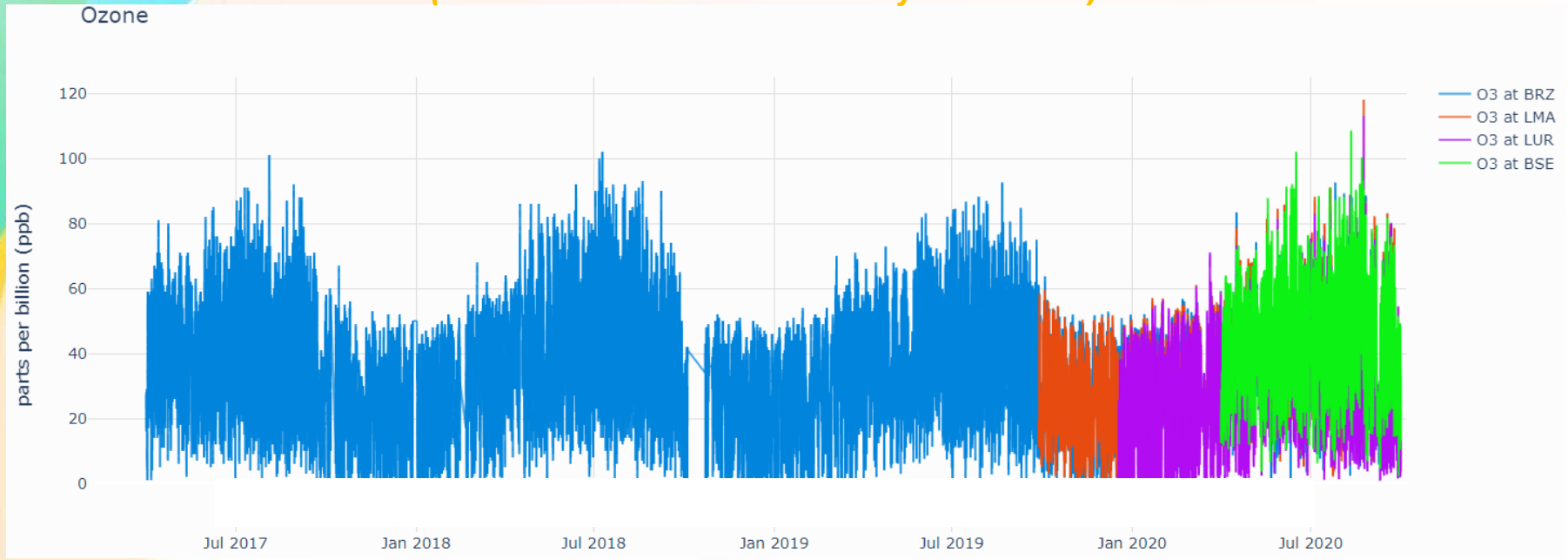
- Shortness of breath
- Chest pain when inhaling deeply
- Wheezing and coughing
- Increased susceptibility to respiratory infections
- Inflammation of the lungs and airways
- Increased risk of asthma attacks

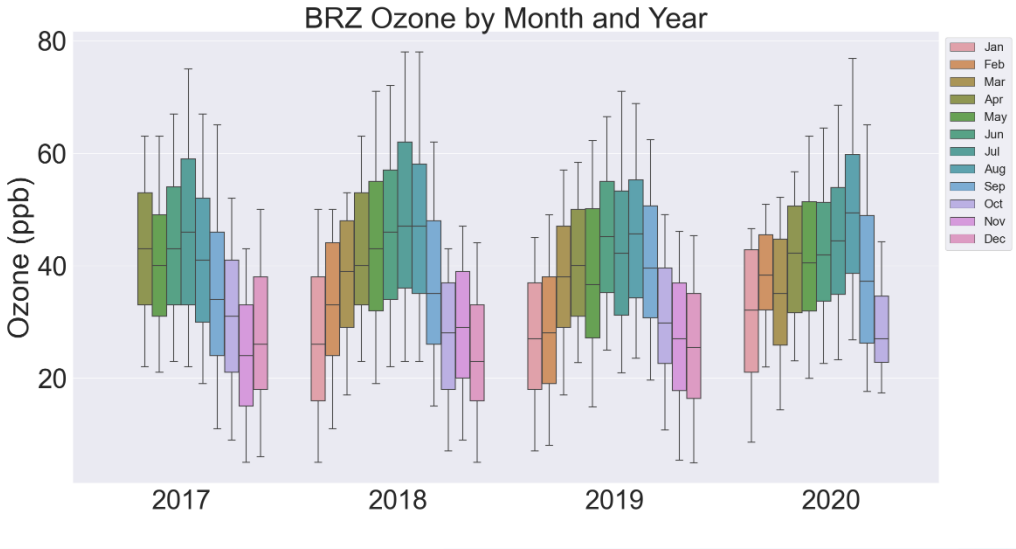
….. (American Lung Association)

→ Increased risk of death;
~ 5000-6000 premature deaths in US per year

BRZ Ozone

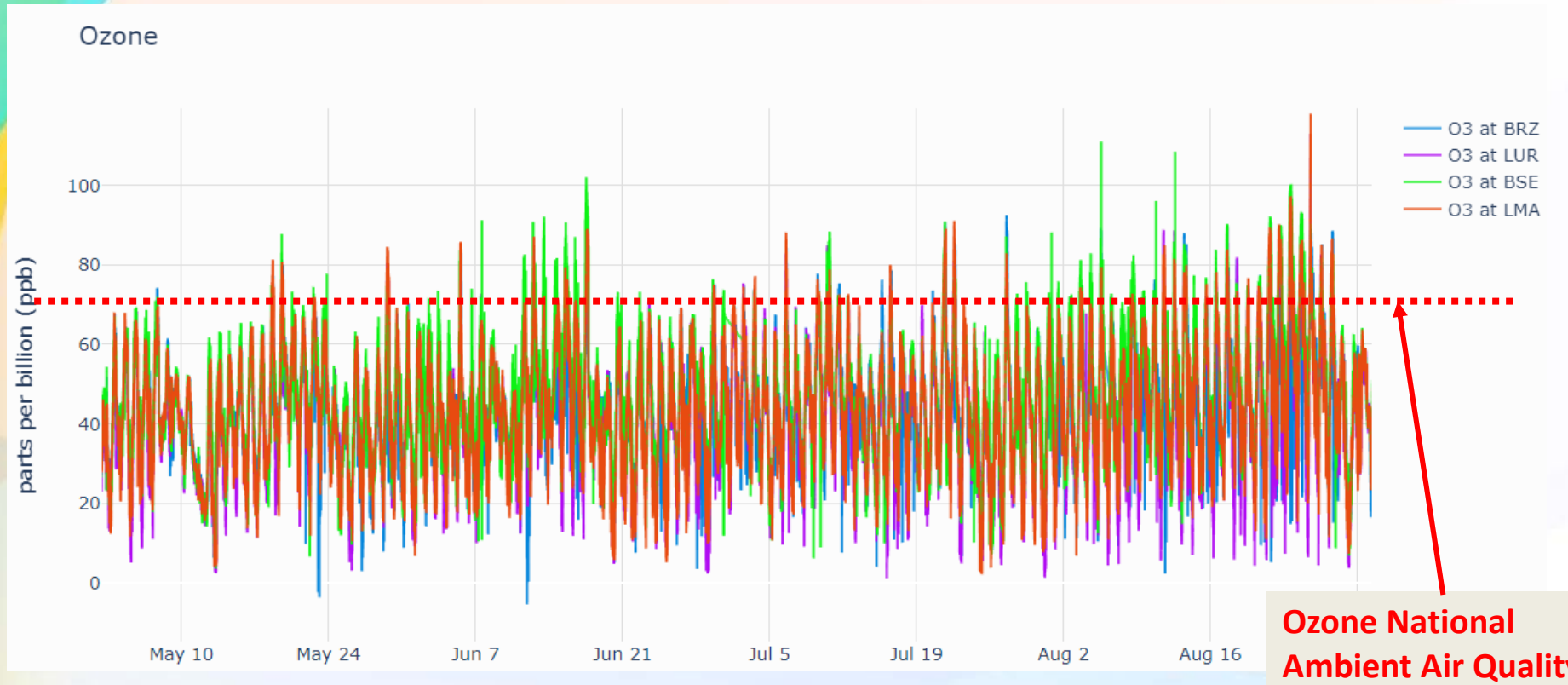
(Note: All BRZ Ozone Data are from CDPHE)





Summer 2020 Ozone

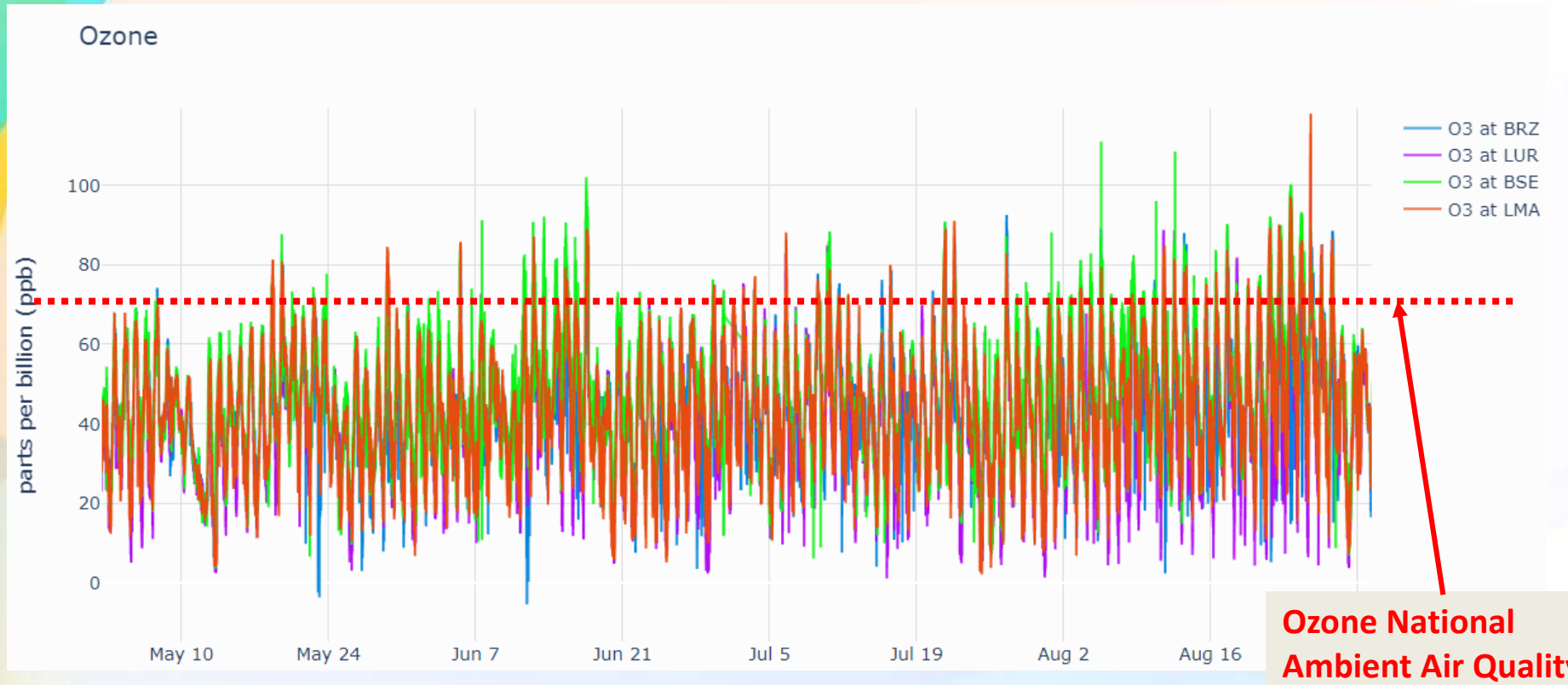
(Note: All Data are Preliminary)



Ozone National Ambient Air Quality Standard (mean 8-hours > 70 ppb)

BRZ – Boulder Reservoir
LMA – Longmont Municipal Airport
LUR – Longmont Union Reservoir
BSE – Broomfield Soaring Eagle

2020:
60-65 Days with Ozone above 70 ppb
~18 Days with 8-hour averaged Ozone above 70 ppb



Ozone National Ambient Air Quality Standard (mean 8 hours > 70 ppb)

BRZ – Boulder Reservoir
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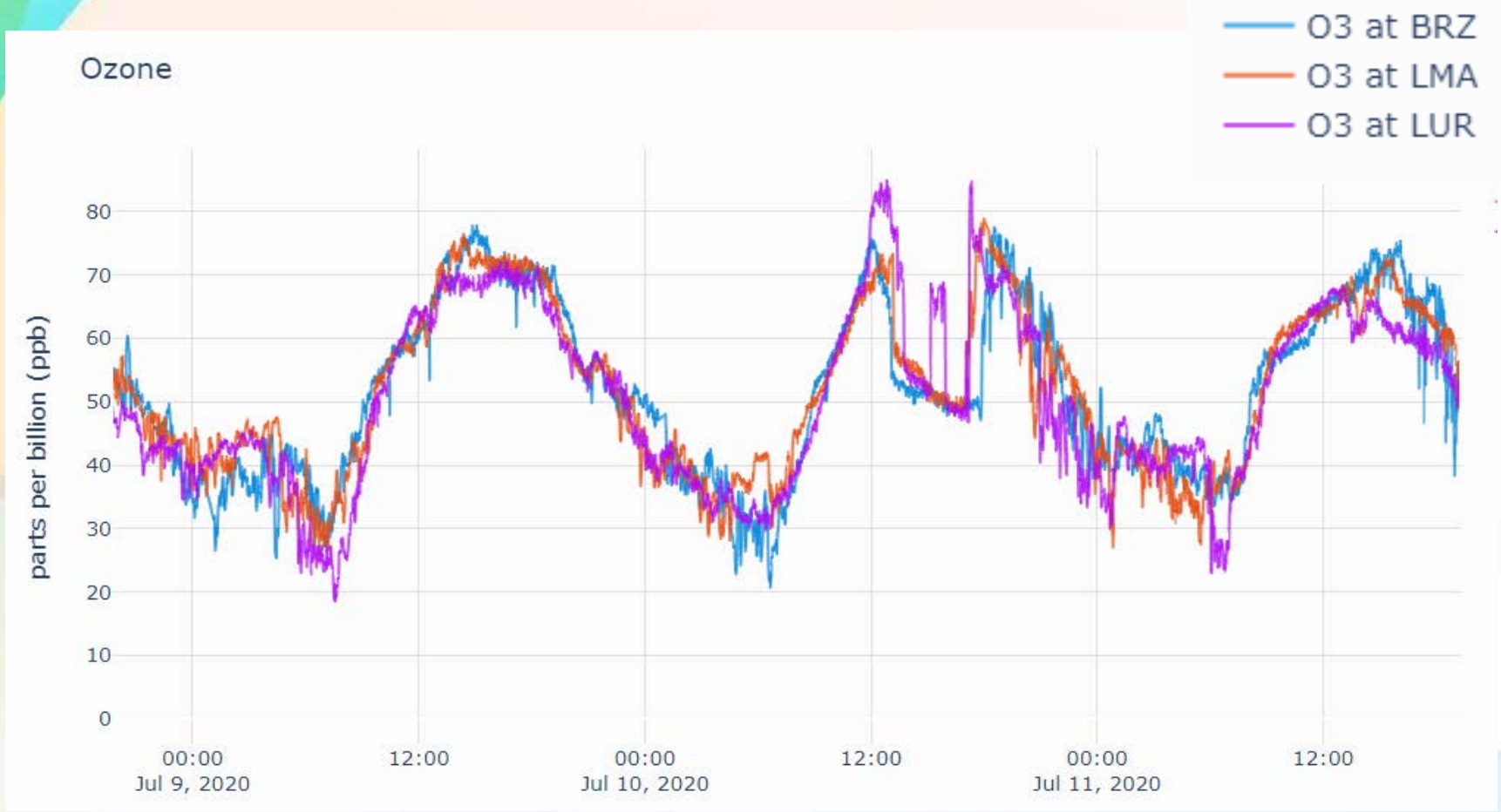
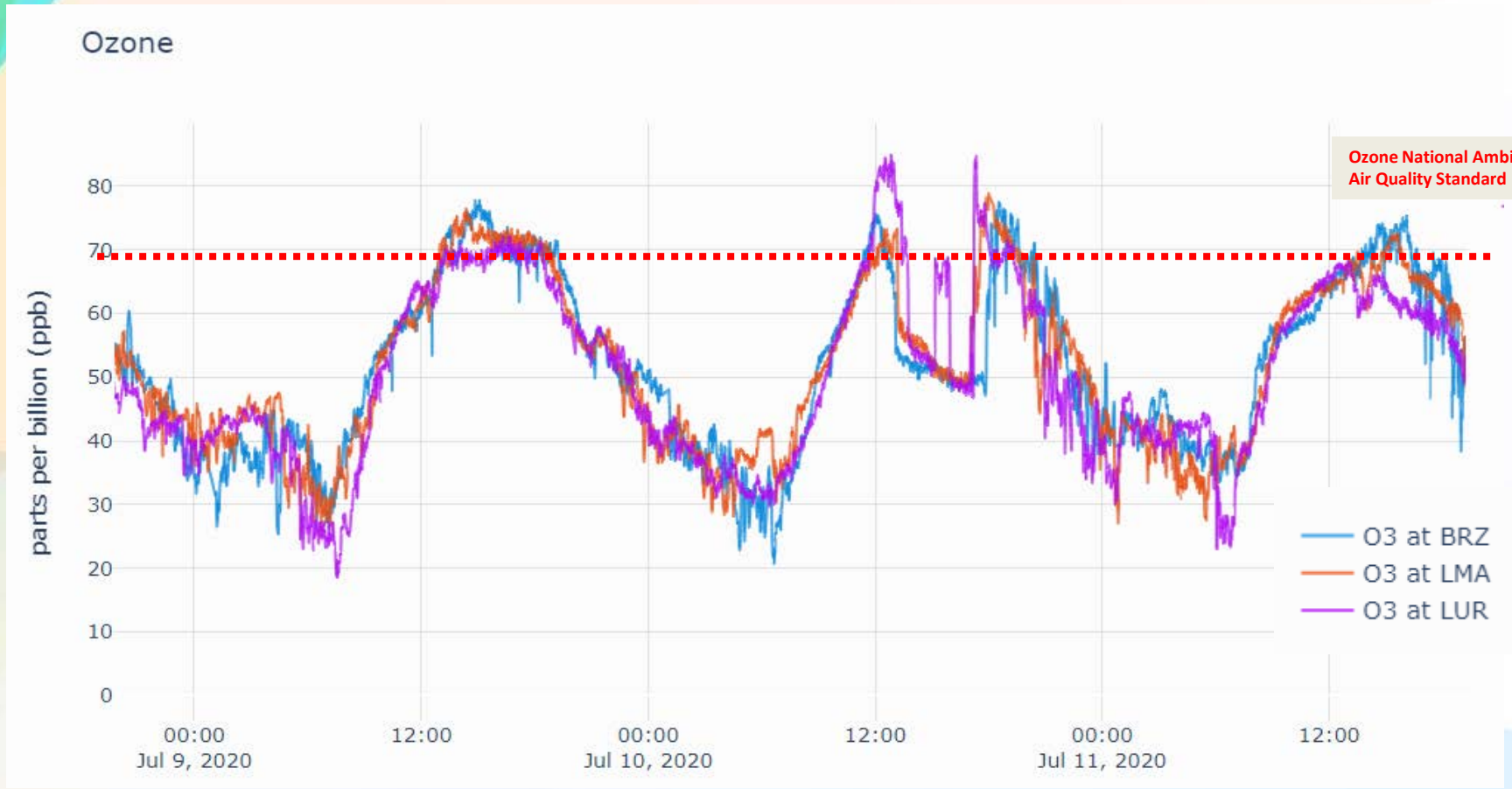
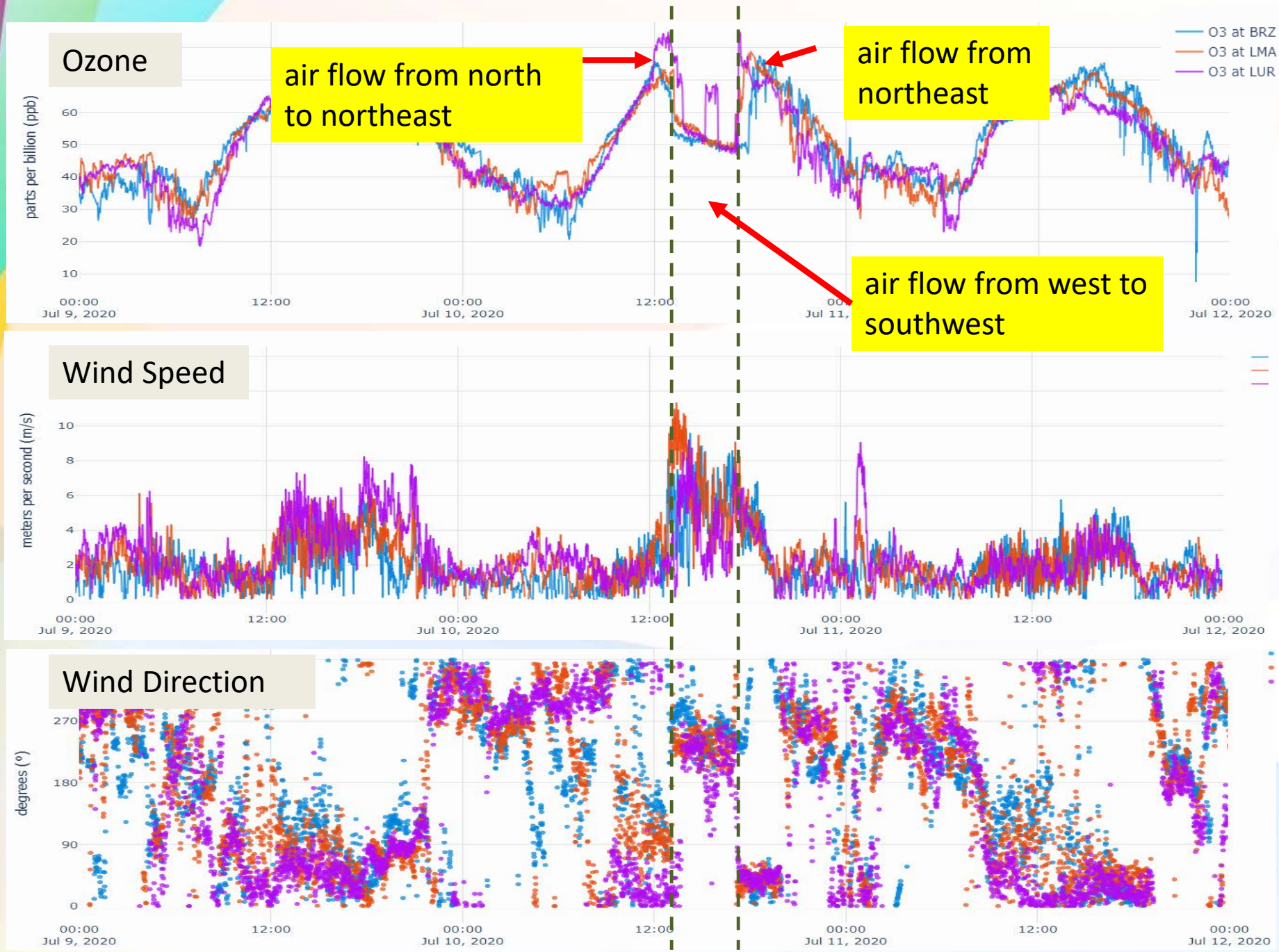
Ozone
July 10 Event



Ozone
July 10 Event

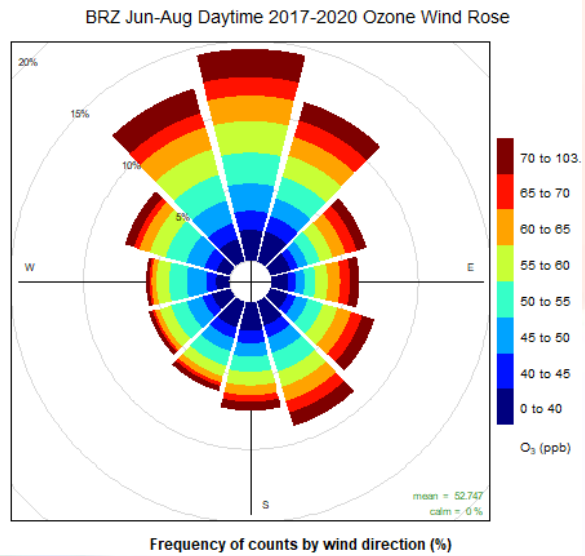


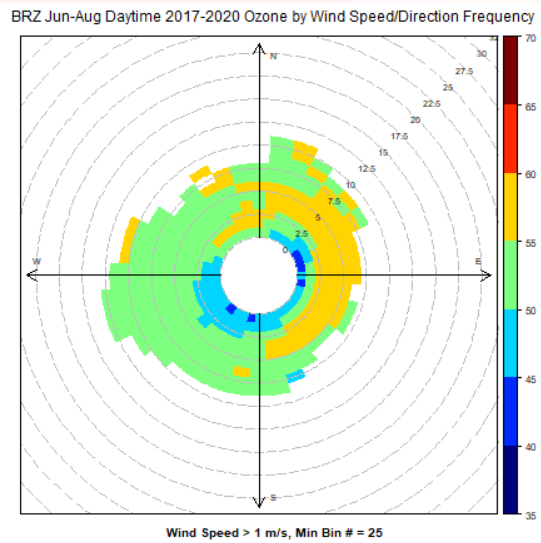

Ozone
O3 at BRZ
O3 at LMA
O3 at LUR
parts per billion (ppb)
60
50
40
30
20
10
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11, 2020
12:00
00:00
Jul 12, 2020
Wind Speed
meters per second (m/s)
10
8
6
4
2
0
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11, 2020
12:00
00:00
Jul 12, 2020
Wind Direction
degrees (°)
270
180
90
0
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11, 2020
12:00
00:00
Jul 12, 2020

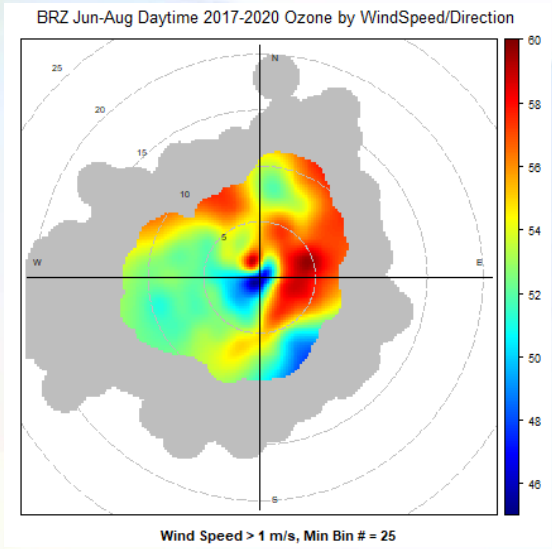

Ozone
air flow from north to northeast
air flow from northeast
air flow from west to southwest
O3 at BRZ
O3 at LMA
O3 at LUR
parts per billion (ppb)
60
50
40
30
20
10
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11,
00:00
Jul 12, 2020
Wind Speed
meters per second (m/s)
10
8
6
4
2
0
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11, 2020
12:00
00:00
Jul 12, 2020
Wind Direction
degrees (°)
270
180
90
0
00:00
Jul 9, 2020
12:00
00:00
Jul 10, 2020
12:00
00:00
Jul 11, 2020
12:00
00:00
Jul 12, 2020

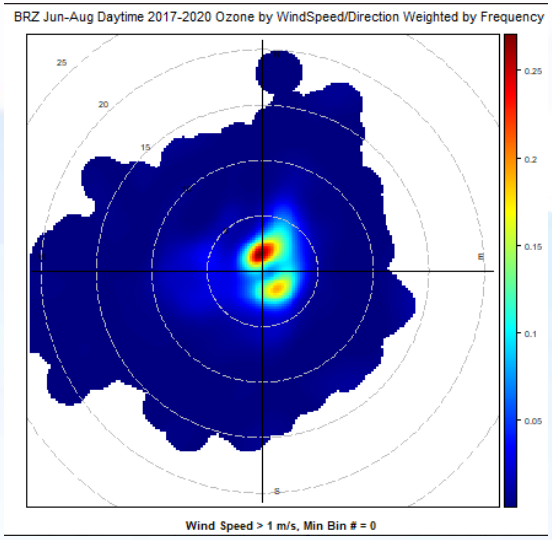
Where is the High Ozone Coming From?

BRZ, 2017-2020, daytime, June-August, winds > 1 m/s

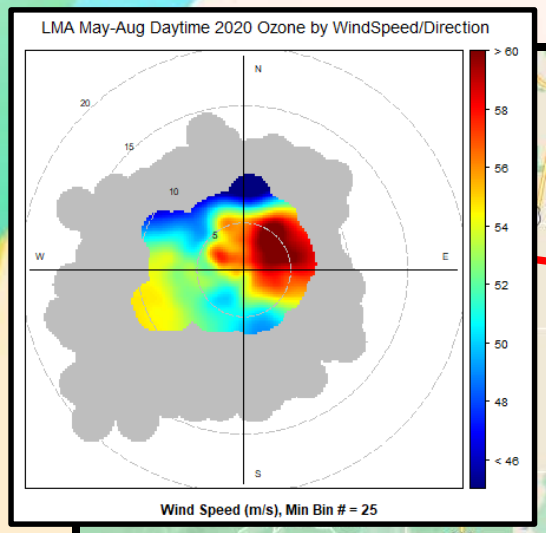


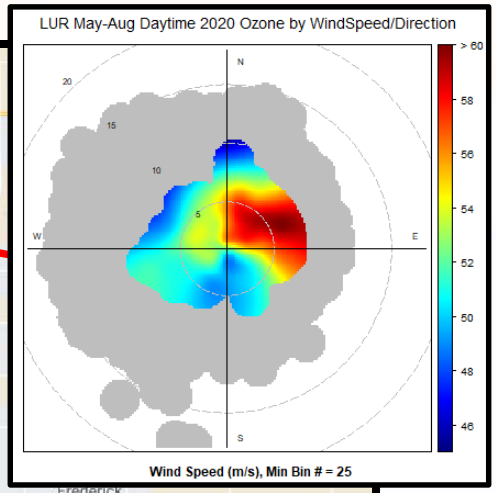


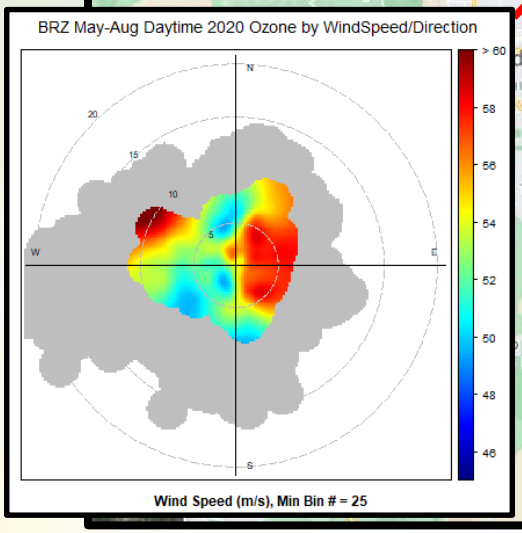


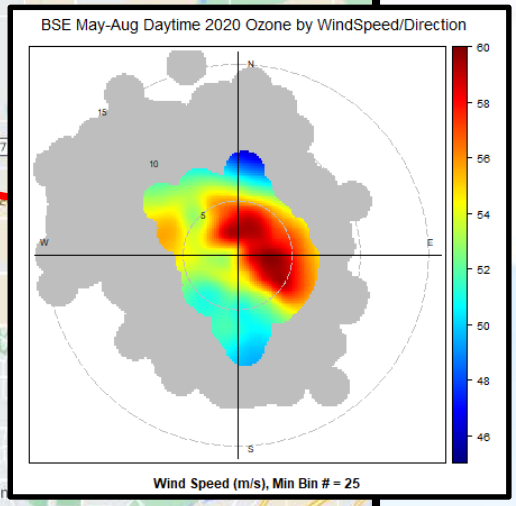


Ozone by Wind Direction/Speed Summer 2020





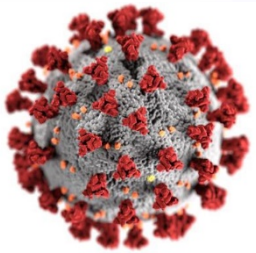


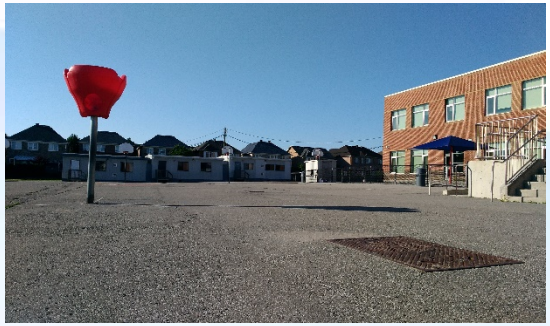


Ozone Summary

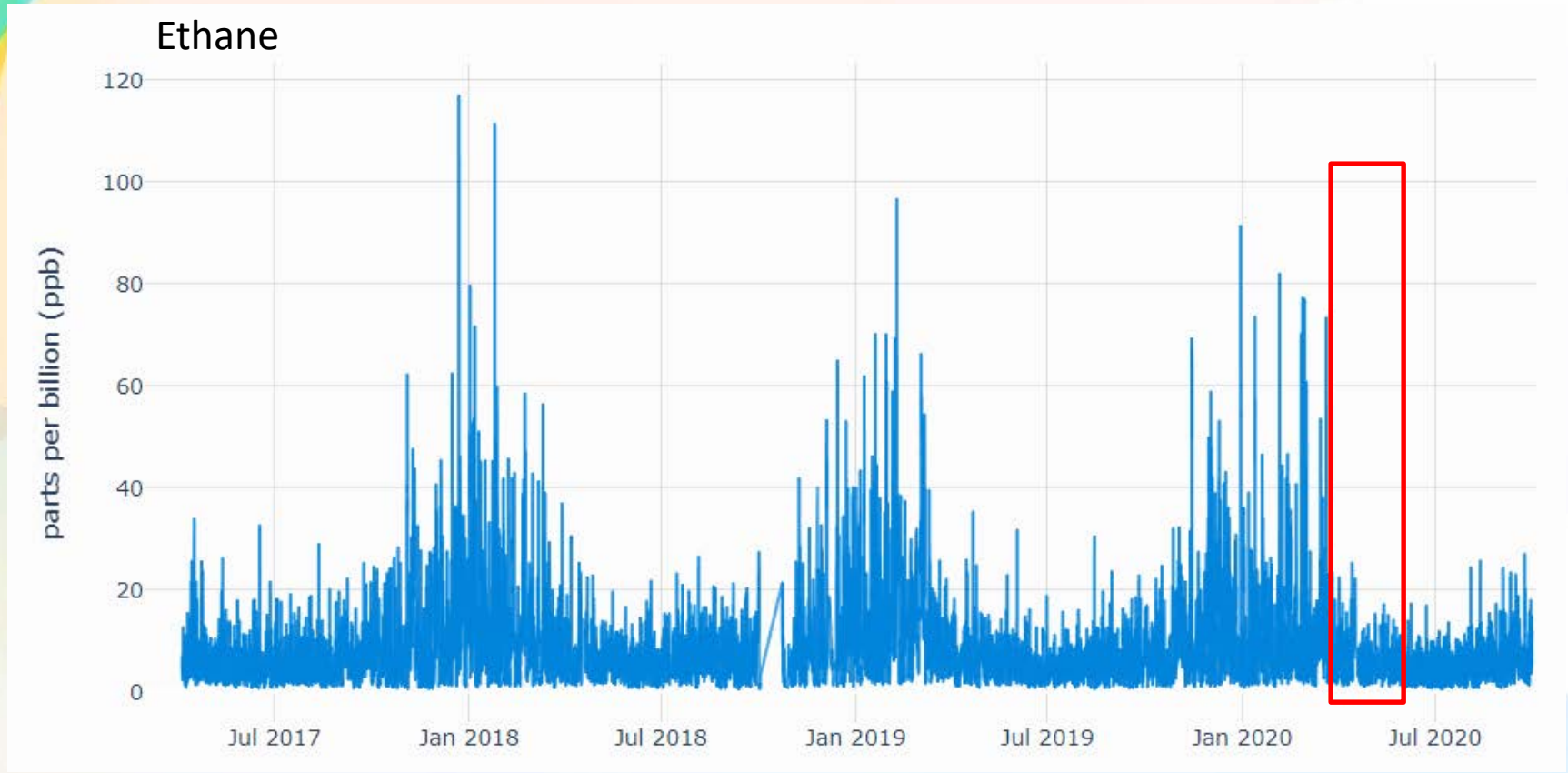
- 2020 was a relatively high ozone year
- 1st ozone exceedance was already observed on April 17
- Latest ozone exceedance observed yesterday (October 7) with 82 ppb maximum at BRZ
- Close to 70 days when ozone exceeded 70 ppb
- Maximum value of 118 ppb observed on August 25
- 5 consecutive days with exceedance of the NAAQS in August
- Overall, approx. 18 days when NAAQS was exceeded.
- High ozone occurrences are predominantly associated with easterly transport. Very consistent across network sites.

Emission Changes from COVID ?

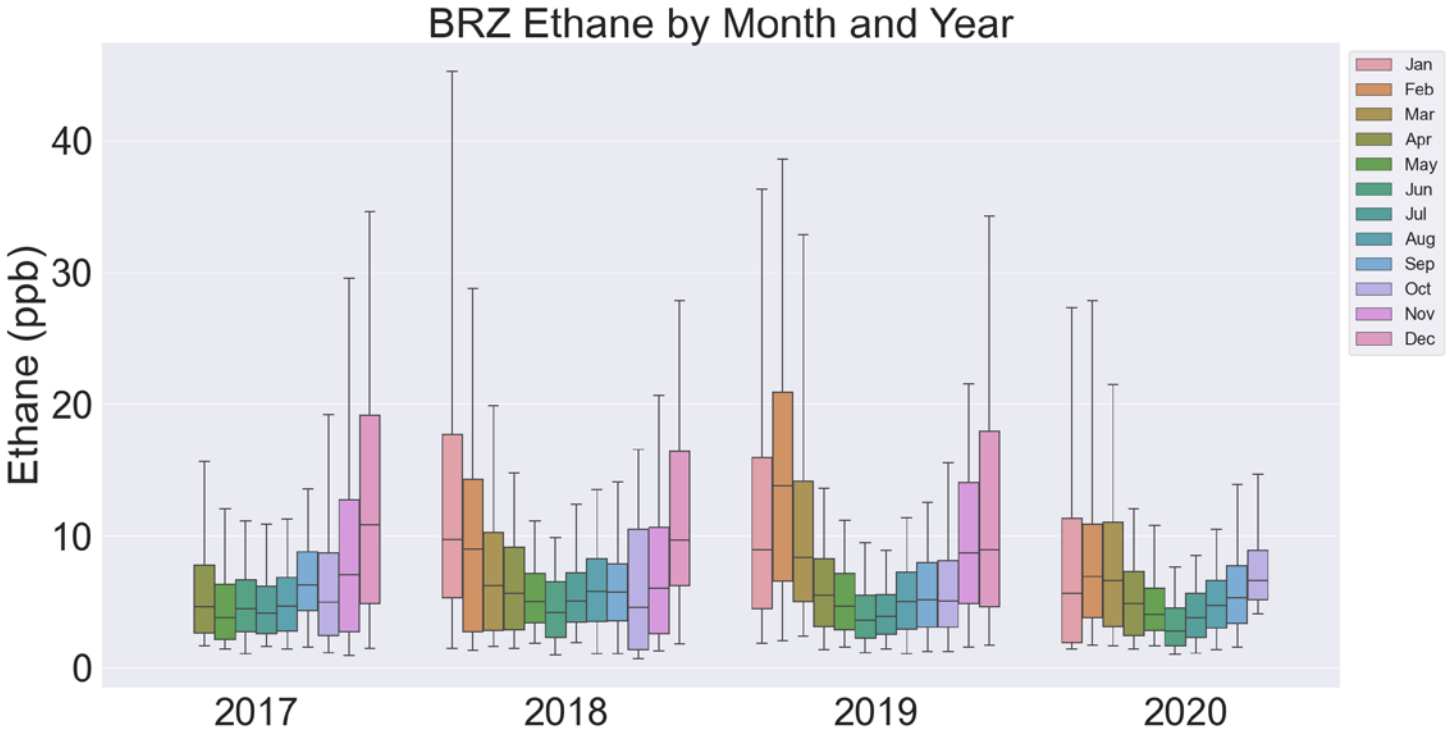




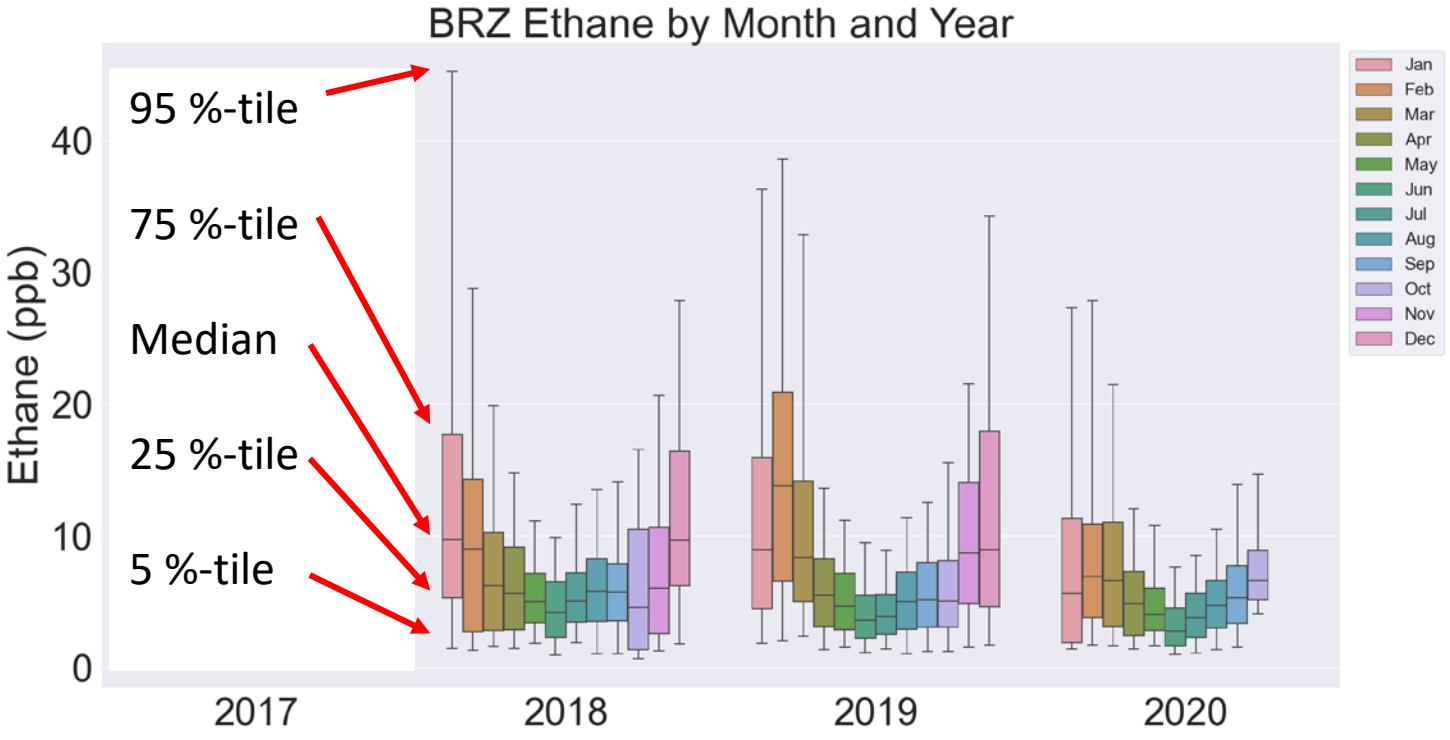
Emission Changes from COVID ?



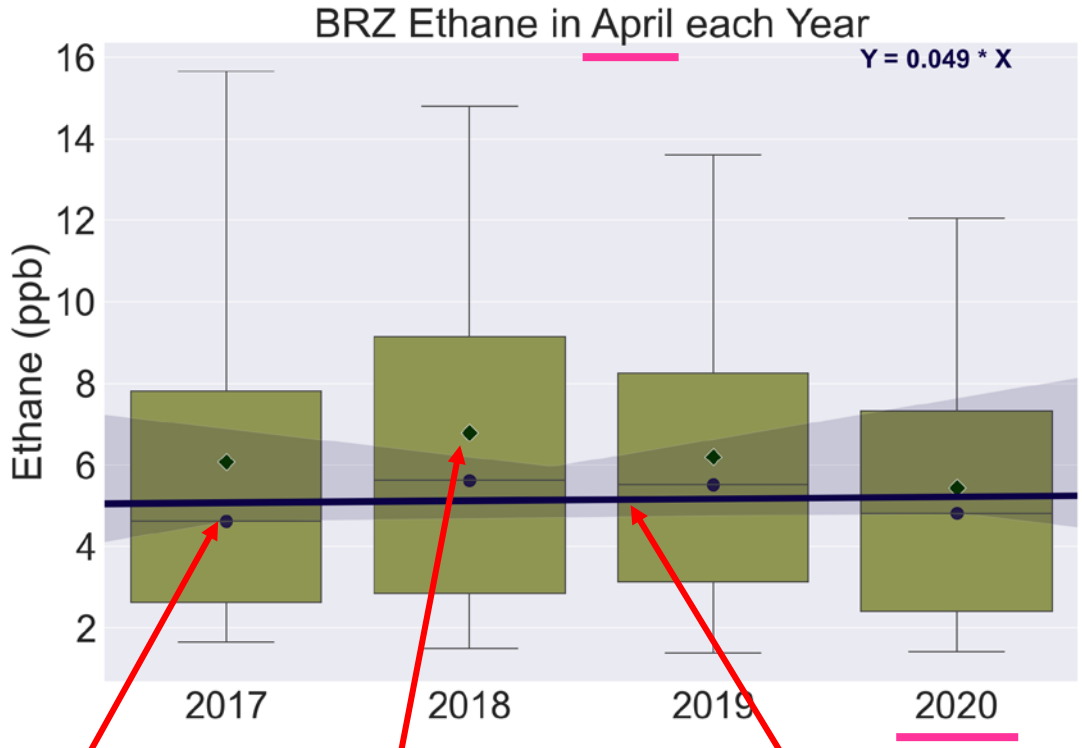
Emission Changes from COVID ?



Emission Changes from COVID ?



Emission Changes from COVID ?



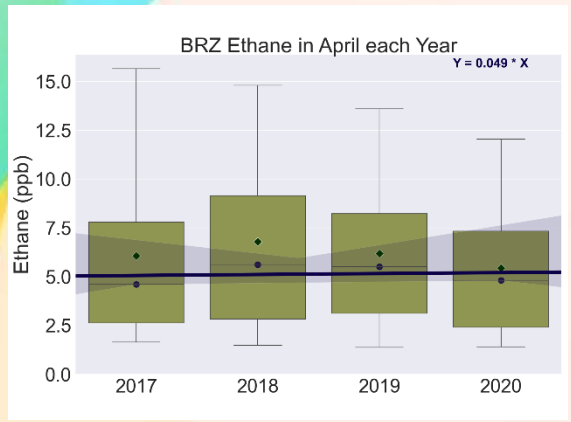
year	2017	2018	2019	2020
count	284	324	351	487
mean	6.07	6.79	6.19	5.44
median	4.61	5.62	5.5	4.81
std	4.84	5.24	4.27	3.79
min	0.86	1.24	0.83	1.03
max	33.8	30.4	35.2	25.3
25%	2.63	2.83	3.13	2.4
75%	7.8	9.14	8.24	7.32

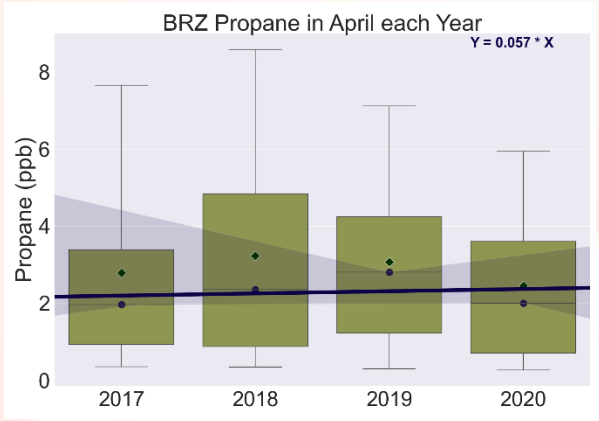
Median

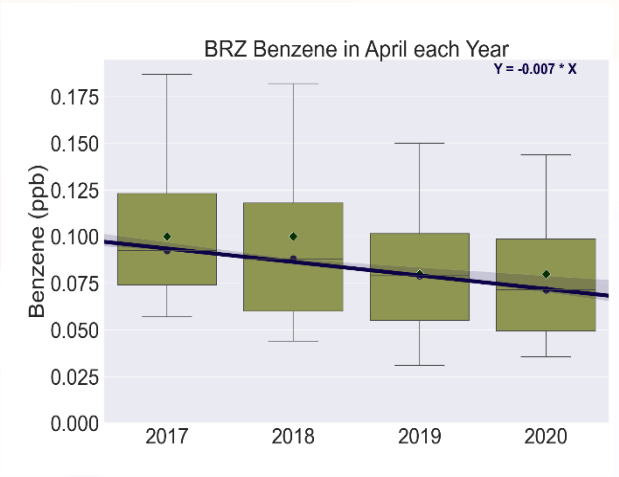
Mean

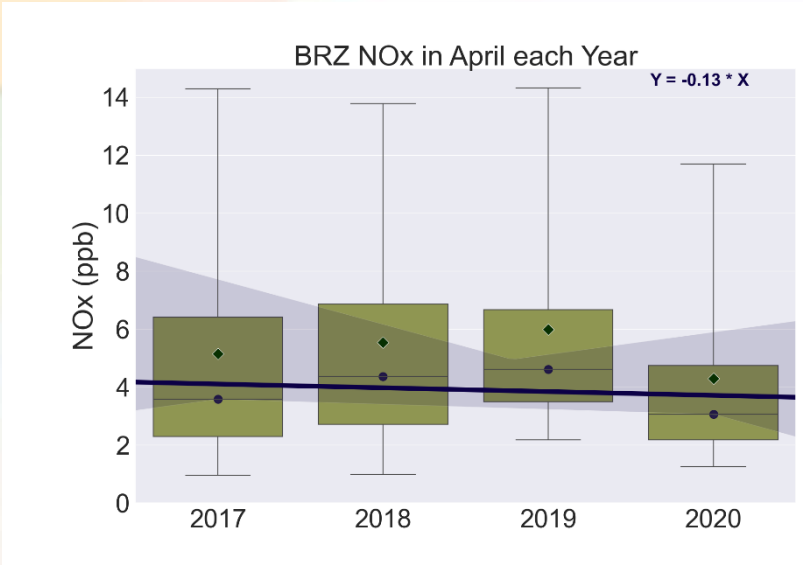
Linear regression trend line through medians

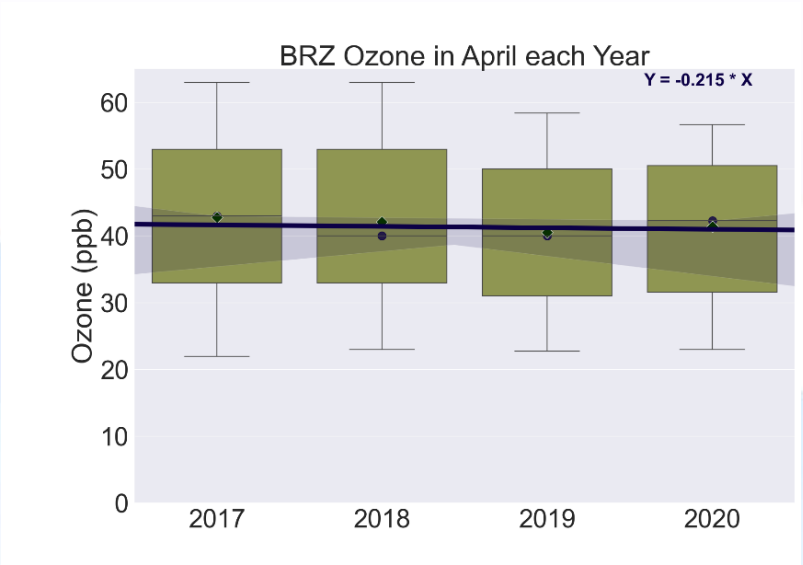
Emission Changes from COVID ?







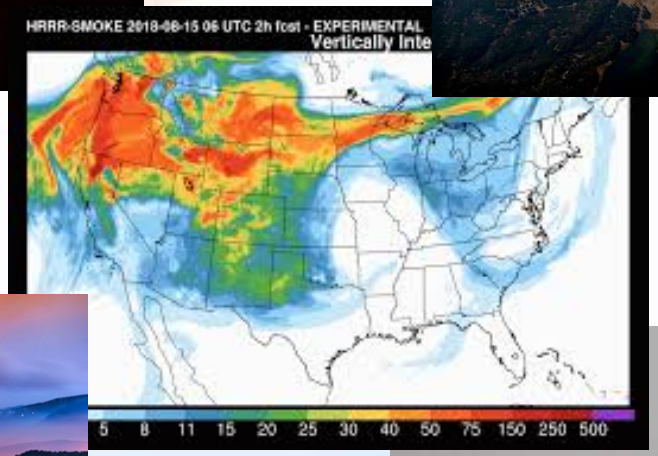




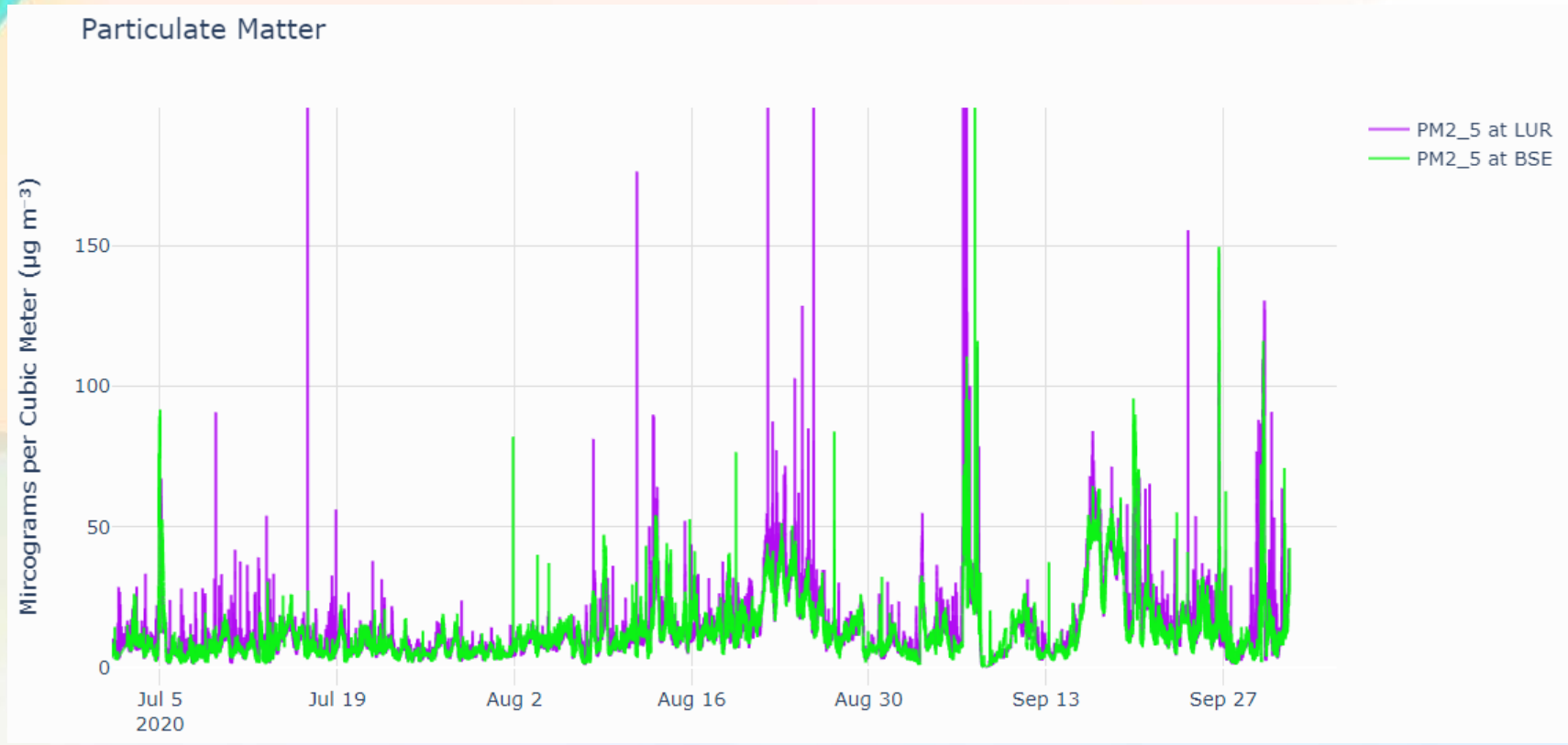
COVID Summary

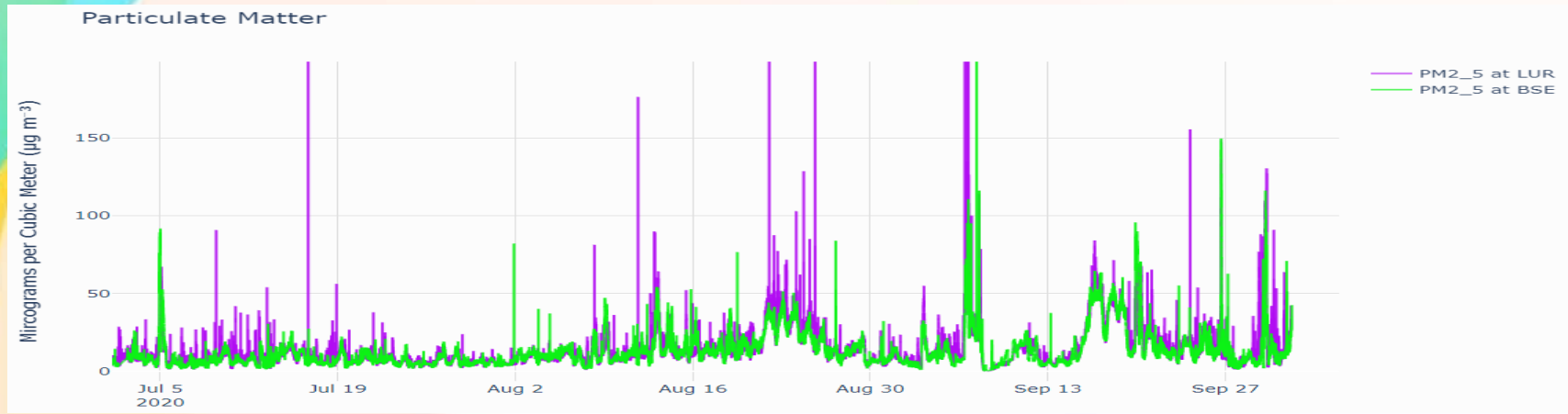
- Difficult to evaluate because of large year-to-year variability
- Further complicated by time of year -> strong seasonal changes during spring
- Can not decipher clear signal for most pollutants.
- Remarkably, had one of the earliest ozone exceedance days (April 17) this year.
- Emissions reduction most likely for nitrogen oxides.

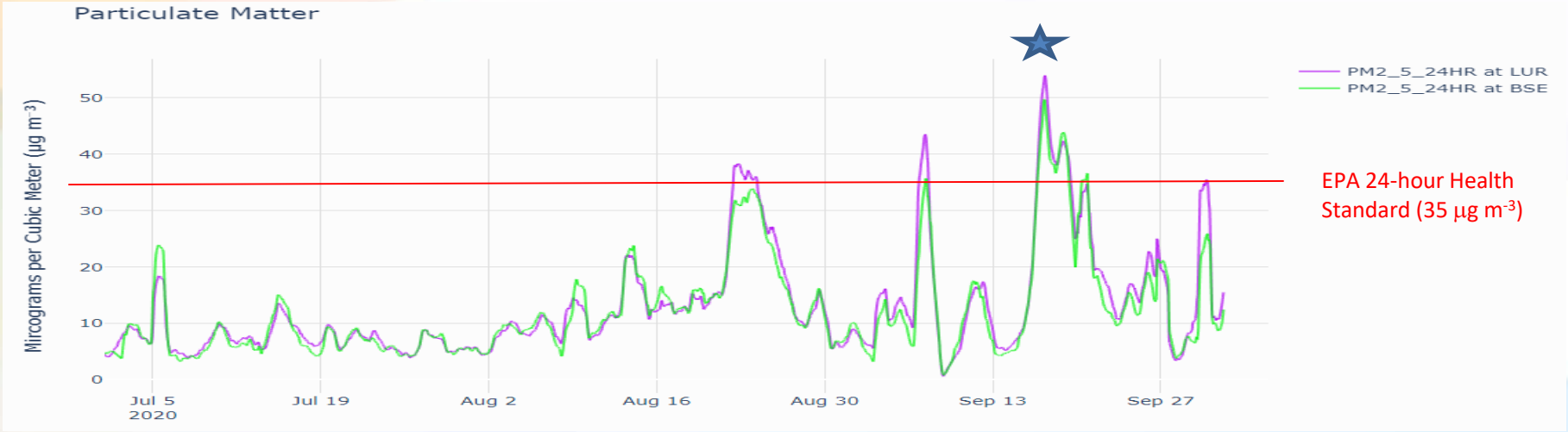
Wildfires


HRRR-SMOKE 2018-06-15 06 UTC 2h fcst - EXPERIMENTAL
Vertically Inte
5 8 11 15 20 25 30 40 50 75 150 250 500

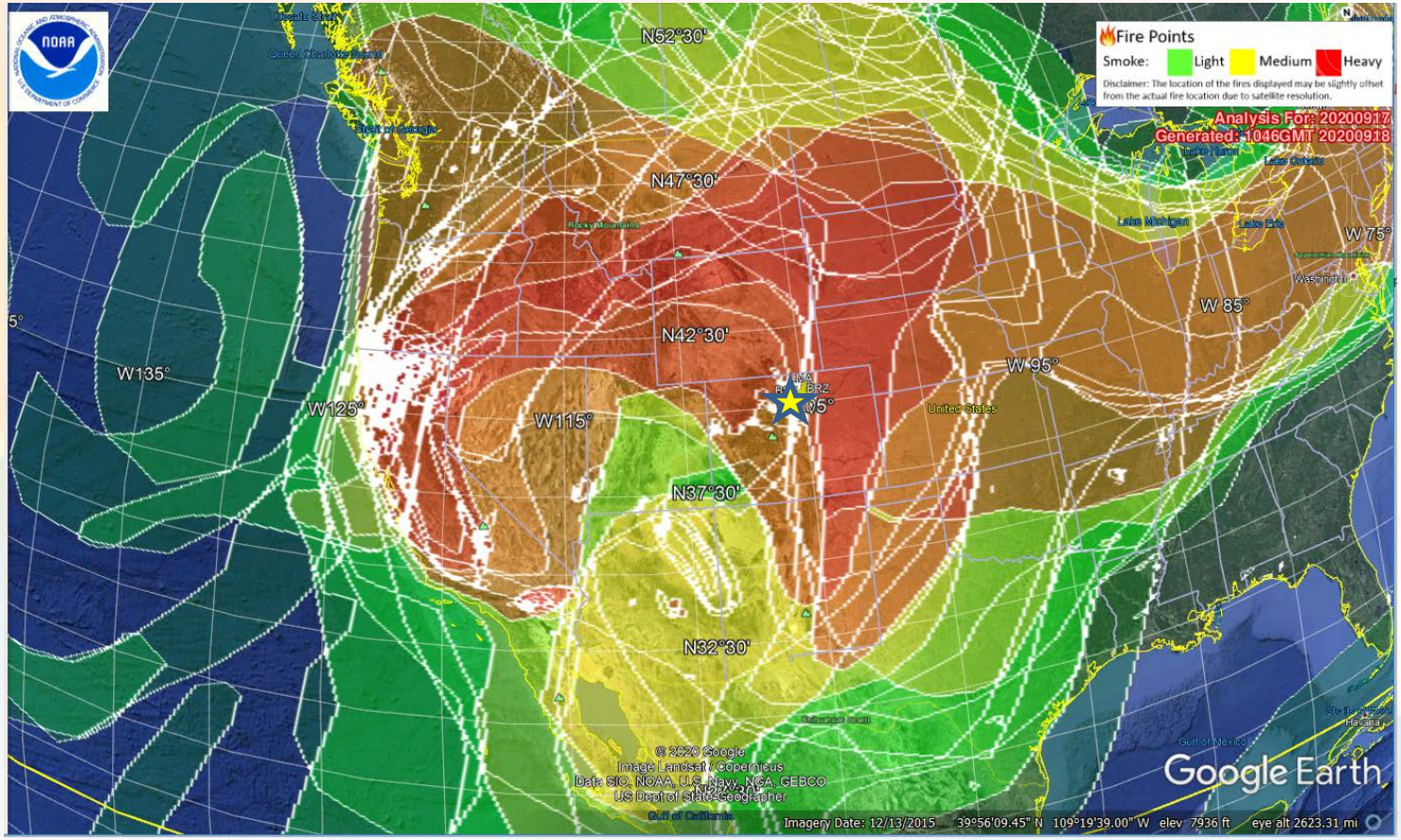
Particles in Fire Smoke Events



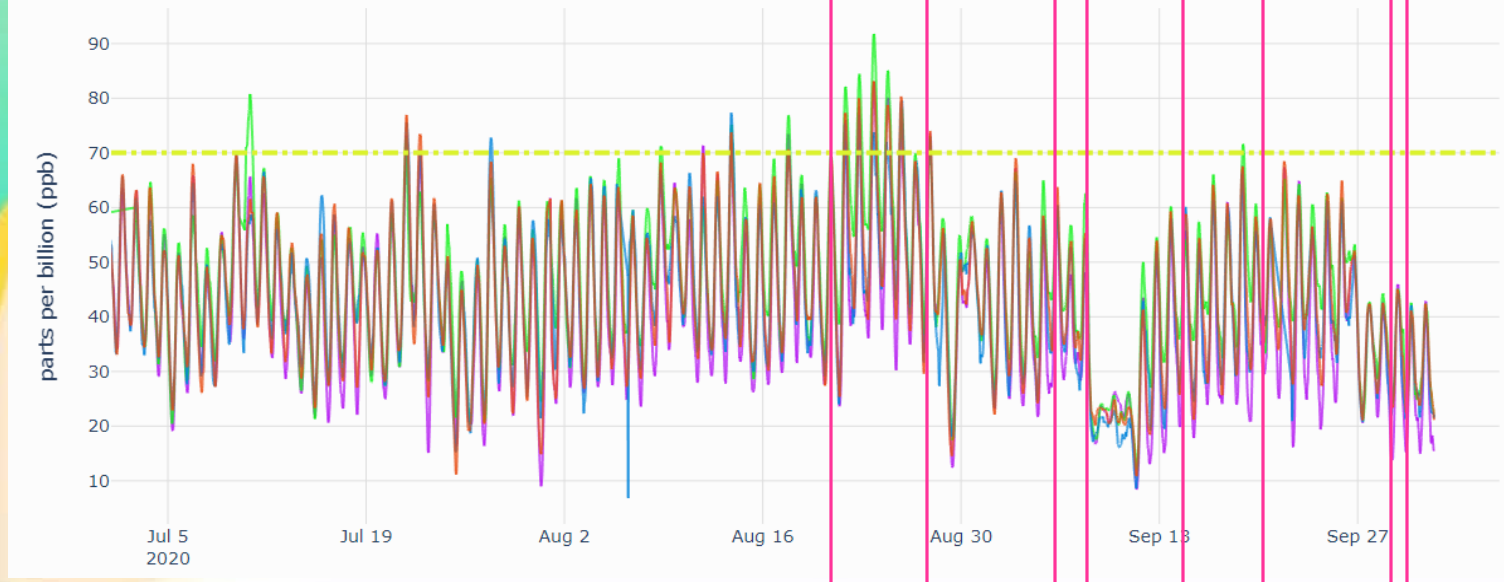

Particulate Matter
Mircograms per Cubic Meter (µg m-3)
150
100
50
0
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
PM2_5 at LUR
PM2_5 at BSE


Particulate Matter
Mircograms per Cubic Meter (µg m-3)
50
40
30
20
10
0
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
PM2_5_24HR at LUR
PM2_5_24HR at BSE
EPA 24-hour Health Standard (35 µg m-3)

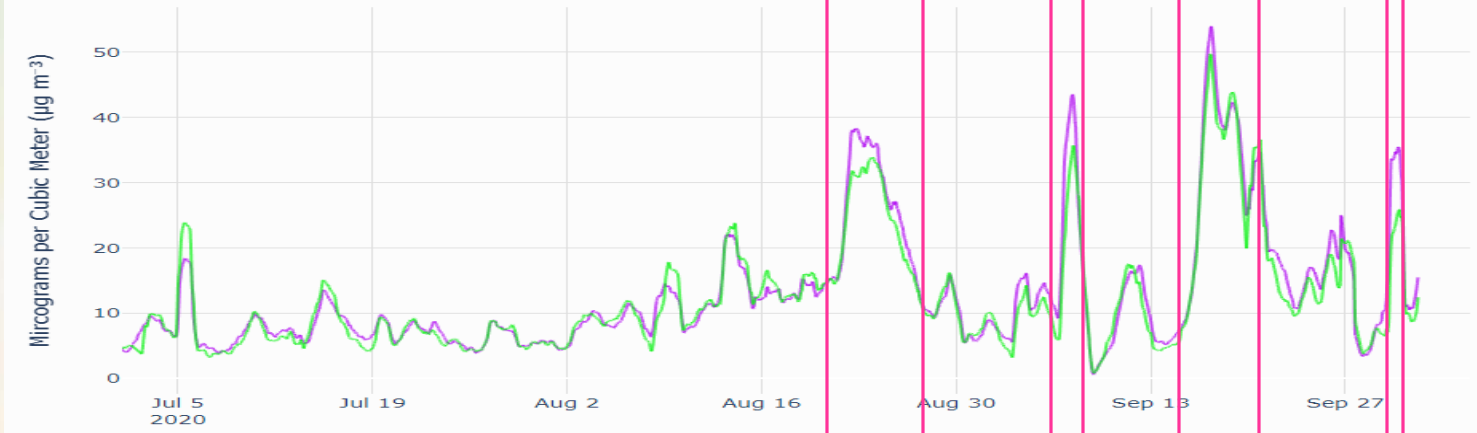
September 17 Smoke Event



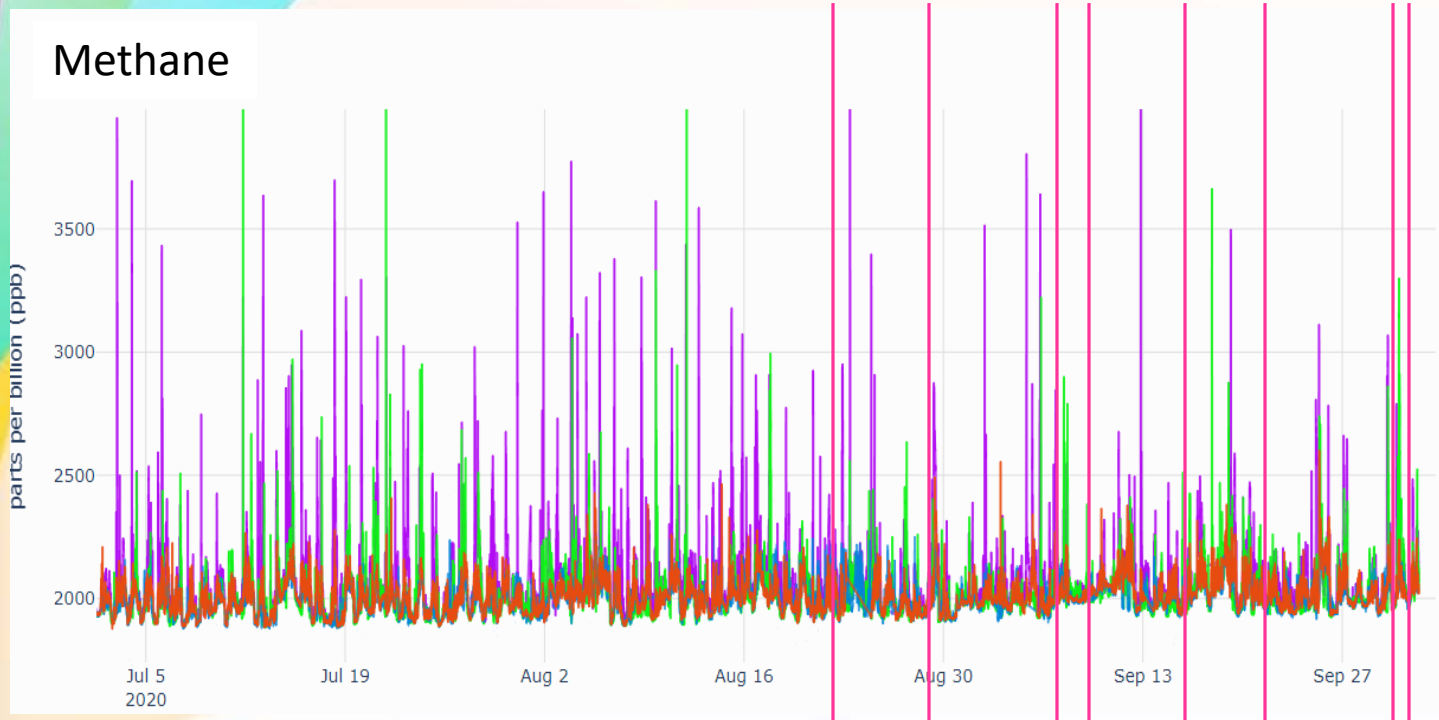
Ozone

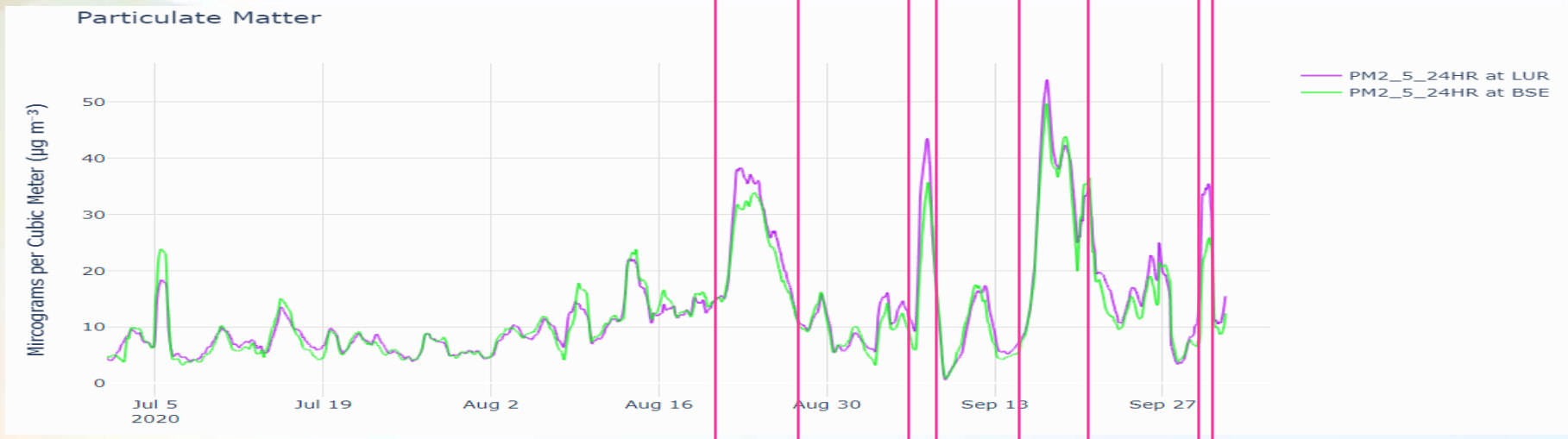


Particulate Matter

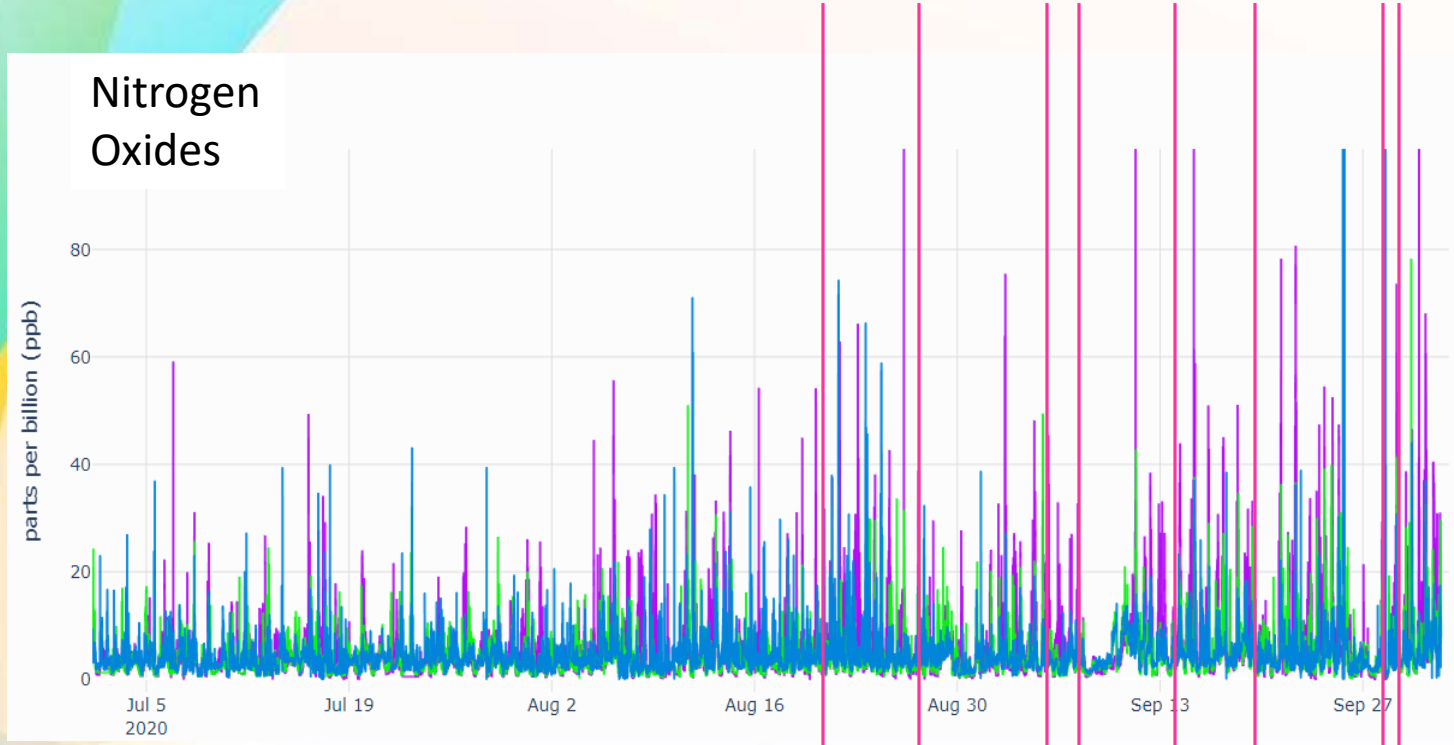


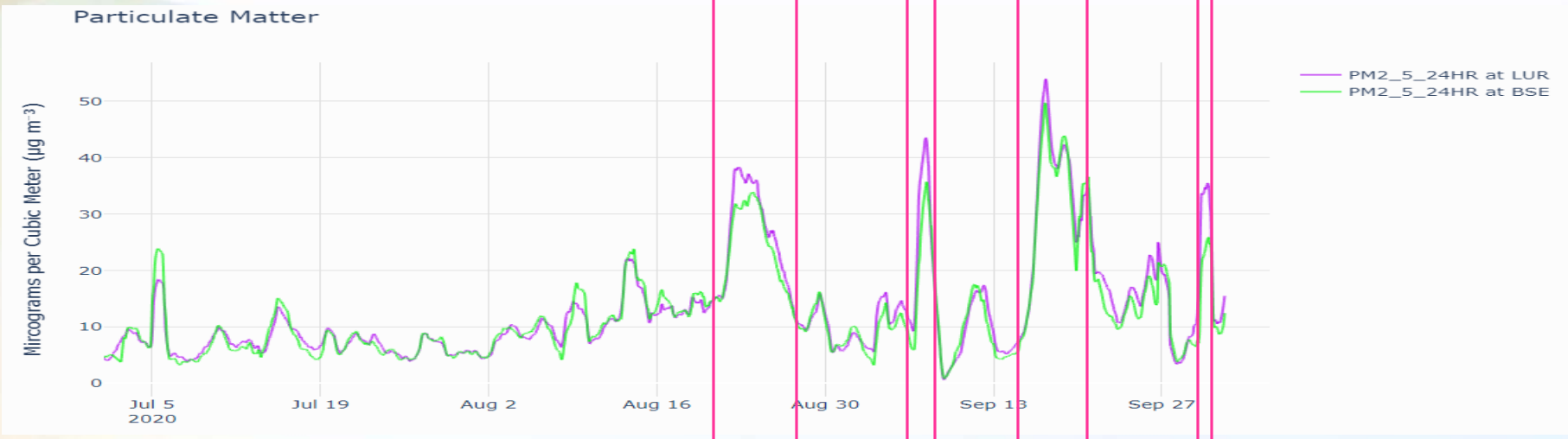
Methane


parts per billion (ppb)
3500
3000
2500
2000
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
CH4 at LUR
CH4 at BSE
CH4 at BRZ
CH4 at LMA

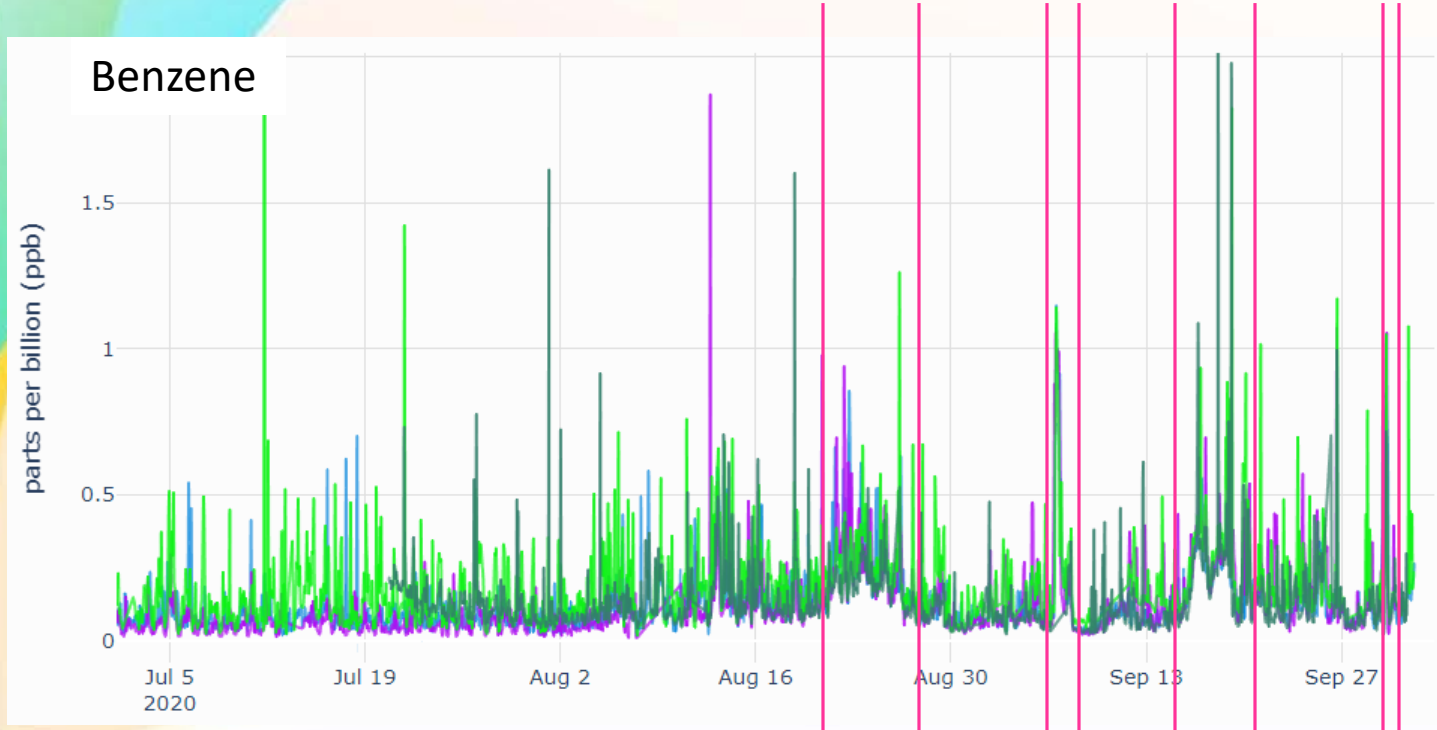

Particulate Matter
Micrograms per Cubic Meter (µg m-3)
50
40
30
20
10
0
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
PM2_5_24HR at LUR
PM2_5_24HR at BSE

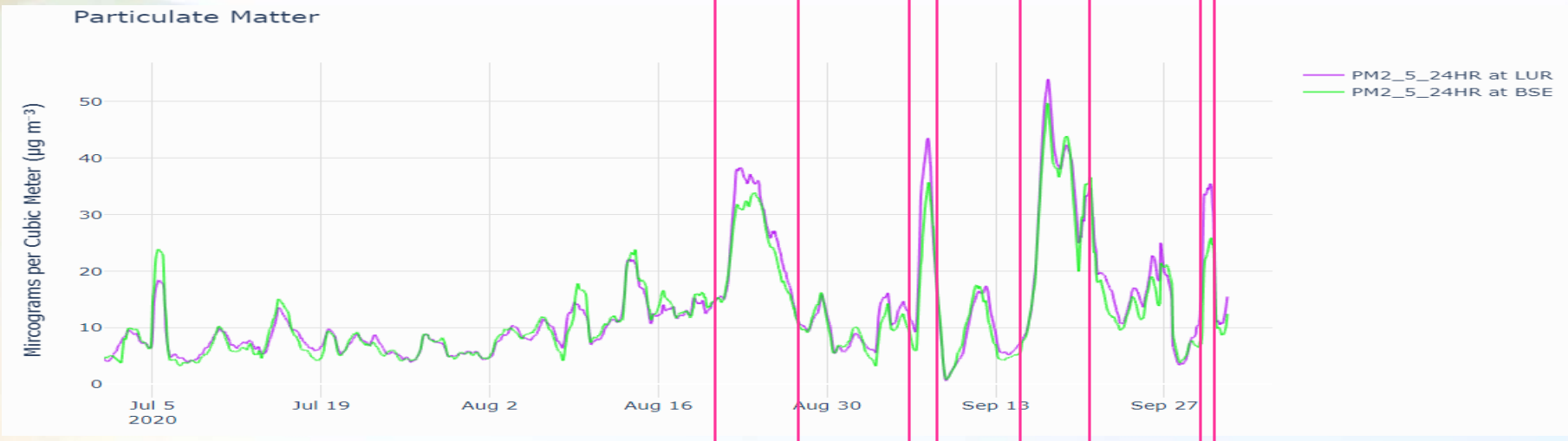
Nitrogen Oxides



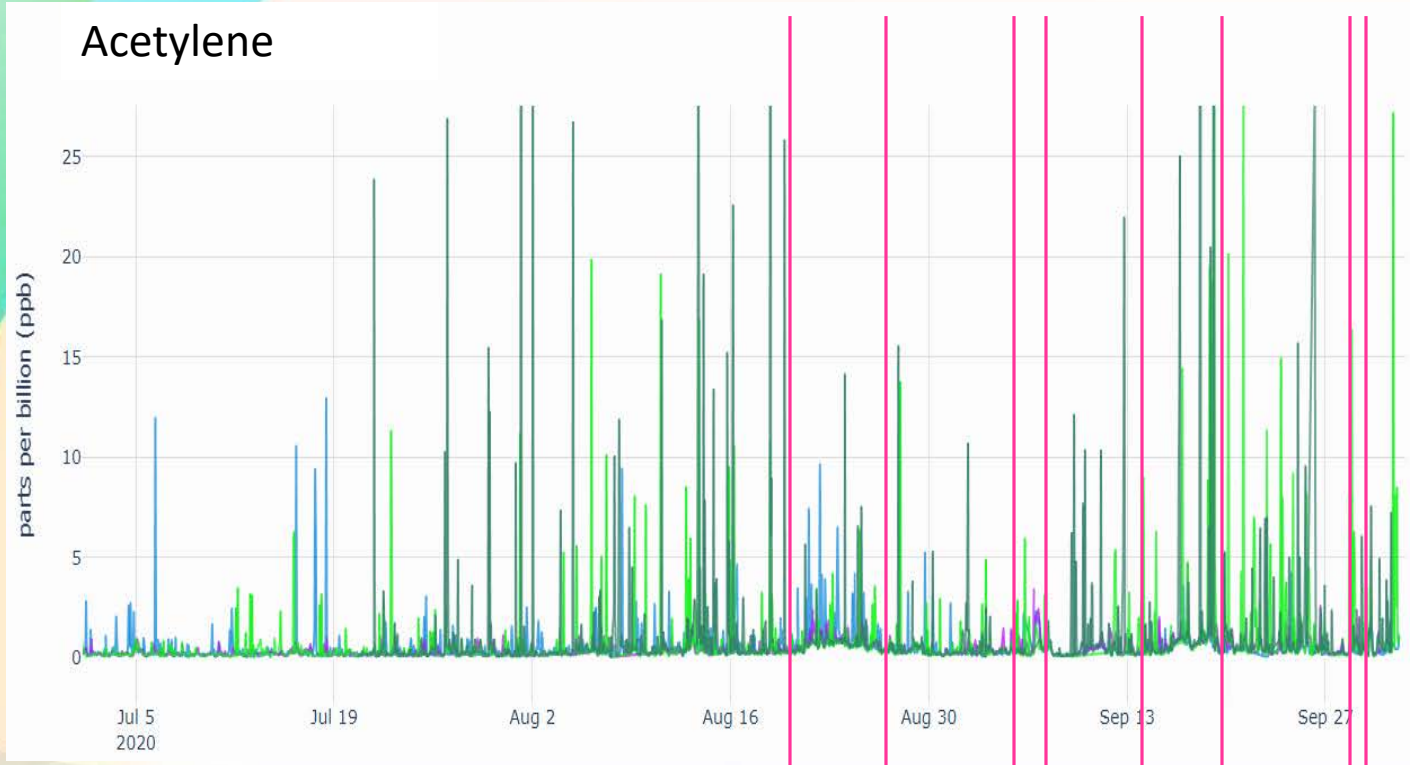


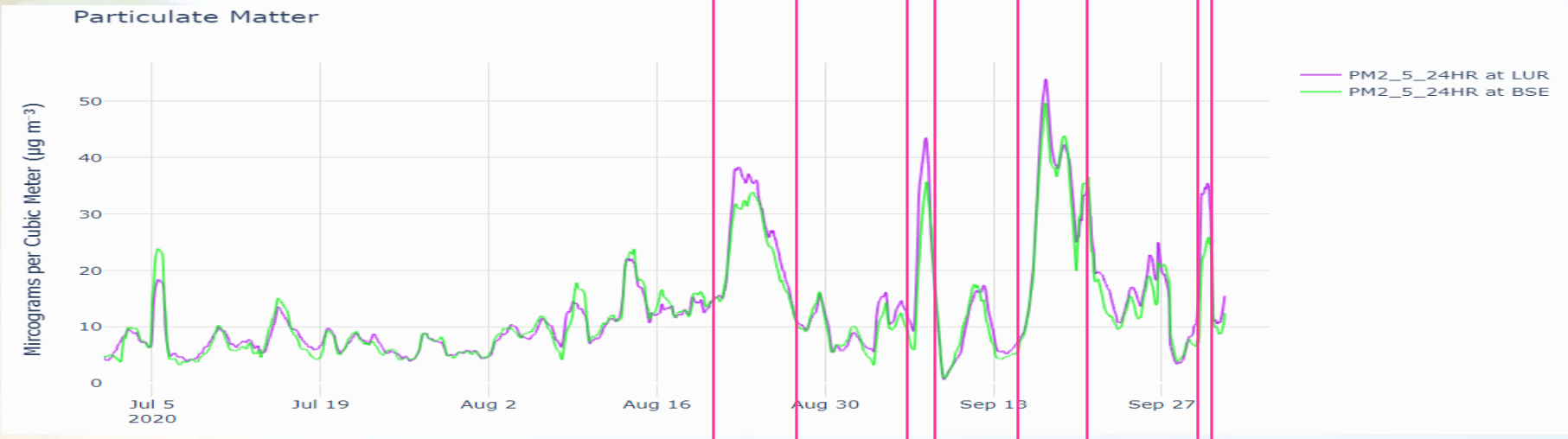
Benzene


parts per billion (ppb)
1.5
1
0.5
0
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
benzene at BRZ
benzene at LUR
benzene at BSE
benzene at BLV


Particulate Matter
Micrograms per Cubic Meter (µg m-3)
50
40
30
20
10
0
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
PM2_5_24HR at LUR
PM2_5_24HR at BSE

Acetylene


parts per billion (ppb)
0
5
10
15
20
25
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
acetylene at BRZ
acetylene at LUR
acetylene at BSE
acetylene at BLV

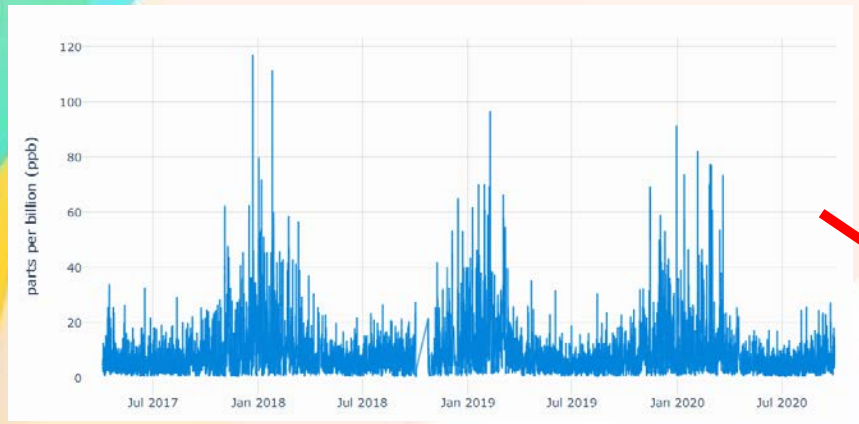

Particulate Matter
Micrograms per Cubic Meter (µg m-3)
0
10
20
30
40
50
Jul 5
2020
Jul 19
Aug 2
Aug 16
Aug 30
Sep 13
Sep 27
PM2_5_24HR at LUR
PM2_5_24HR at BSE

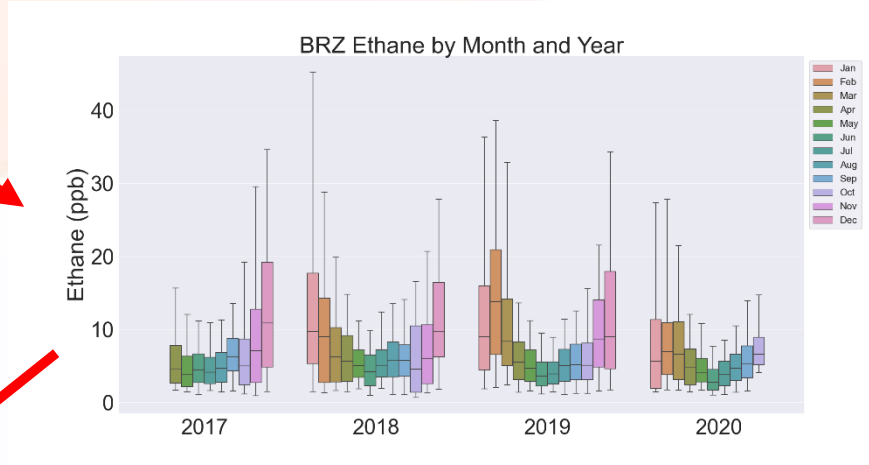
Fire Plumes Summary

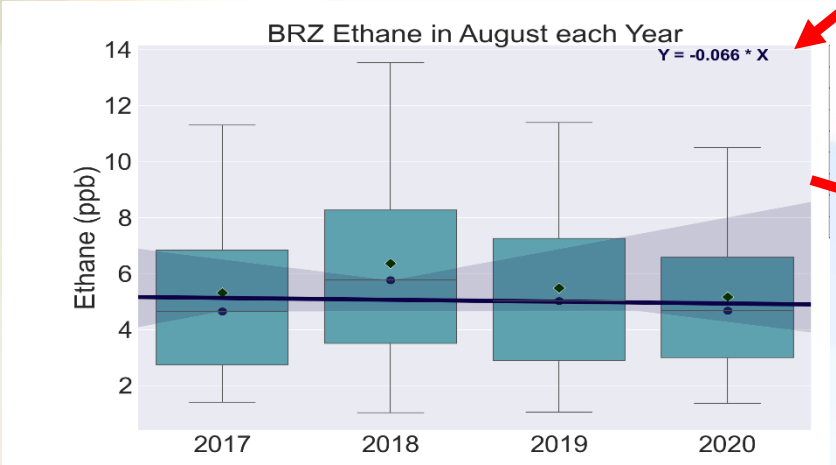
- Very clear enhancements in particulate matter PM10 and PM2.5. Up to 100 x background.
- Exceeded EPA health standard for PM2.5 on eight days.
- No clear association between fire plume occurrences and elevated ozone.
- Ozone precursors (VOCs, NOx) do not show clear enhancements in fire plumes above typical regional levels.
- Background of benzene and acetylene is enhanced, but still well below variability and pollution spikes seen from regional non-wildfire pollution sources.

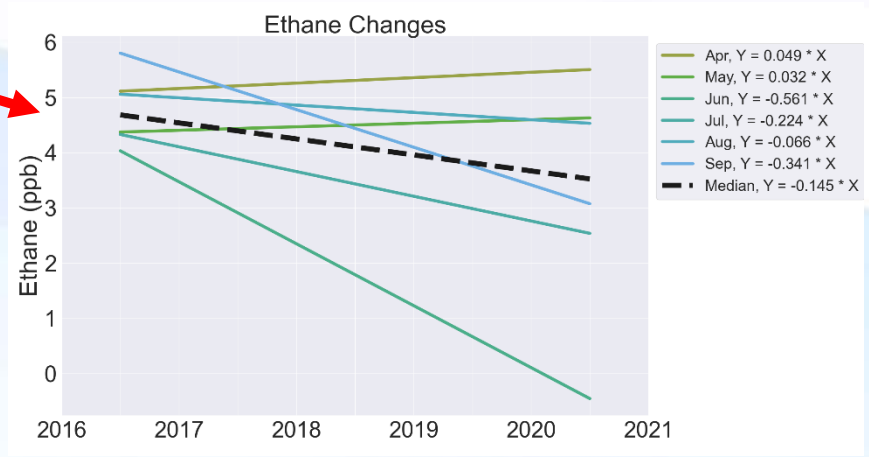
Changes in Concentrations ("Trends")

Ethane at BRZ

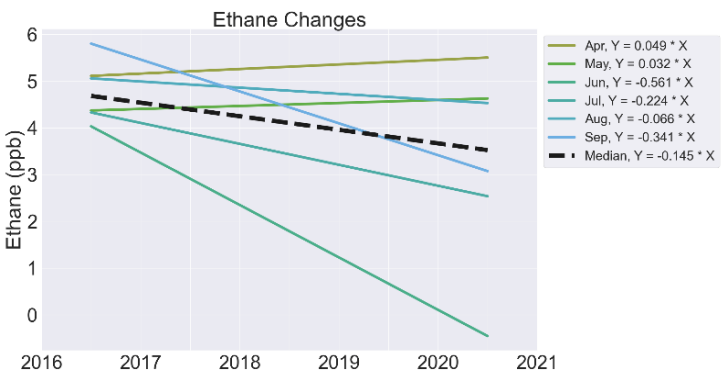


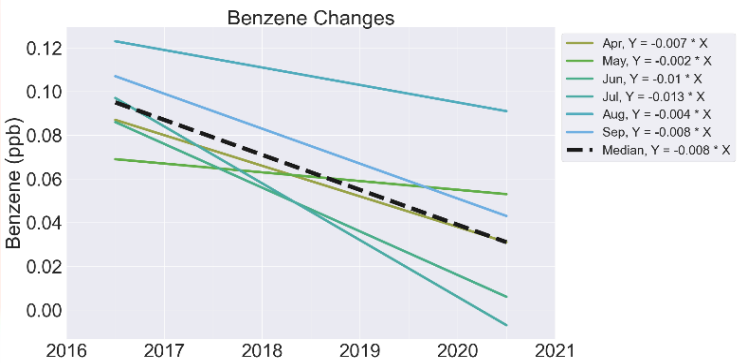


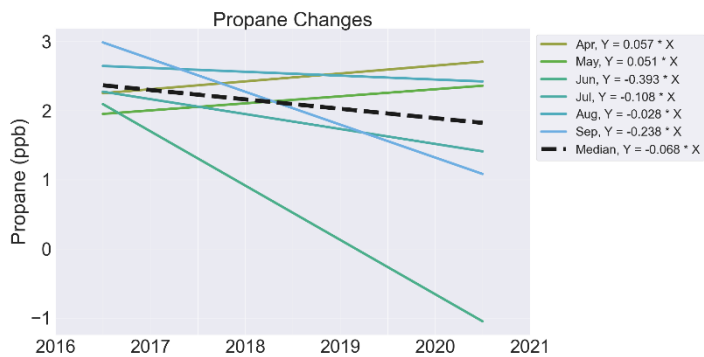


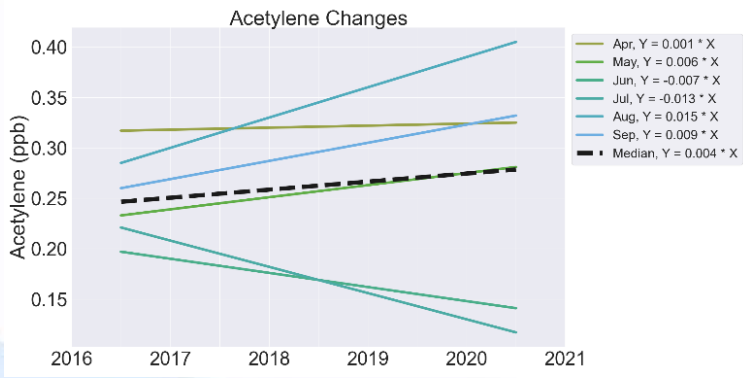


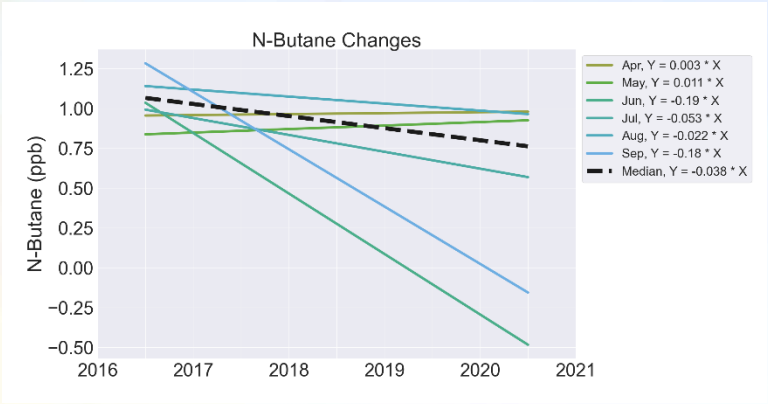
Changes in Concentrations ("Trends")

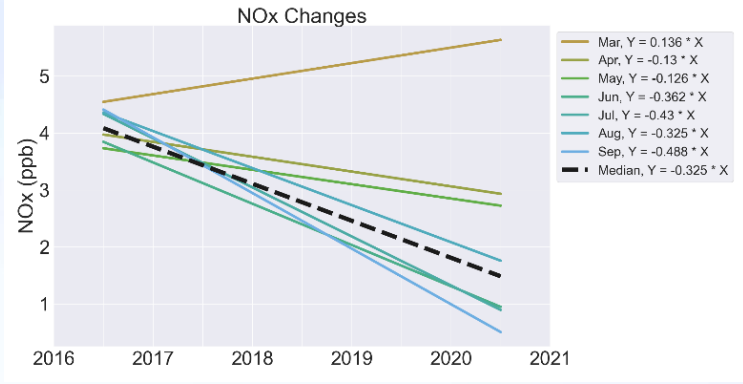




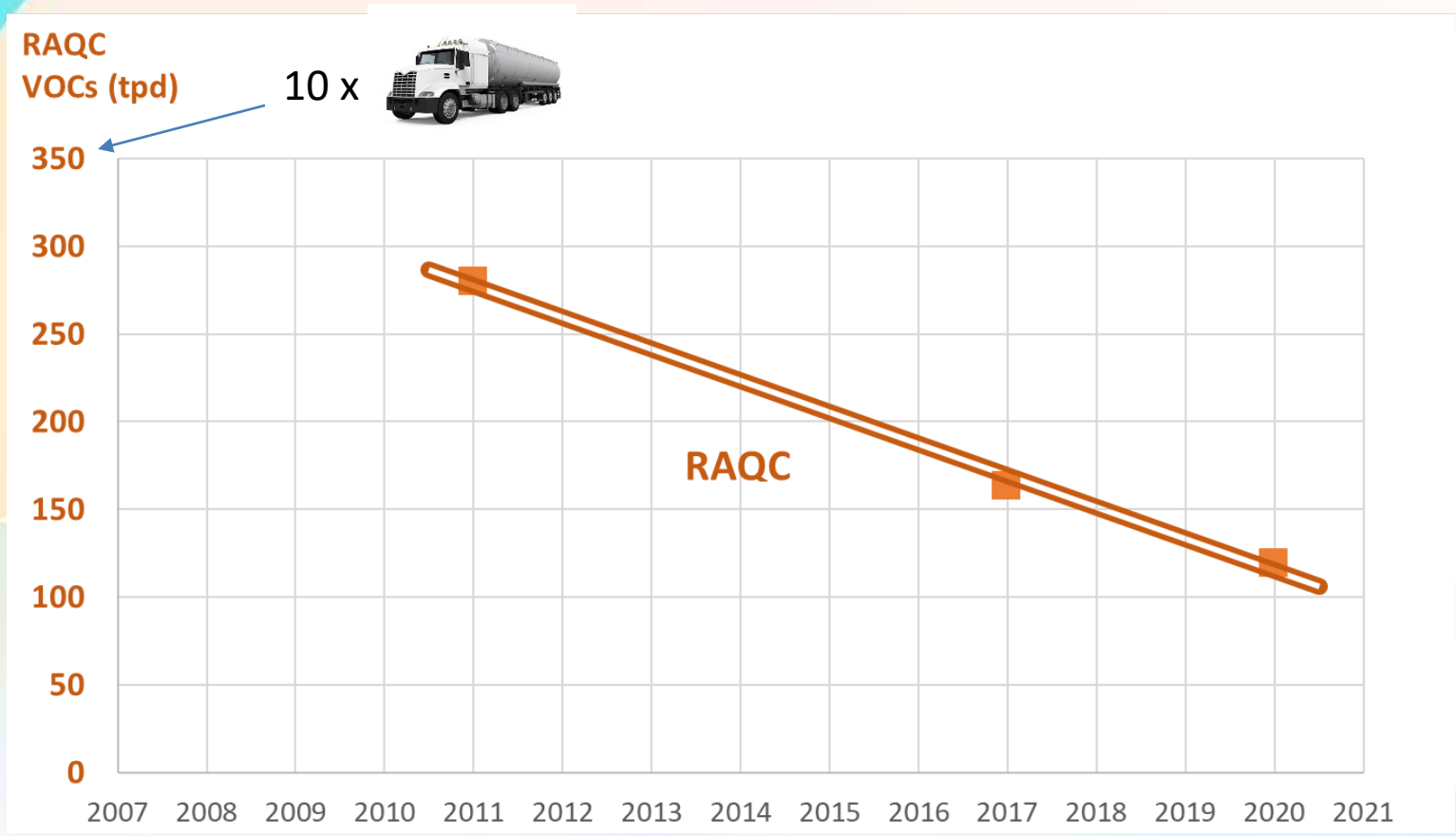






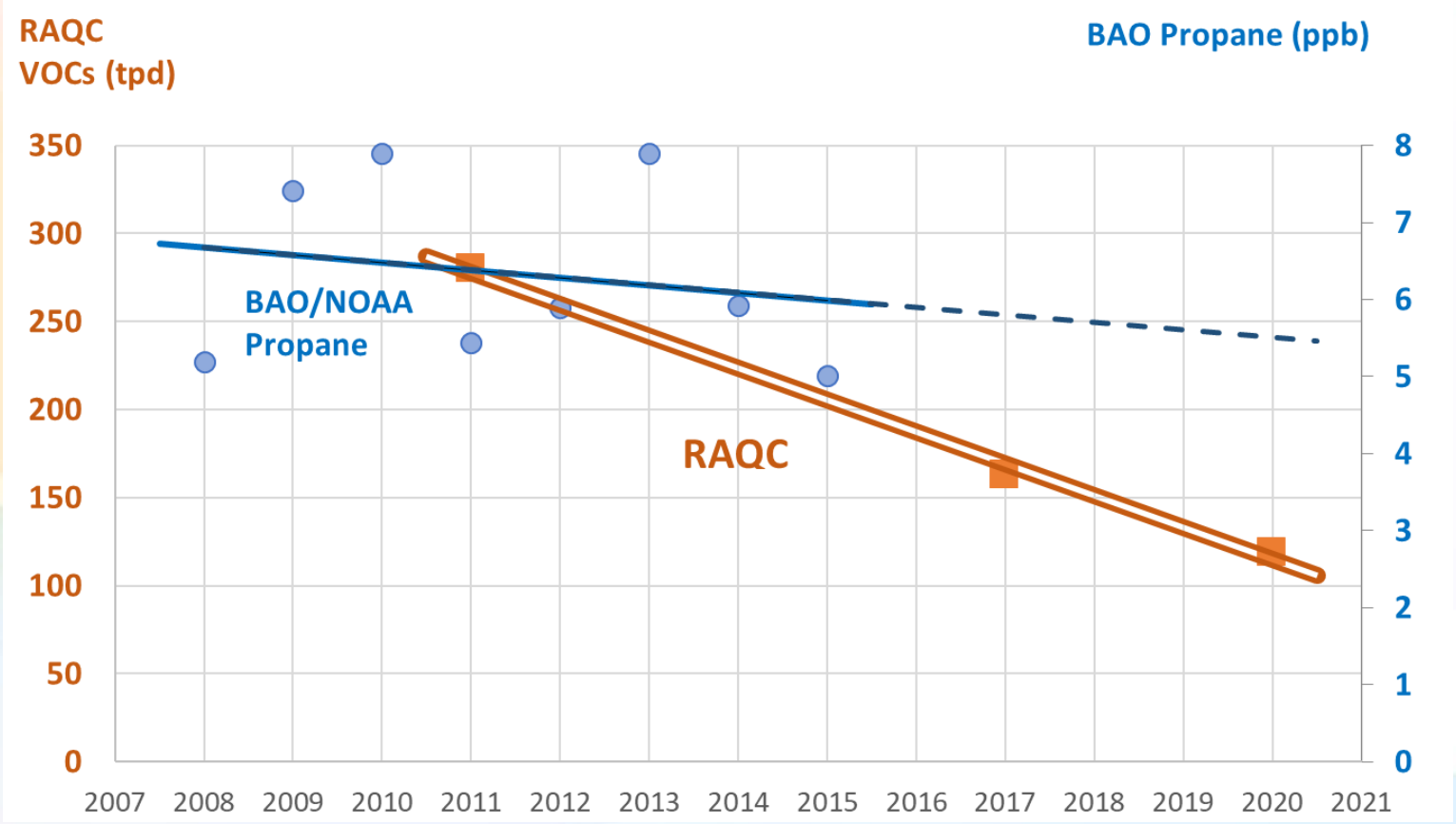


Comparison of Inventory Oil and Gas VOCs Emission Changes with Observational Data



RAQC/CDPHE/AQCC: Regional Air Quality Council, State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard, 2020

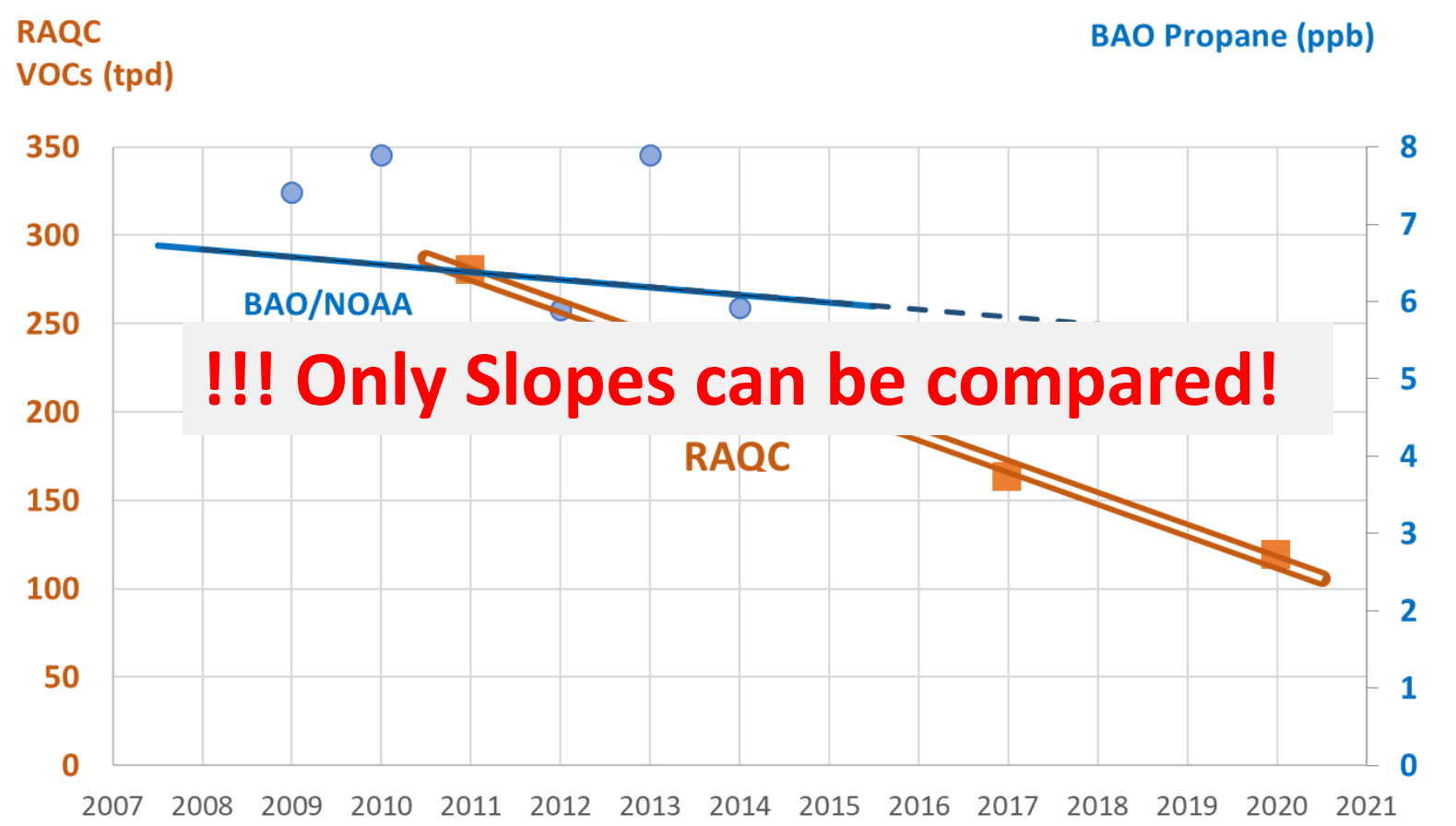
Comparison of Inventory Oil and Gas Emission Changes with Observational Data



RAQC/CDPHE/AQCC: Regional Air Quality Council, State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard, 2020

BAO/NOAA: Oltmans et al., Atmospheric Oil and Natural Gas Hydrocarbons in SW Weld County, CO, During 2008-2016 Show Little Change Despite Stricter Industry Emissions Regulations, submitted for publication. NE sector samples, year-round medians minus propane background (5^{th} percentile value), scaled to intercept 2011 RAQC value.

Comparison of Inventory Oil and Gas Emission Changes with Observational Data



RAQC/CDPHE/AQCC: Regional Air Quality Council, State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard, 2020

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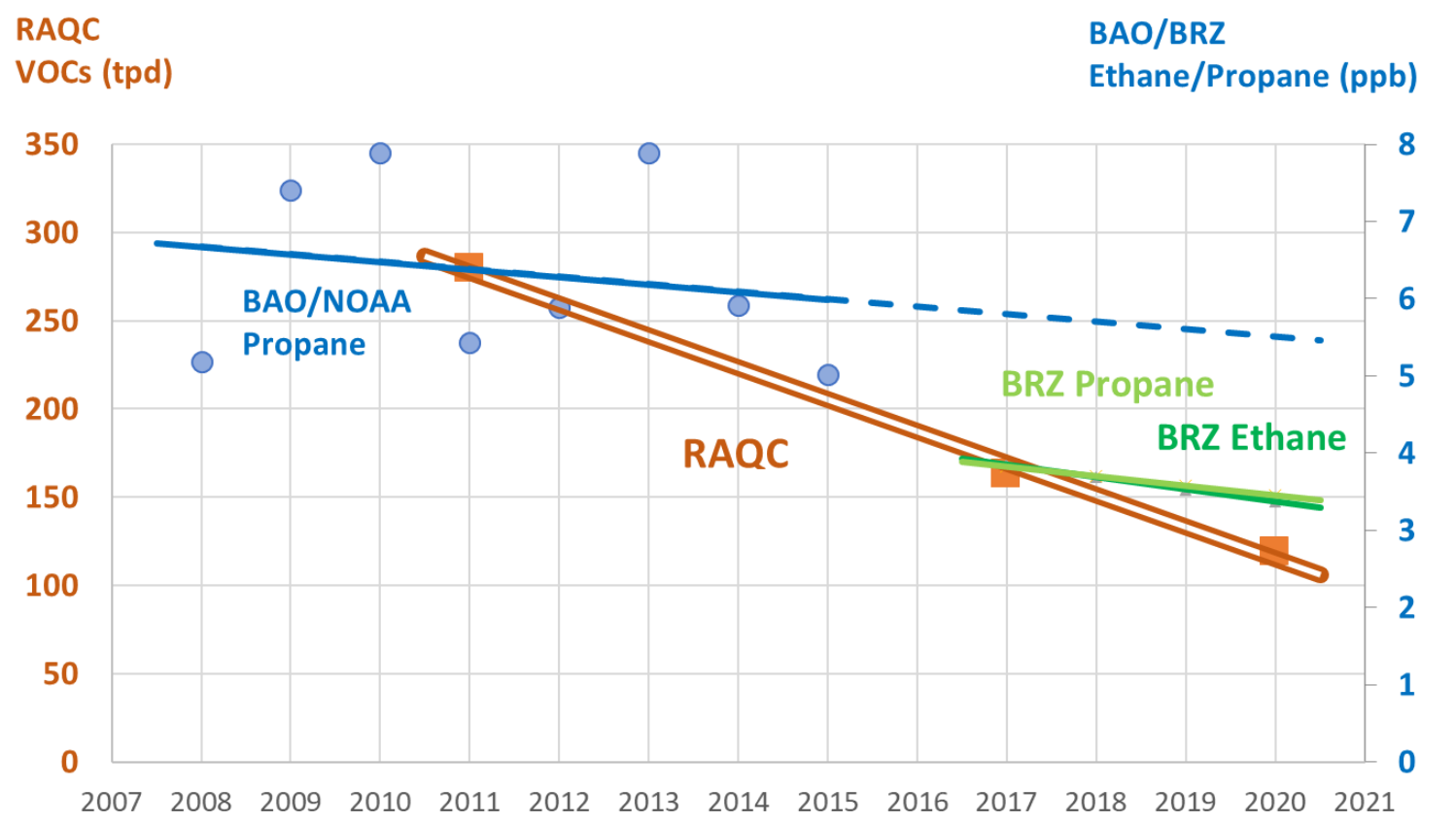
Comparison of Inventory Oil and Gas Emission Changes with Observational Data

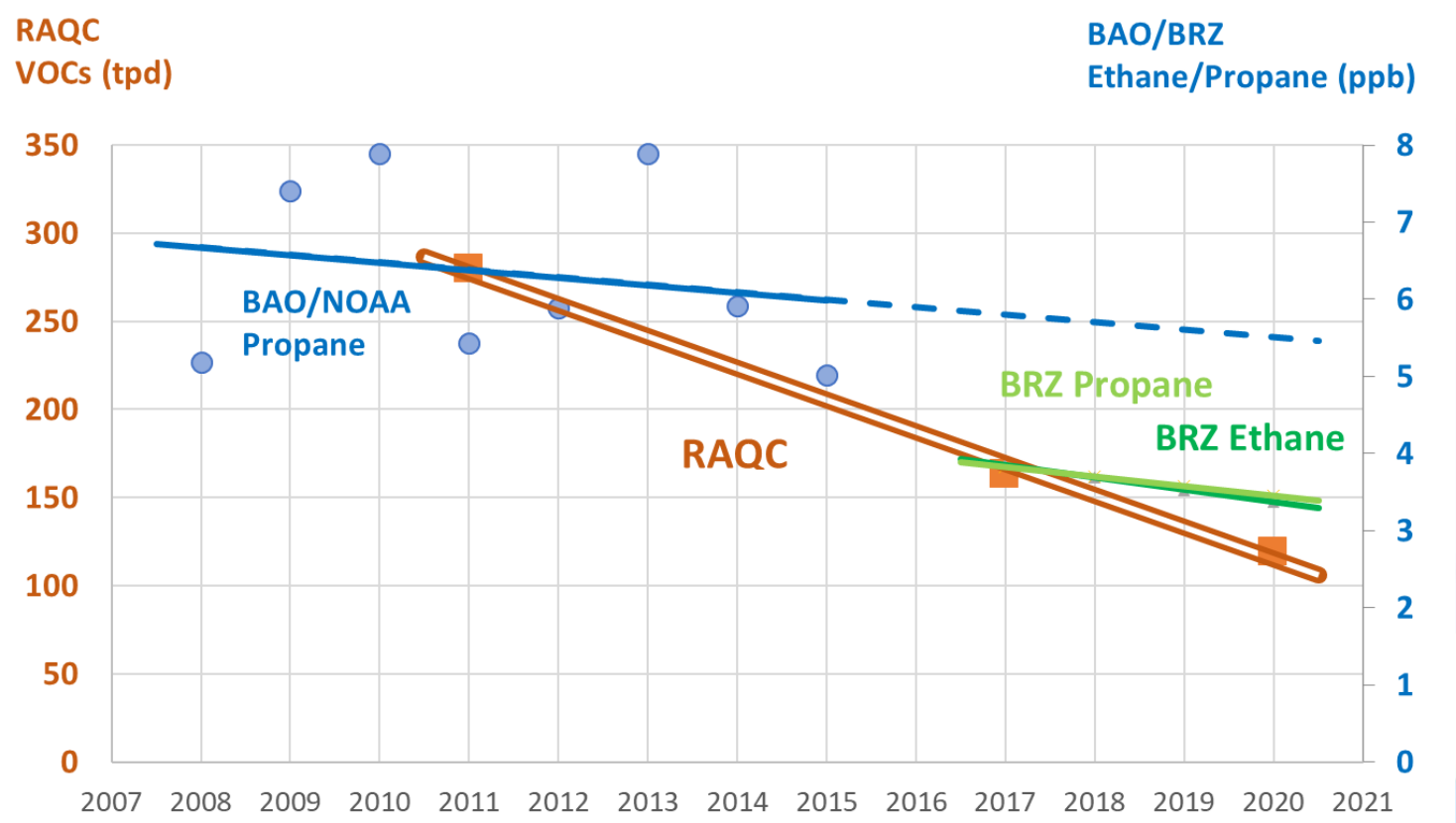


RAQC/CDPHE/AQCC: Regional Air Quality Council, State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard, 2020

BAO/NOAA: Oltmans et al., Atmospheric Oil and Natural Gas Hydrocarbons in SW Weld County, CO, During 2008-2016 Show Little Change Despite Stricter Industry Emissions Regulations, submitted for publication. NE sector samples, year-round medians minus propane background (5th percentile value).

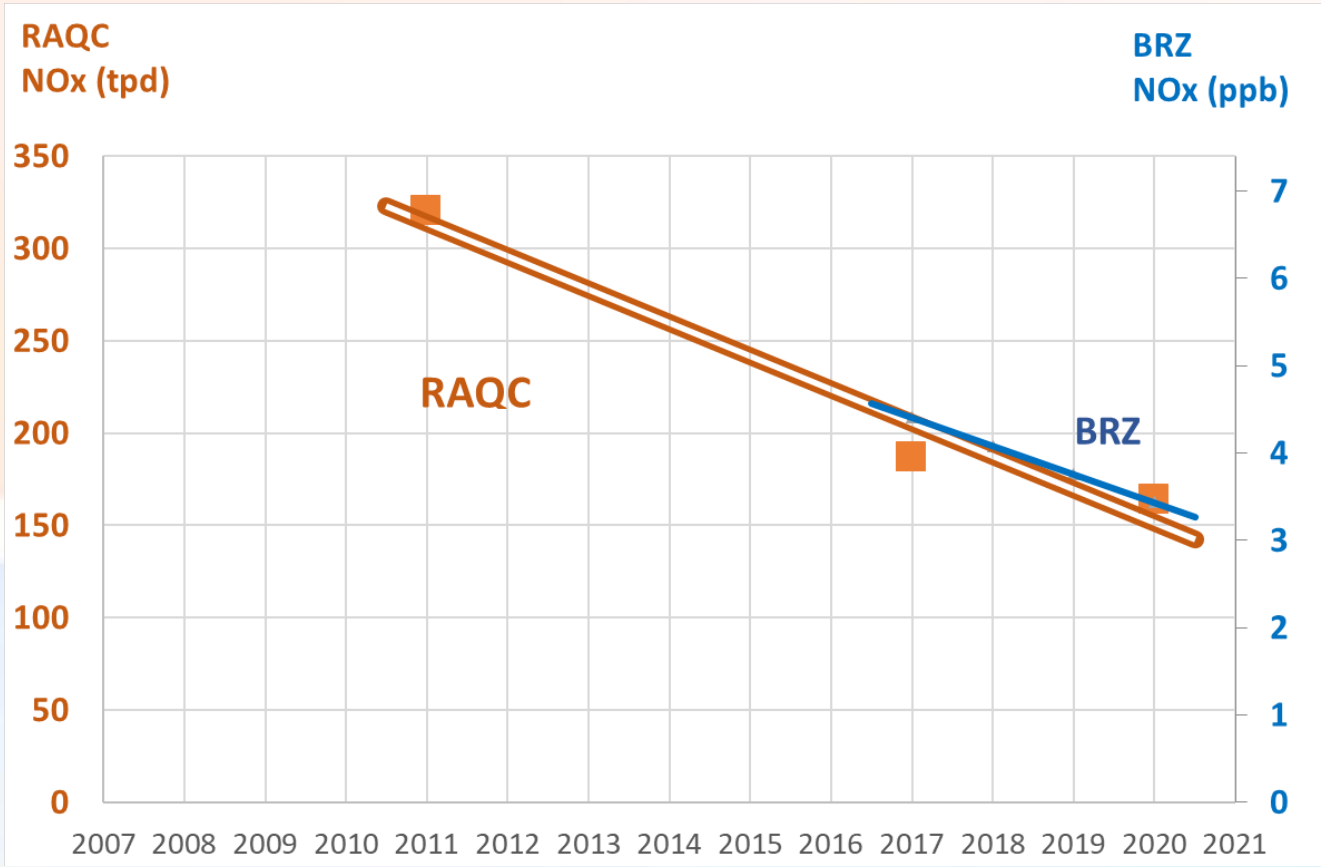
BRZ: All yearly data, minus background (overall 5th percentile value)

Comparison of Inventory Oil and Gas Emission Changes with Observational Data



Inventory projections of emissions reductions have been 5 x higher than what the data show.

Comparison Inventory NOx All Sources Changes versus BRZ observations

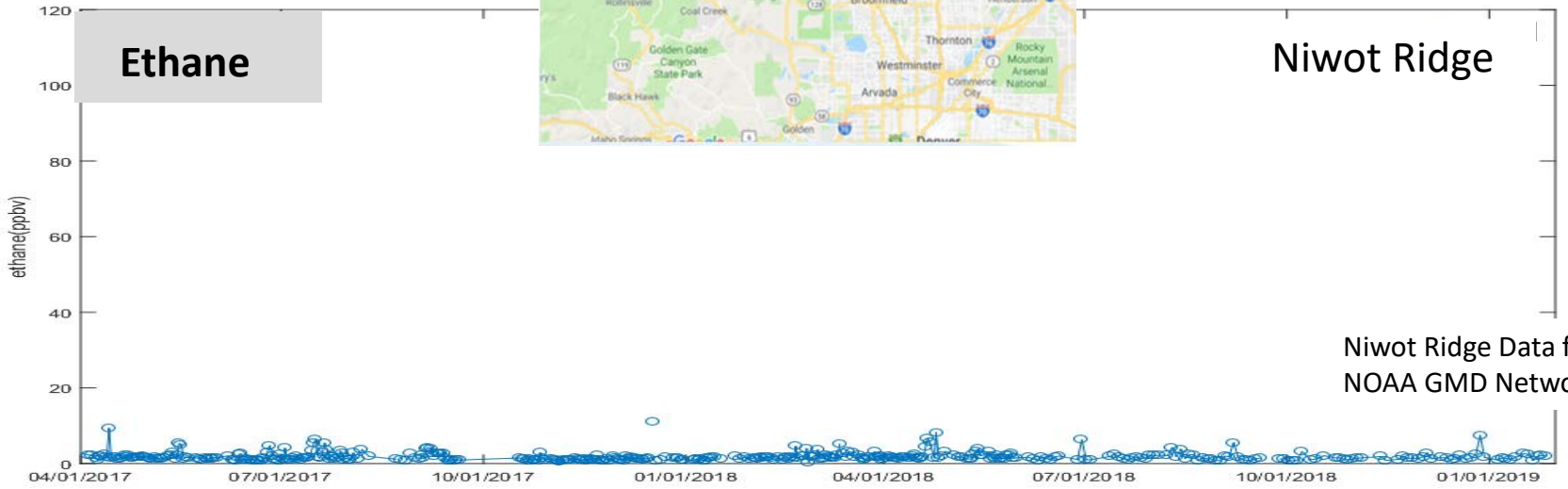


RAQC/CDPHE/AQCC: Regional Air Quality Council, State Implementation Plan for the 2008 8-Hour Ozone National Ambient Air Quality Standard, 2020

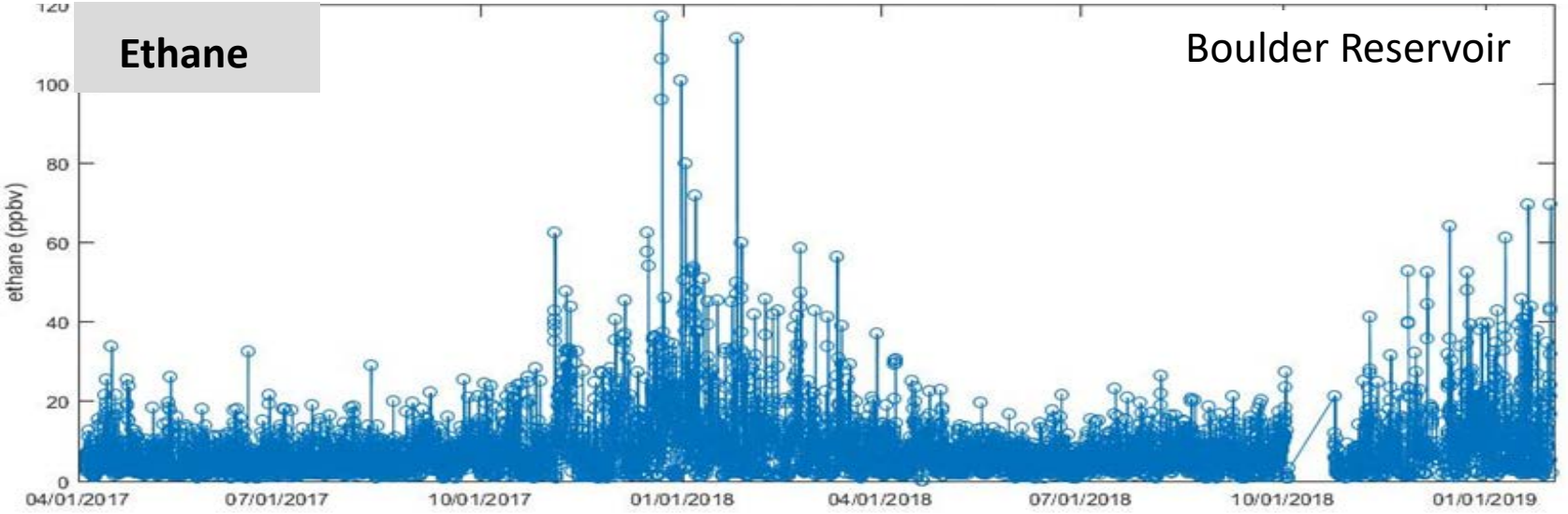
BRZ: All data, median of seven monthly regression results.

Where Do the VOCs originate?

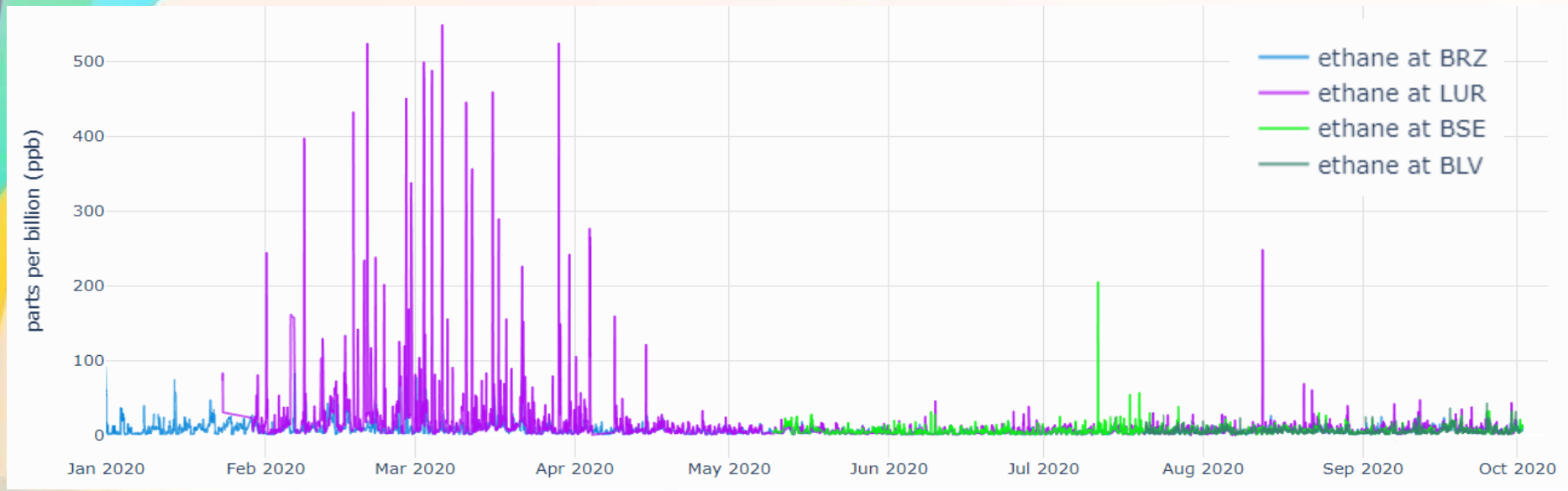
Ethane at BRZ <-> Niwot Ridge

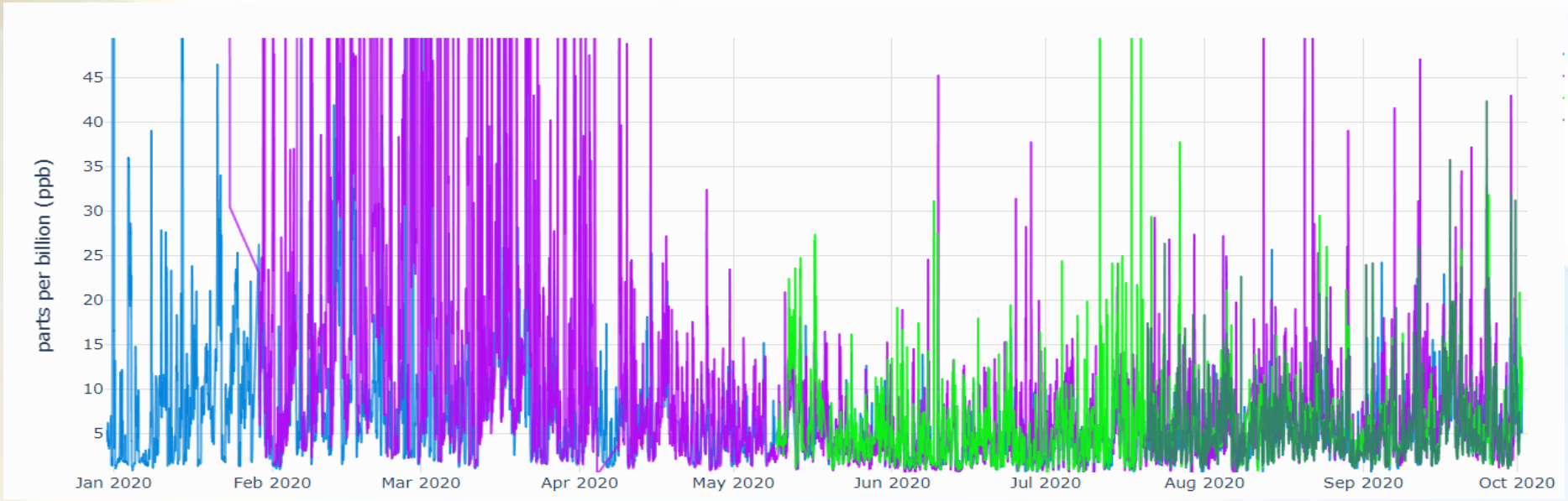


Niwot Ridge Data from NOAA GMD Network

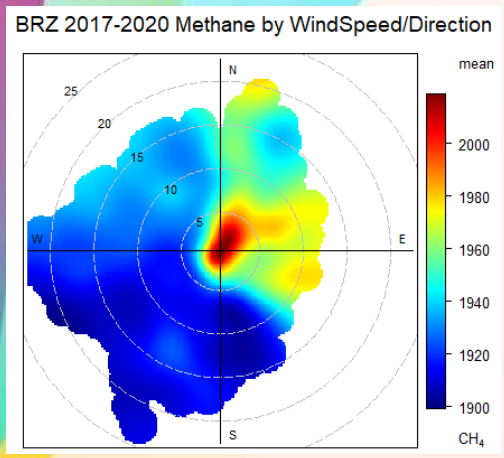


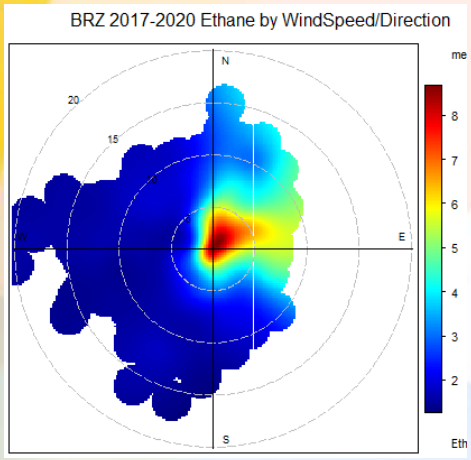
Ethane at BRZ compared to Longmont and Broomfield sites

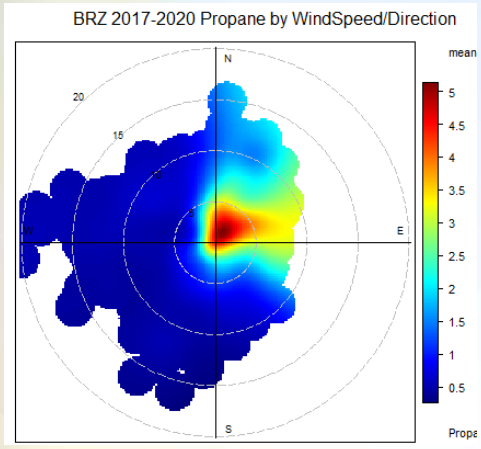




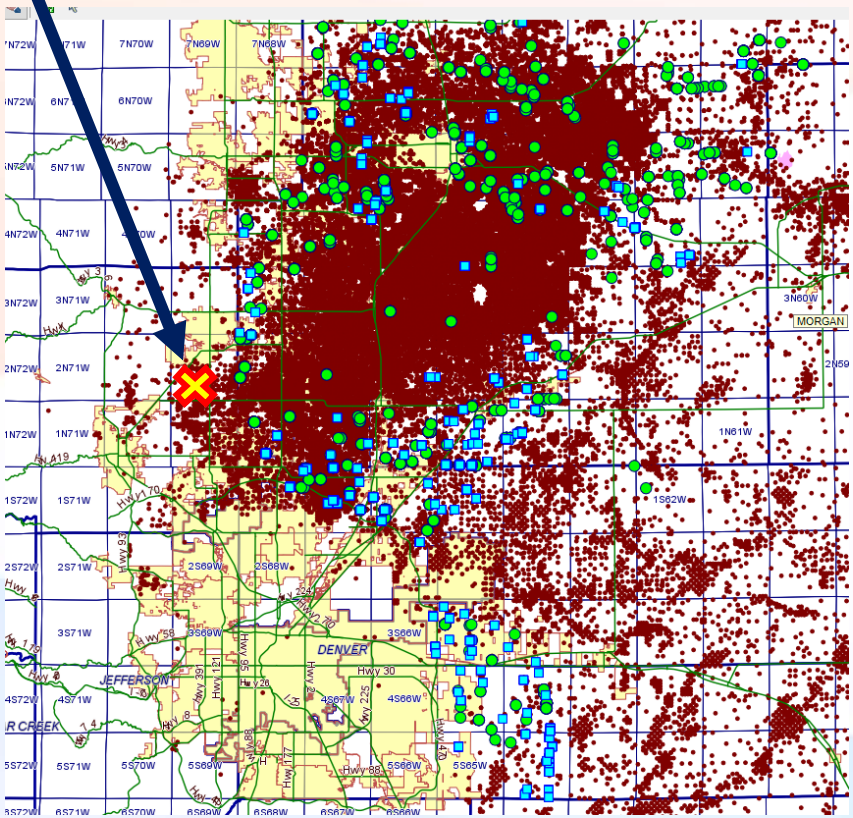
Dependency of Selected Gases on Winds

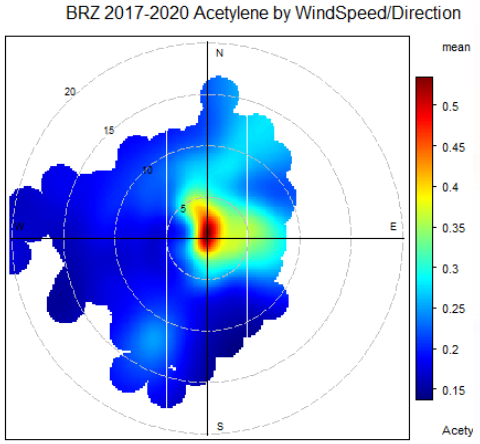


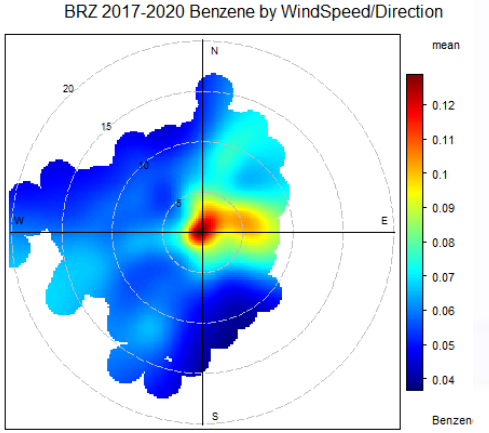


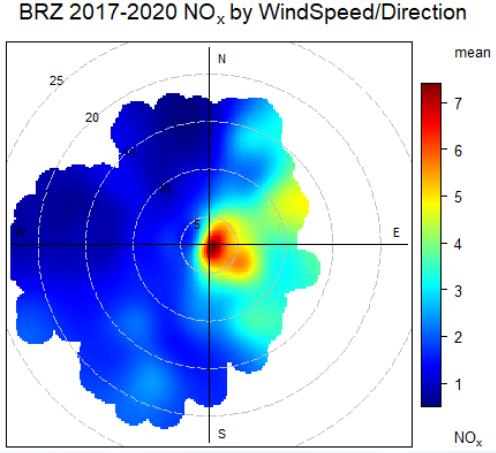


BRZ









Presentation Summary

- 3.5 years of air quality monitoring at BRZ.
- Site has become a flagship of a now 5-station network.
- Continuous data, >95% data coverage.
- Results are reported in near real-time to website portal.
- Several new partner and merged data websites added.
- Data have become a resource to evaluate horizontal concentration gradients within the county and beyond, pollution events and emission changes, trends in pollutants, inventories, ……