# NASA Student Airborne Research Program (SARP) Whole Air Sampling across the United States during the COVID-19 Pandemic

Melissa Yang[1], Donald Blake[2], Alex Jarnot[2], Simone Meinardi[2], Gloria Weitz[3], Brent Love[3], Barbara Barletta[2], Barbara Chisholm[2], James Flynn[4], Sergio Alvarez[4], Travis Griggs[4], Maya Zimmerman[5], Jordan Zachmann[6], MacKenzie Warner[7], Gabriela Vidad[8], Graham Trolley[9], Jacob Schenthal[10], Morgan Schachterle[11], Everett Rzeszowski[12], Dominick Ryan[13], Amanda Rodell[14], McKenna Price-Patak[15], Elena Press[16], Scarlet Passer[17], Nathan Pappalardo[18], Joseph Palmo[19], David Moore[20], An Li[21], Jessica Kasamoto[22], Tatiana Jimenez[23], Amelia Hurst[24], Kendra Herweck[25], Paola Granados[26], Katey Dong[27], Walker Demel[28], Ariana Deegan[29], Mackenzie Conkling[30], John Carlson[31], Joel Been[32], Nicole Taylor[33], Patrick Sullivan[34], Alexander MacDonald[35], Jesse Bausell[33], Dar Roberts[36], Raphael Kudela[33], Andreas Beyersdorf[37], Roya Bahreini[38], Barry Lefer[39], Jack Kaye[39], Hal Maring[40], Ryan Stauffer[41], Joseph Bennett[42], and Emily Schaller[42]

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[2]University of California Irvine
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[7]Ripon College
[8]Adelphi University
[9]Cornell University
[10]Vanderbilt University
[11]University of Colorado - Colorado Springs
[12]Bowdoin College
[13]Northern Arizona University
[14]Missouri University of Science and Technology
[15]Tulane University
[16]Stanford University
[17]University of California - Santa Cruz
[18]Pomona College
[19]Amherst College
[20]University of Albany
[21]University of Chicago
[22]Johns Hopkins University
[23]Harvard University
[24]Univeristy of Connecticut
[25]Northern Kentucky University
[26]University of Texas - Rio Grande Valley

[27]Oregon State University
[28]Butler University
[29]University of Georgia
[30]Centre College
[31]Norwich University
[32]Colorado School of Mines
[33]University of California Santa Cruz
[34]University of Utah
[35]University of Arizona
[36]University of California Santa Barbara
[37]NASA Langley Research Center
[38]University of California Riverside
[39]NASA Headquarters
[40]NASA-Scien Mission Directorate
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November 23, 2022

**Abstract**

The 2020 COVID-19 pandemic provided a unique opportunity to sample atmospheric gases during a period of very low industrial/human activity. Over 1000 Whole Air Samples were collected in over 30 cities and towns across the United States from April through July 2020 as part of the NASA Student Airborne Research Program (SARP). Sample locations leveraged the geographic distribution across the United States of the undergraduate and graduate students, faculty, and NASA personnel associated with the internship program (44 people total). Each person collected approximately 24 air samples in their city/town with the goal of characterizing local emissions with time during the pandemic. Samples were collected in 2-Liter stainless steel evacuated canisters at approximately 2 meters above ground level. The canisters were shipped to the Rowland/Blake Laboratory at the University of California Irvine and analyzed for methane, carbon dioxide, carbon monoxide, non-methane hydrocarbons, and halocarbons using the gas chromatographic system described in Colman et al. (2001) and Barletta et al. (2002). Initial samples collected in April coincided with the peak of stay-at-home/social distancing orders across most of the United States while samples collected later in the spring and early summer reflect the easing of these measures in most locations. Overall trends in emissions with time across the United States during the pandemic (in several large metro areas as well as rural locations) will be discussed.

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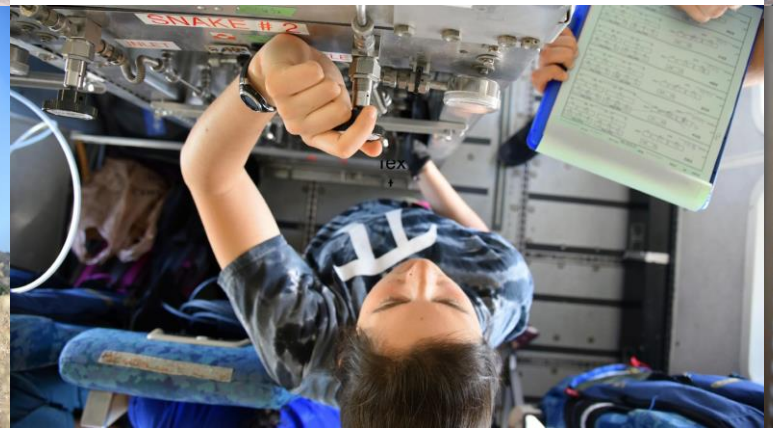
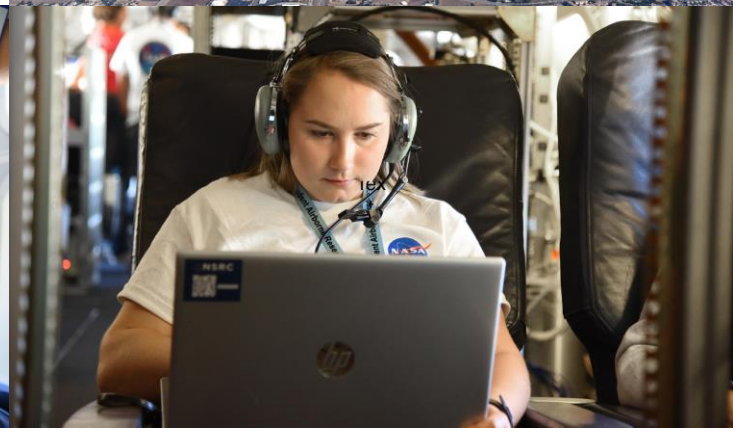






# High Flying Interns:

## NASA Student Airborne Research Program (SARP) 2009-2020

Competitive summer internship for 28 junior/senior undergraduate STEM majors from across the USA

# SARP Program Elements

- Expose and engage participants in NASA Airborne Science and its role in Earth system research
- Provide participants with hands-on experience of the end-to-end aspects of a scientific mission using NASA research aircraft and instrumentation
- Ensure that authentic student projects can be completed

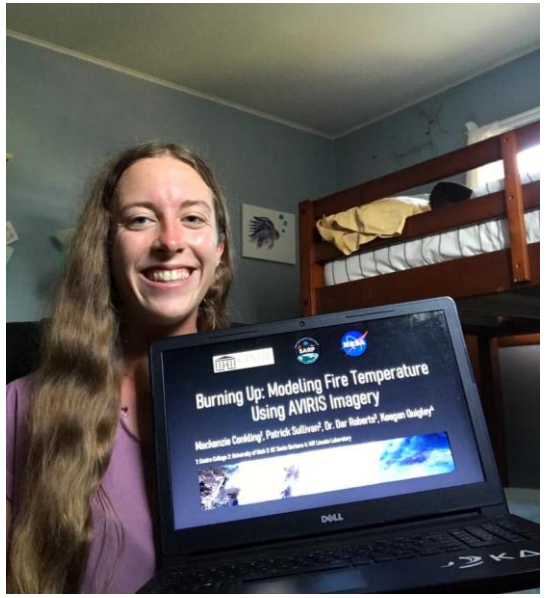
**Week 1 (NASA Armstrong)**
- Background lectures on Earth Science Research
- Tours of NASA facilities and aircraft in southern California
- Students divided into 4 research groups

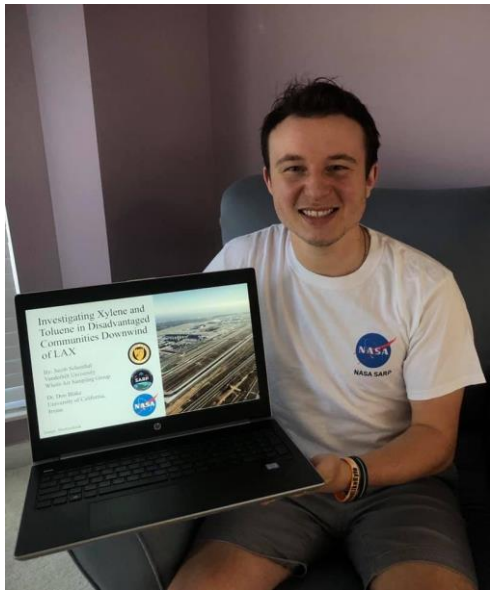
**Week 2 (NASA Armstrong)**
- Fly onboard NASA research aircraft and assist in the collection of remote sensing and atmospheric chemistry data
- Field trips for ground truth validation measurements

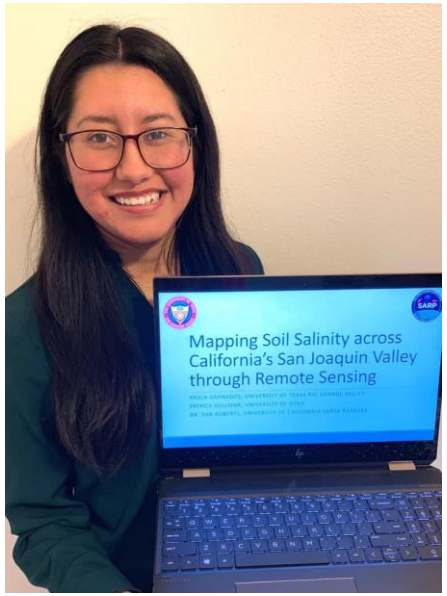
**Week 3-7 (UC Irvine)**
- Develop individual research projects in the atmosphere, oceans and land from data collected onboard aircraft, and from satellites and the field
- Laboratory and data analysis
- Coding and science lectures
- Weekend trips and tours

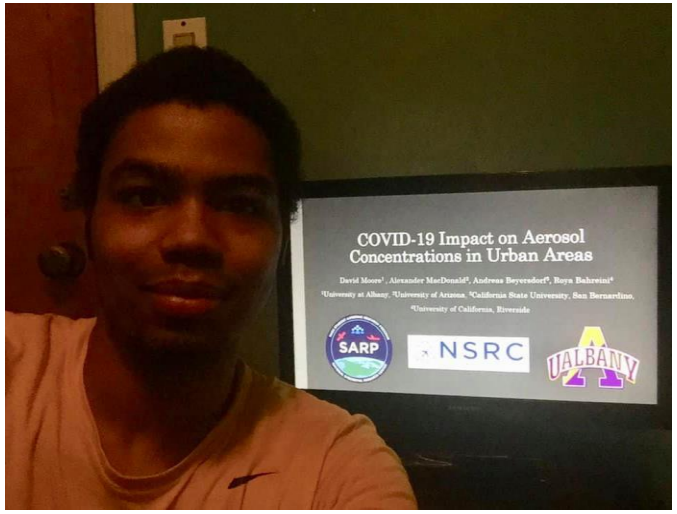
**Week 8 (UC Irvine)**
- Formal presentation of results and conclusions
- Submission of top abstracts to AGU scientific sessions


# SARP 2020 at Home



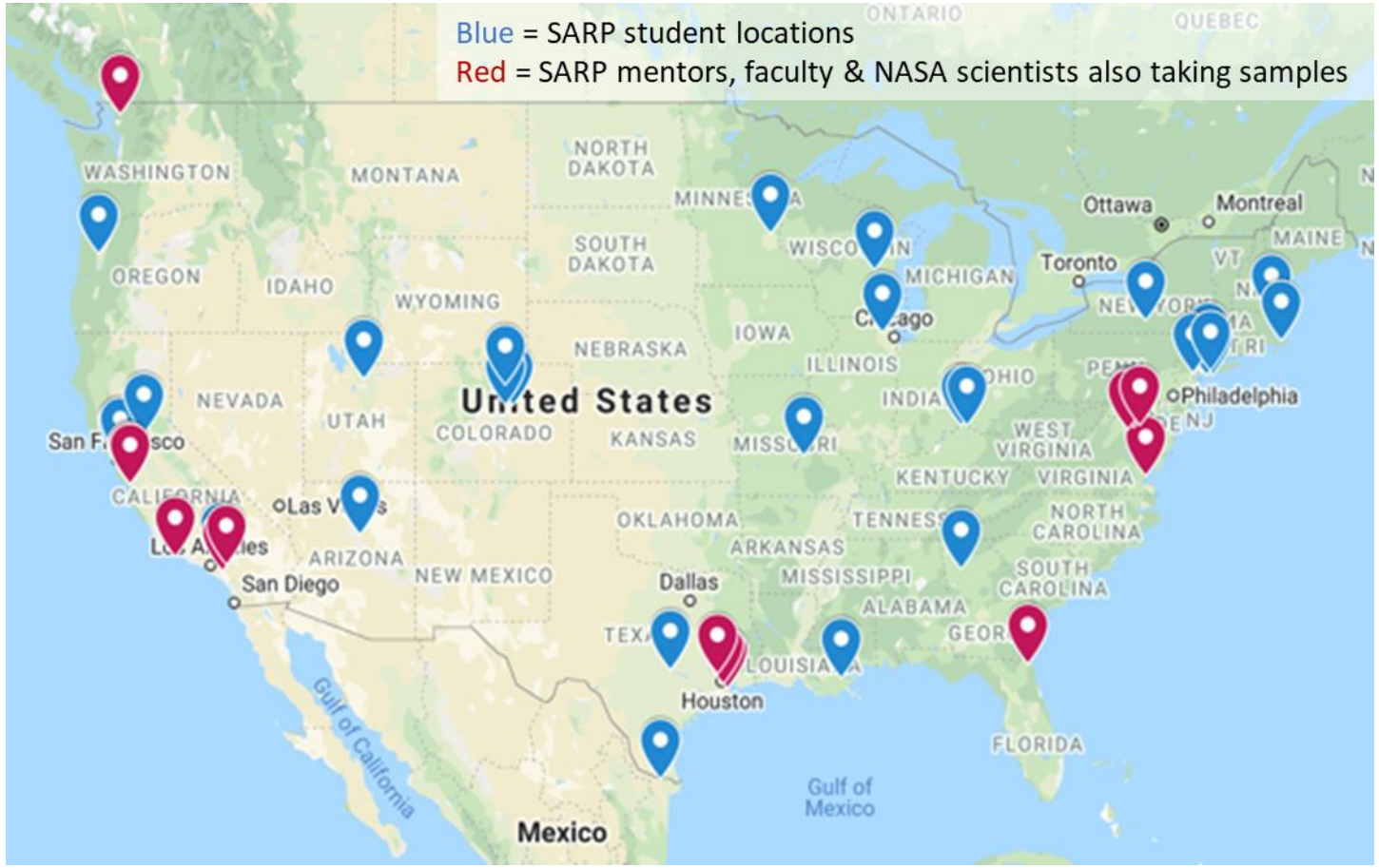


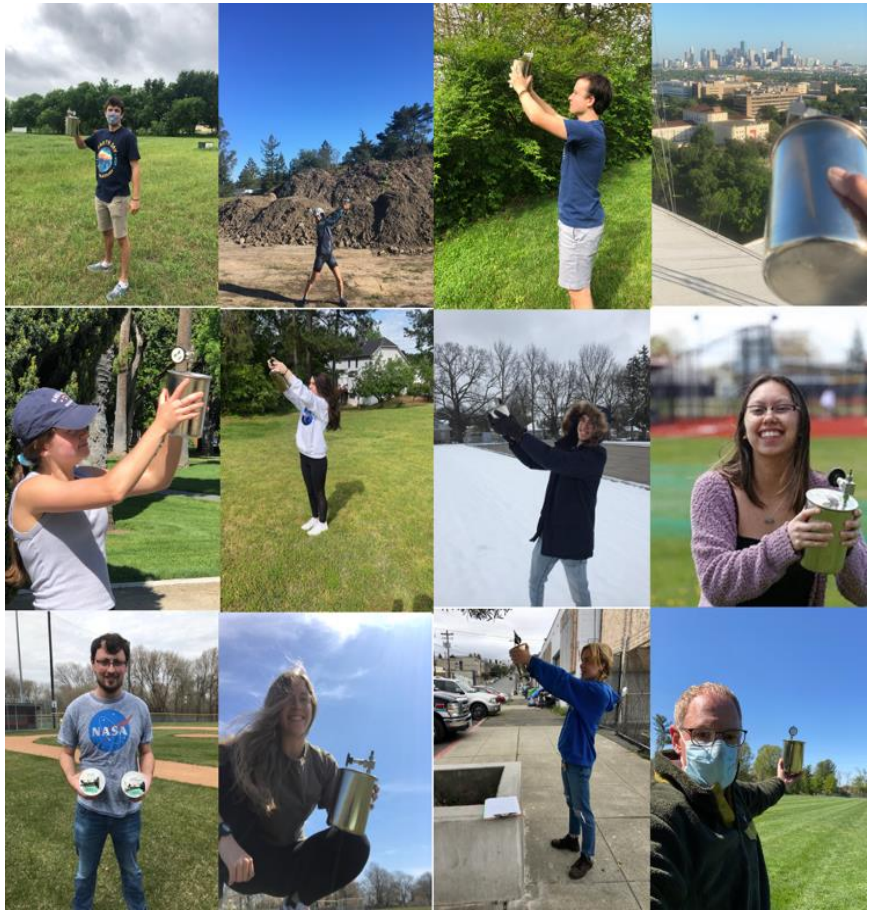
## 2020 Program Elements

28 individual student research projects using data from 2009-2019 SARP flights, other airborne campaigns, satellites and ground stations

Hands-on at home group projects:
- Whole Air Sampling (WAS)
- Aerosol measurements

# SARP at Home: Whole Air Sampling Group Project



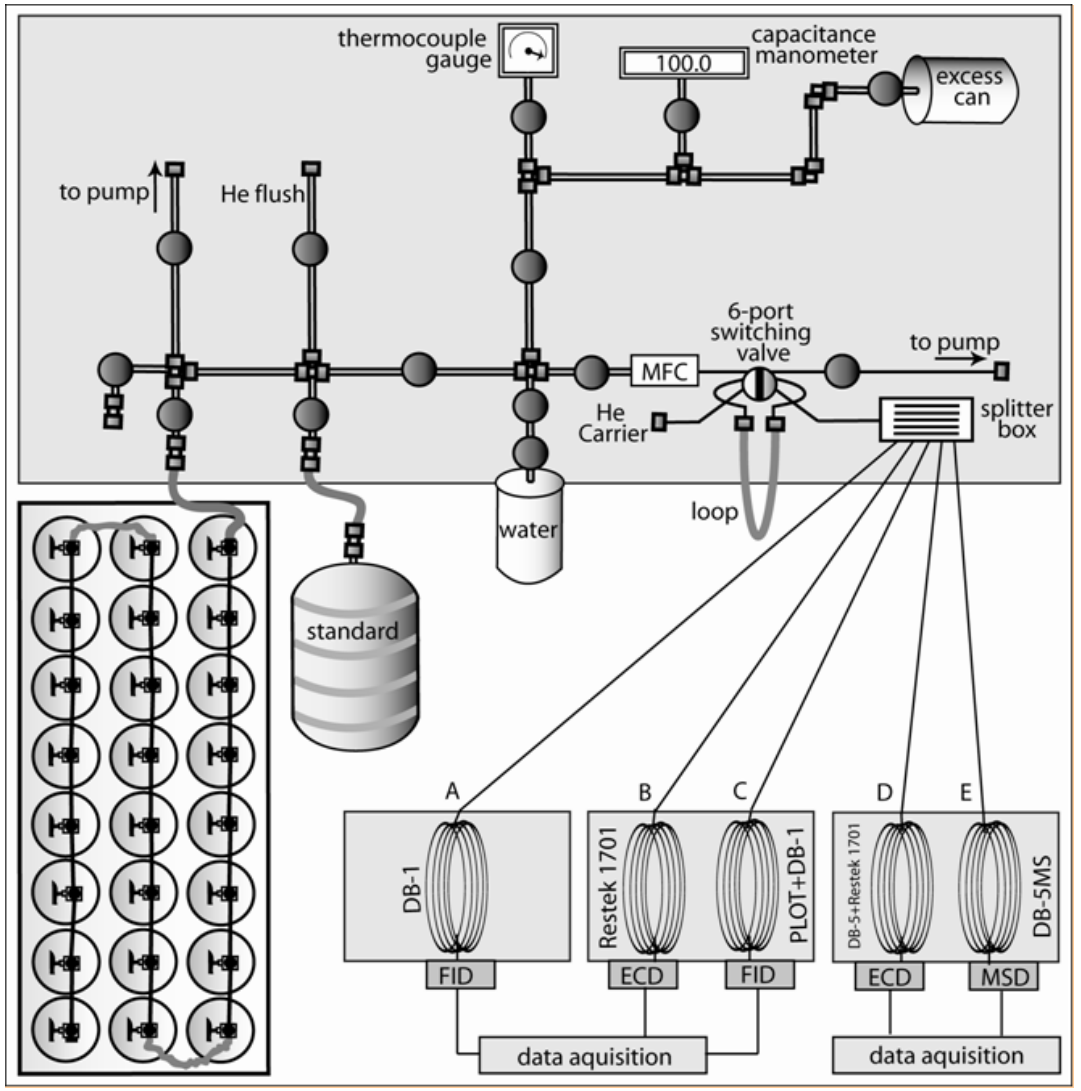



SARP students, mentors, faculty and NASA scientists took air samples near their homes that were subsequently analyzed for nearly 100 different trace gases

# Sample Analysis using Gas Chromatography

Detectors:

- Flame Ionization Detection (FID)
  - Sensitive to hydrocarbons
- Electron Capture Detection (ECD)
  - Sensitive to halocarbons, alkyl nitrates
- Mass Spectrometer Detection (MSD)
  - Unambiguous compound identification



# VOCs quantified for SARP 2020 samples (*n* = 1100)

## Alkanes

1. Ethane
2. Propane
3. *i*-Butane
4. *n*-Butane
5. *i*-Pentane
6. *n*-Pentane
7. *n*-Hexane
8. *n*-Heptane
9. *n*-Octane
10. *n*-Nonane
11. *n*-Decane
12. 2,3-Dimethylbutane
13. 2-Methylpentane
14. 3-Methylpentane
15. Cyclopentane
16. Methylcyclopentane
17. Cyclohexane
18. Methylcyclohexane

## Alkyl Nitrates

19. $MeONO_2$
20. $EtONO_2$
21. *i*-$PrONO_2$
22. *n*-$PrONO_2$
23. 2-$BuONO_2$
24. 2-$PeONO_2$
25. 3-$PeONO_2$
26. 3-Methyl-2-$BuONO_2$

## Alkenes, Alkynes

27. Ethene
28. Propene
29. 1-Butene
30. *i*-Butene
31. *cis*-2-Butene
32. *trans*-2-Butene
33. 1,3-butadiene
34. Isoprene
35. *α-Pinene*
36. *β-Pinene*
37. Ethyne

## Aromatics

38. Benzene
39. Toluene
40. Ethylbenzene
41. *m,p*-Xylene
42. *o*-Xylene
43. Styrene
44. *i*-Propylbenzene
45. *n*-Propylbenzene
46. 2-Ethyltoluene
47. 3-Ethyltoluene
48. 4-Ethyltoluene
49. 1,2,3-Trimethylbenzene
50. 1,2,4-Trimethylbenzene
51. 1,3,5-Trimethylbenzene

## Halocarbons (GHGs)

52. CFC-11
53. CFC-12
54. CFC-112
55. CFC-113
56. CFC-114
57. $CCl_4$
58. $CH_3CCl_3$
59. H-1211
60. H-1301
61. H-2402
62. HCFC-22
63. HCFC-141b
64. HCFC-142b
65. HFC-134a
66. HFC-152a
67. HFC-227ea
68. HFC-365mfc
69. $CH_3Cl$
70. $CH_3Br$
71. $CH_3I$
72. $CH_2Cl_2$
73. $CHCl_3$
74. $C_2HCl_3$
75. $C_2Cl_4$
76. $CH_2Br_2$
77. $CHBr_3$
78. $CHBrCl_2$
79. $CHBr_2Cl$
80. Ethyl chloride
81. 1,2-Dichloroethane

## Sulfur Species

82. OCS
83. DMS

## Oxygenates

84. MAC
85. MVK
86. Butanal
87. Butanone
88. Acetone
89. Acetaldehyde
90. Methyl acetate
91. Ethyl acetate

## Some VOC tracers

Oceans:
- $MeONO_2$

Biomass burning:
- Ethyne

Urban/industrial:
- $C_2Cl_4$

Solvents:
- Toluene

Natural gas:
- Ethane

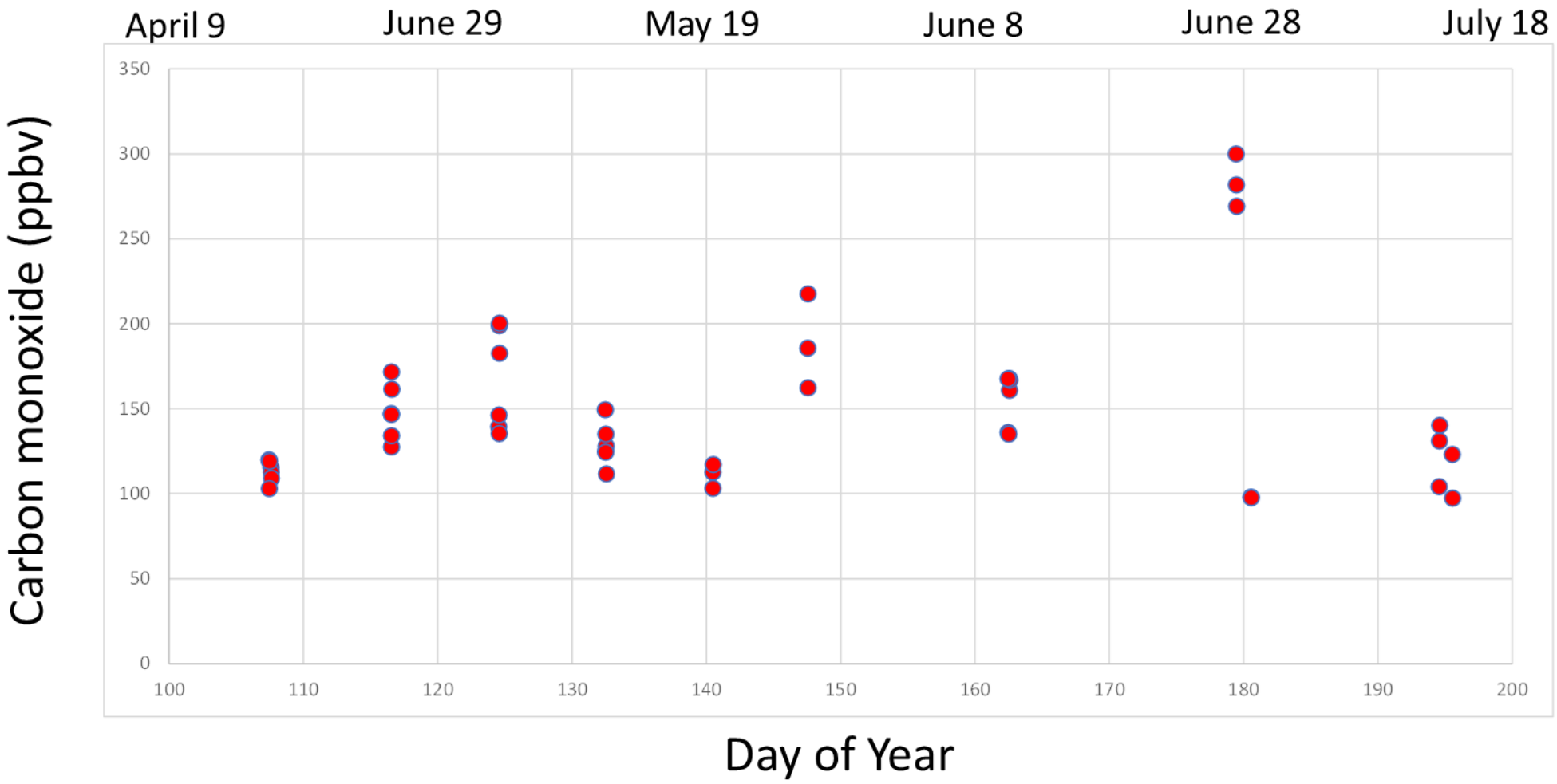
Gas evaporation:
- *i*-Pentane

Vehicle exhaust:
- Ethene

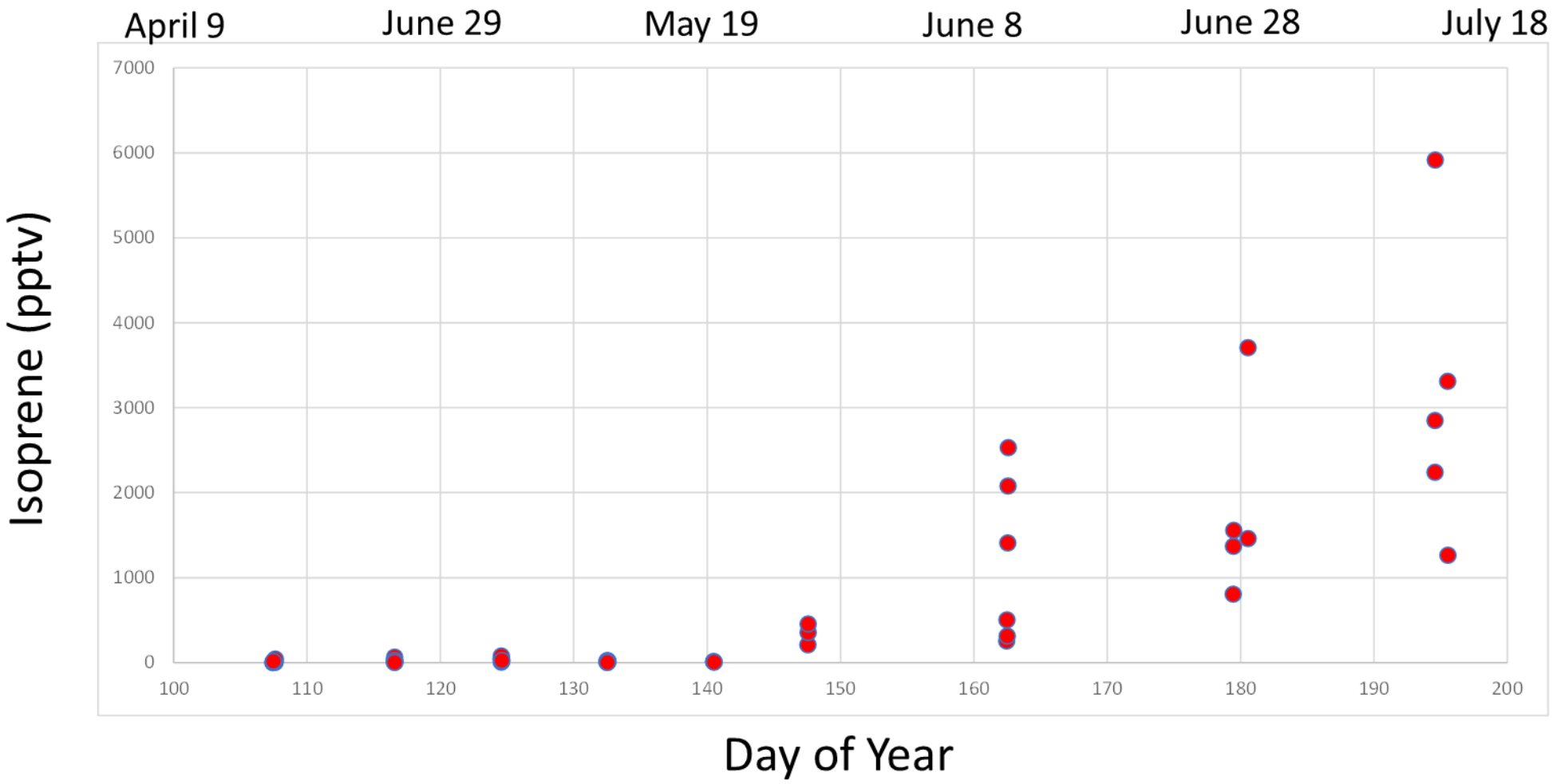
Biogenic:
- Isoprene

GHG = greenhouse gas; VOC = volatile organic compound

# Carbon monoxide (CO) time series:
## New Jersey and Connecticut samples

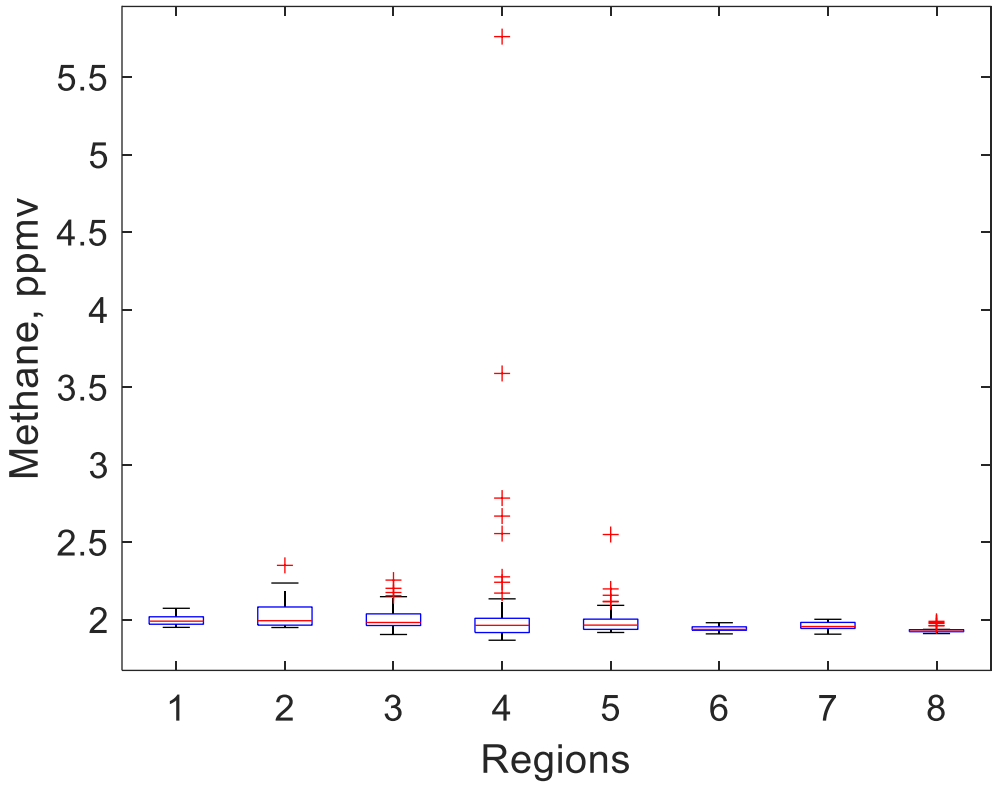


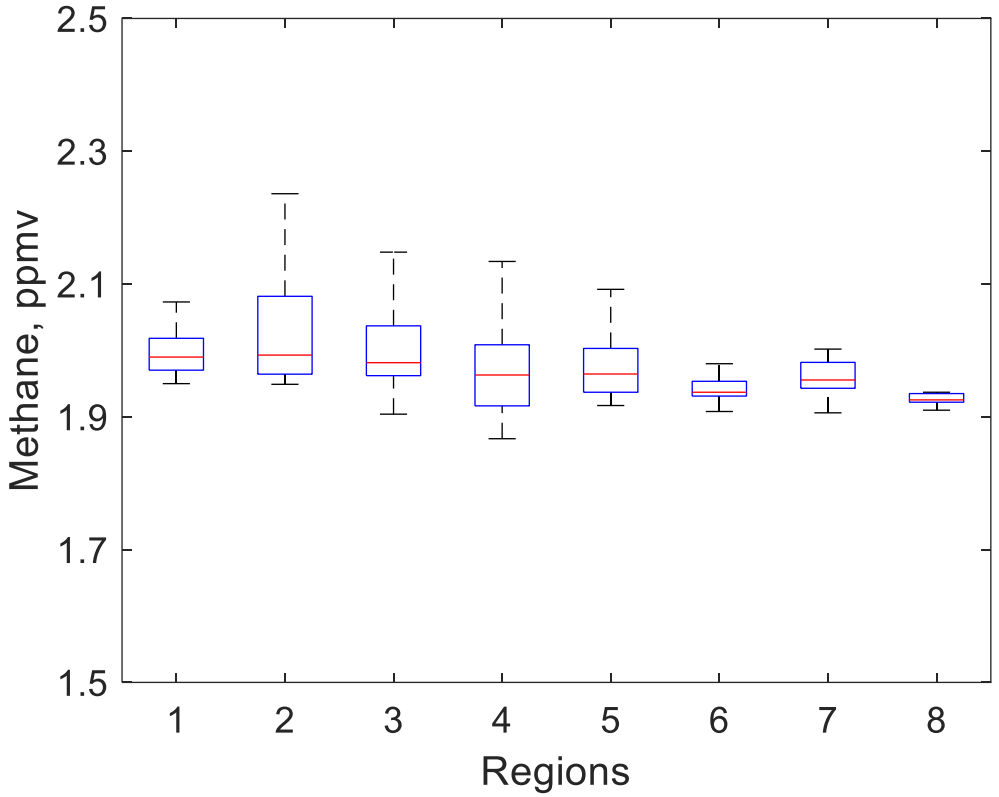

# Isoprene time series:
## New Jersey and Connecticut samples




# Methane

## SARP 2020 ground samples



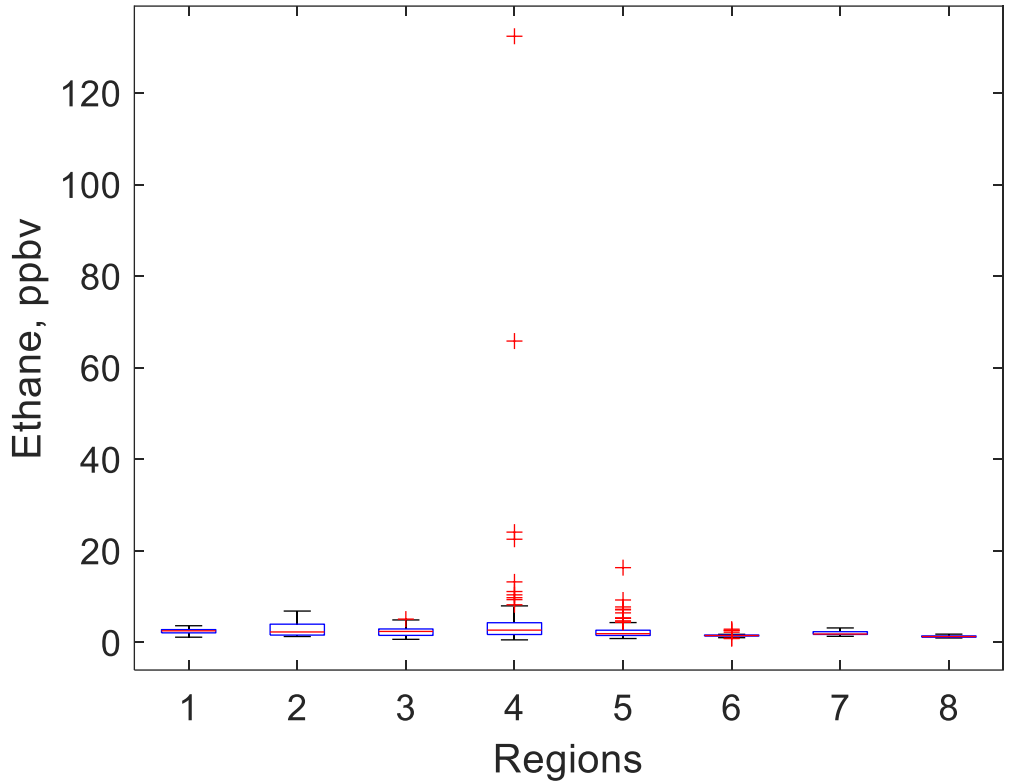



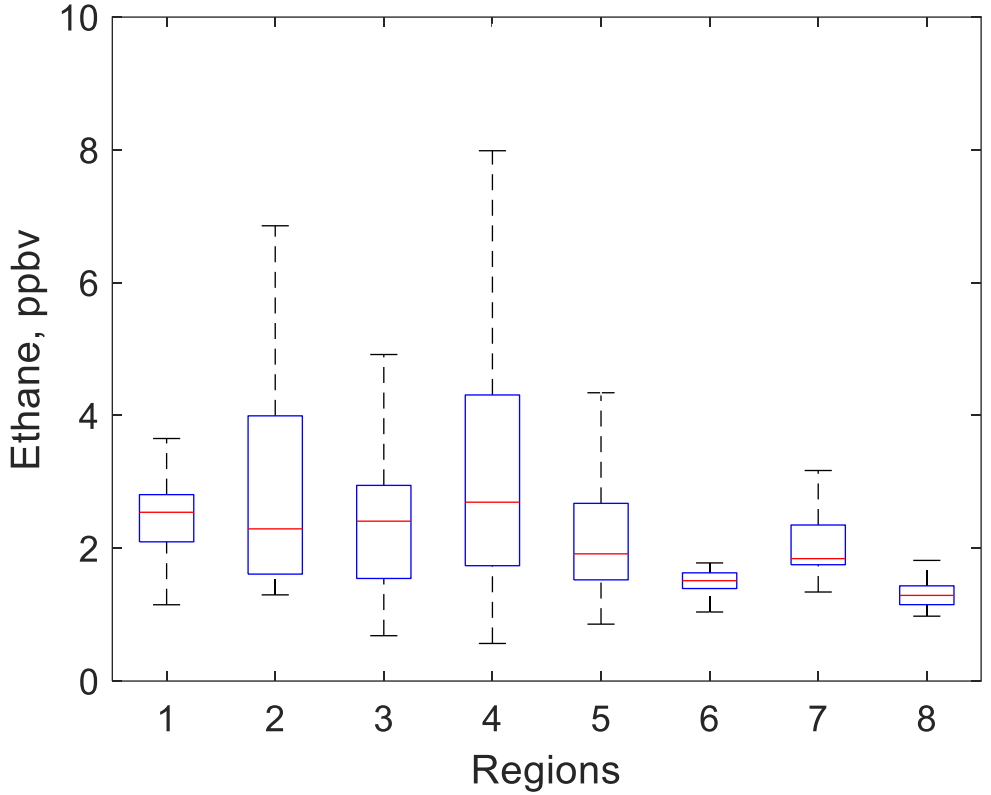

**Regions**

| | |
|---|---|
| 1 = New Jersey | 5 = California |
| 2 = Connecticut | 6 = Utah |
| 3 = New York | 7 = Missouri |
| 4 = Texas | 8 = Oregon |

# Ethane

## SARP 2020 ground samples

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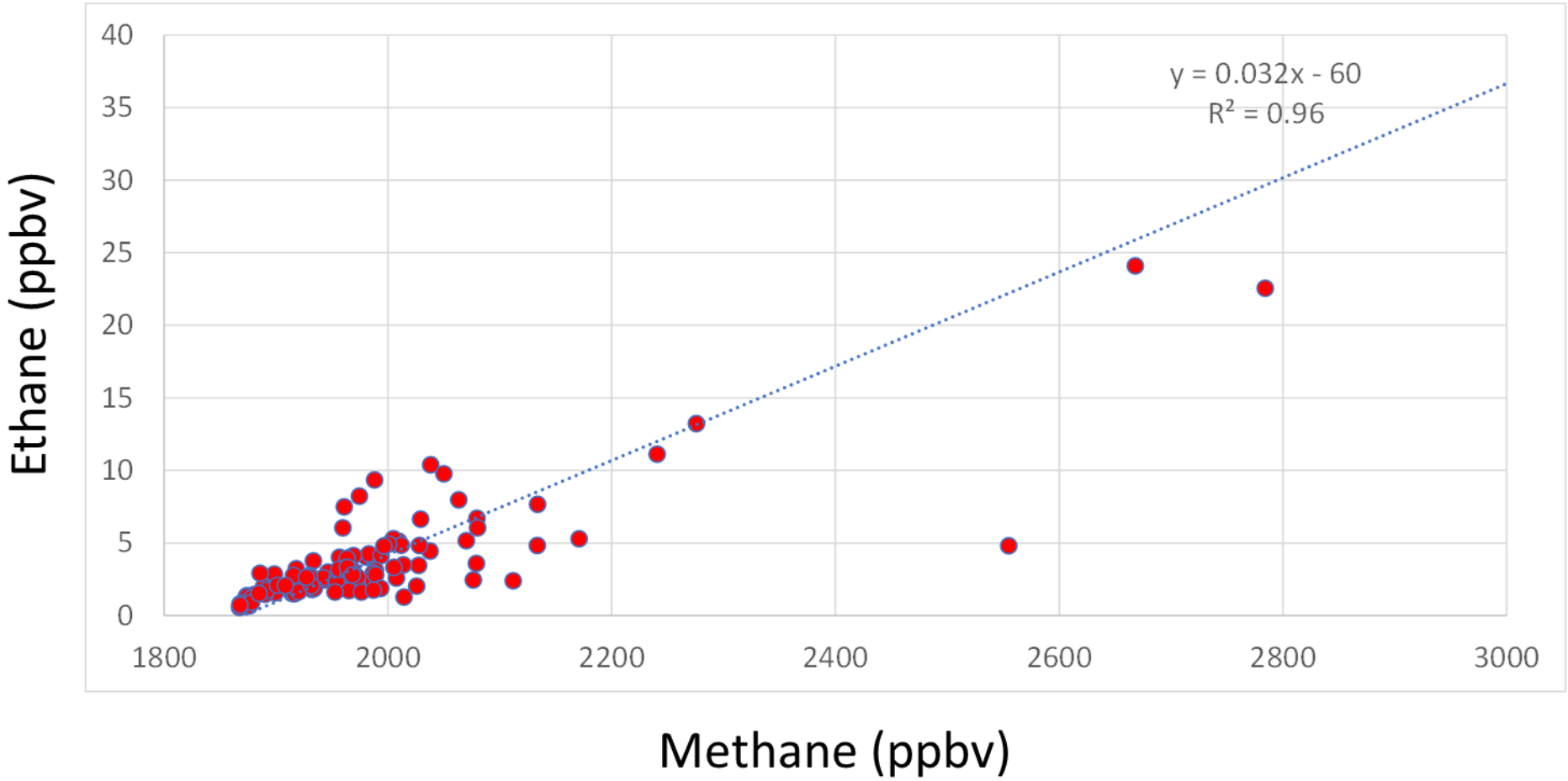
# Ethane vs methane for Texas samples:

## The slope of ~3% is consistent with natural gas



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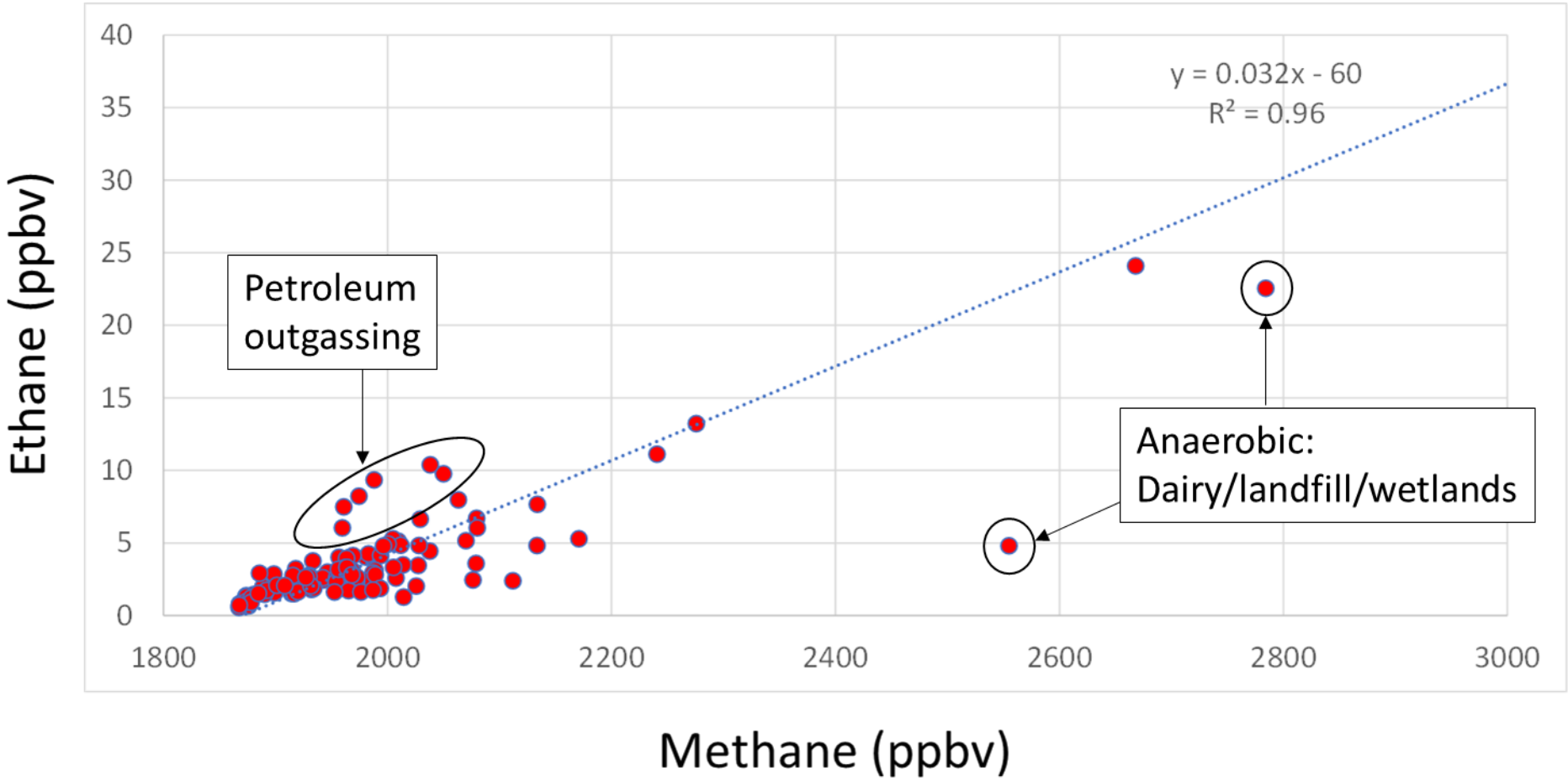
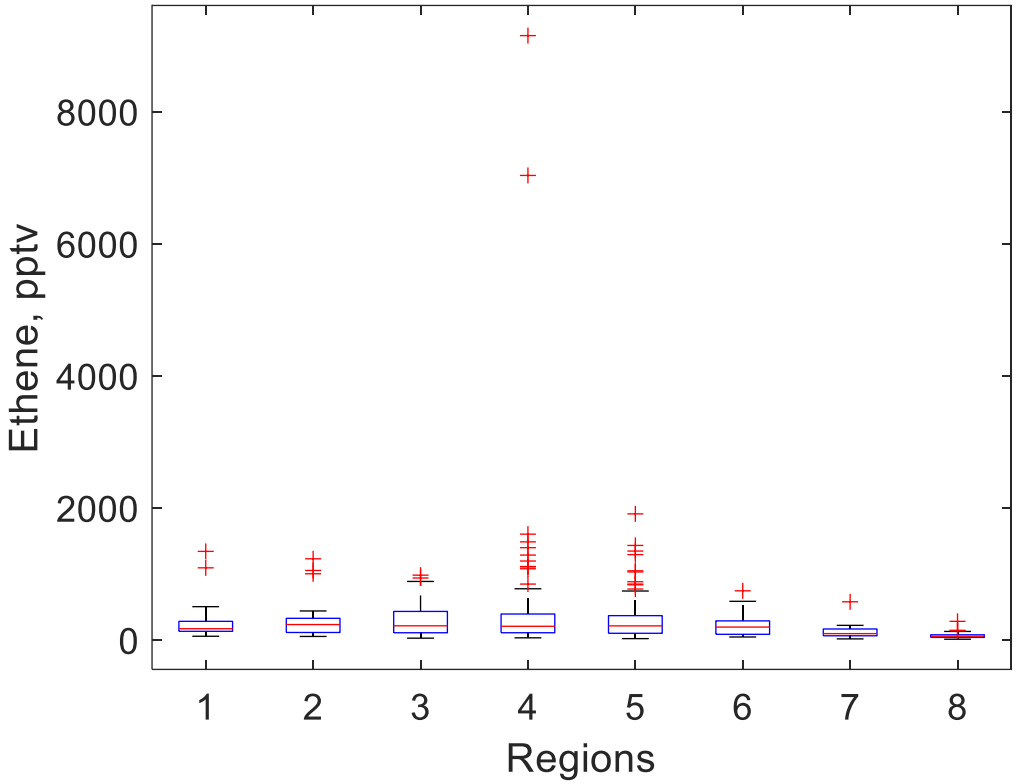
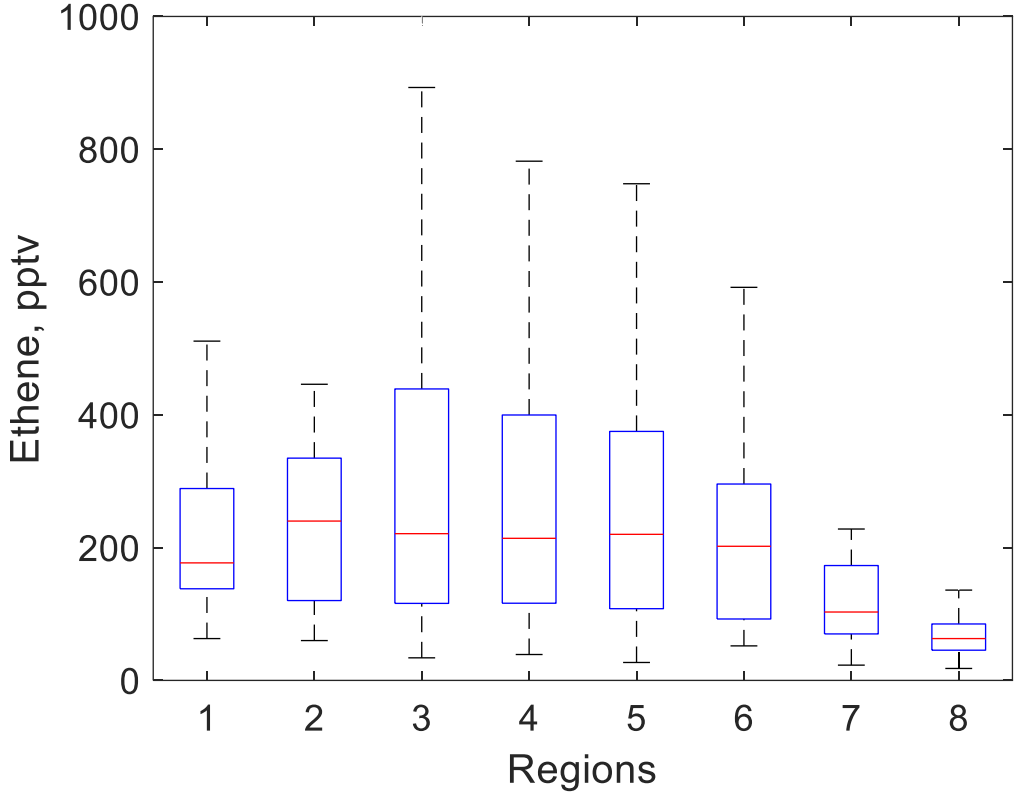


# Ethene

## SARP 2020 ground samples

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# Propene

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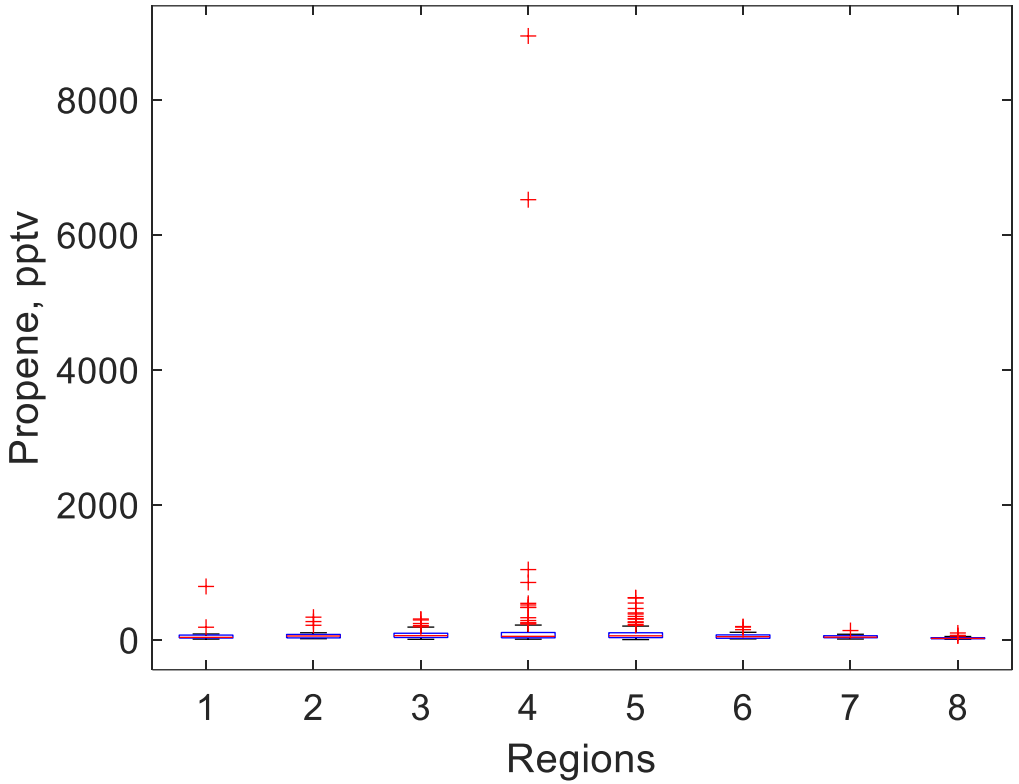


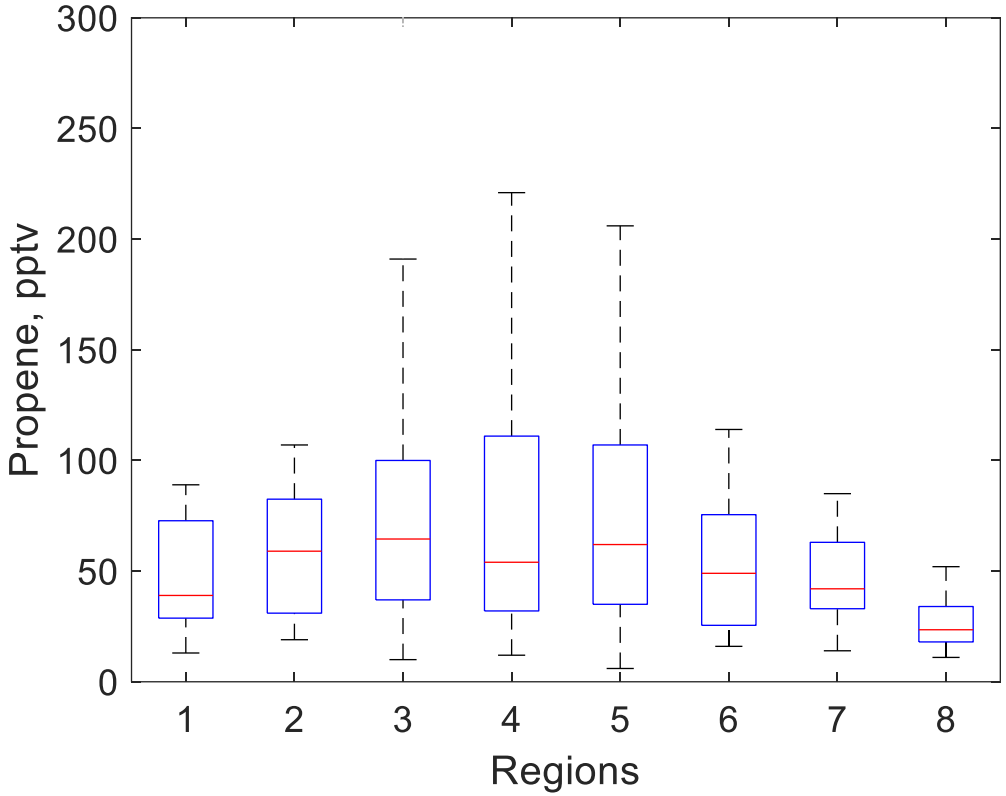


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# Benzene

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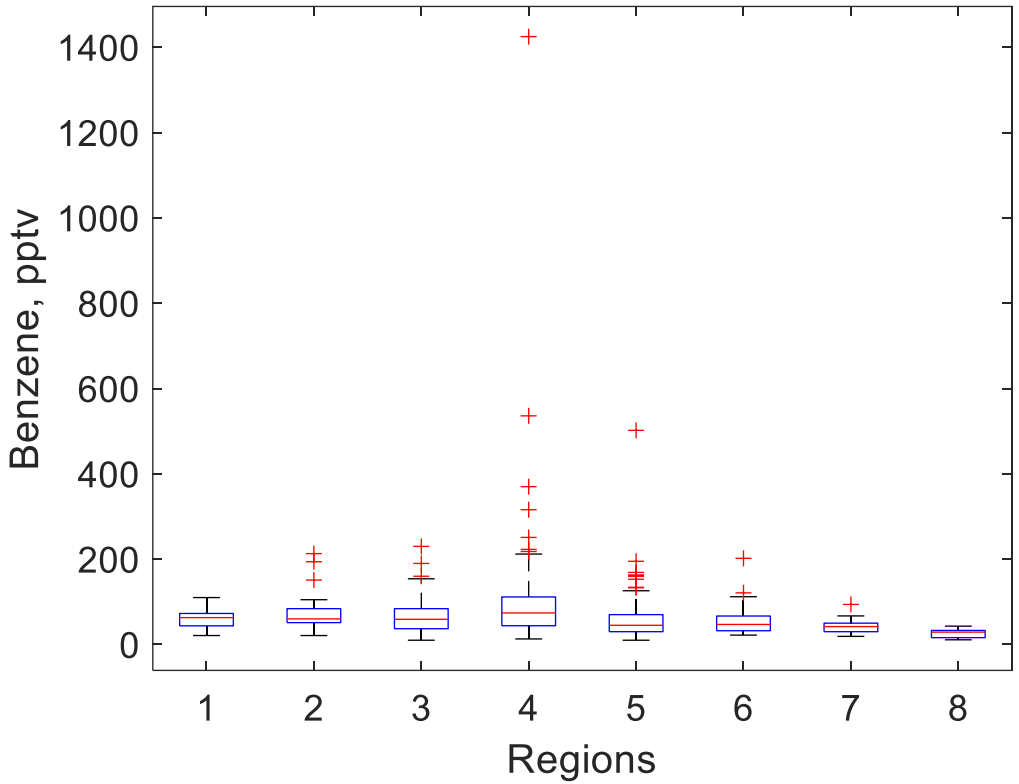


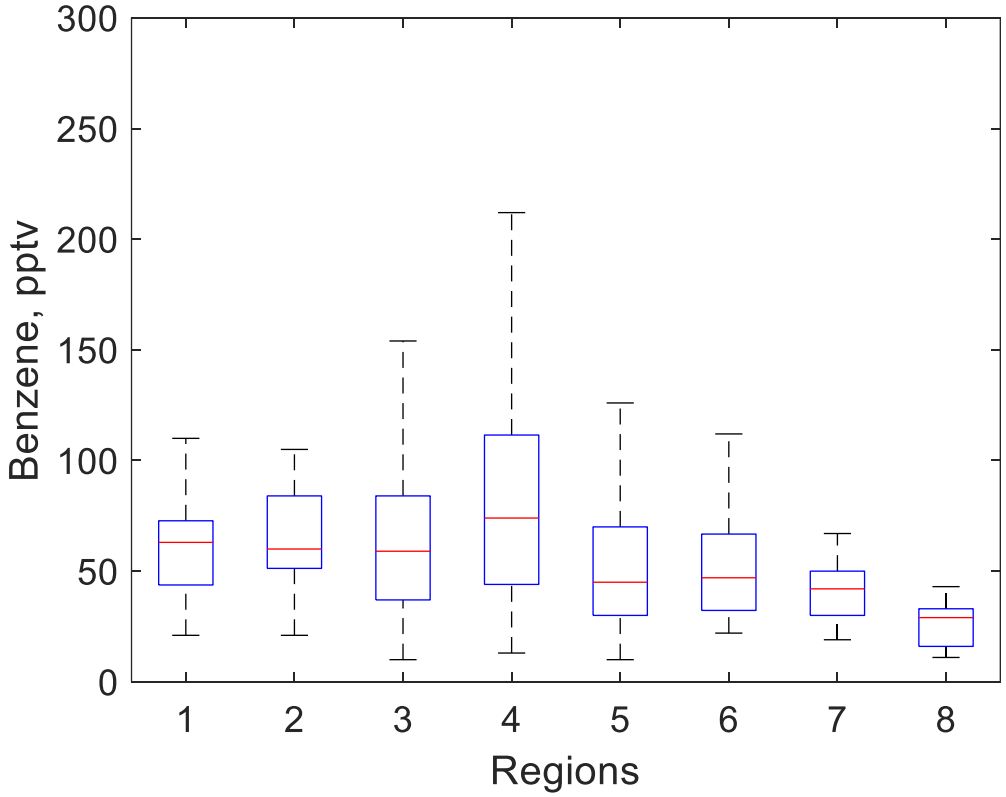


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# Toluene

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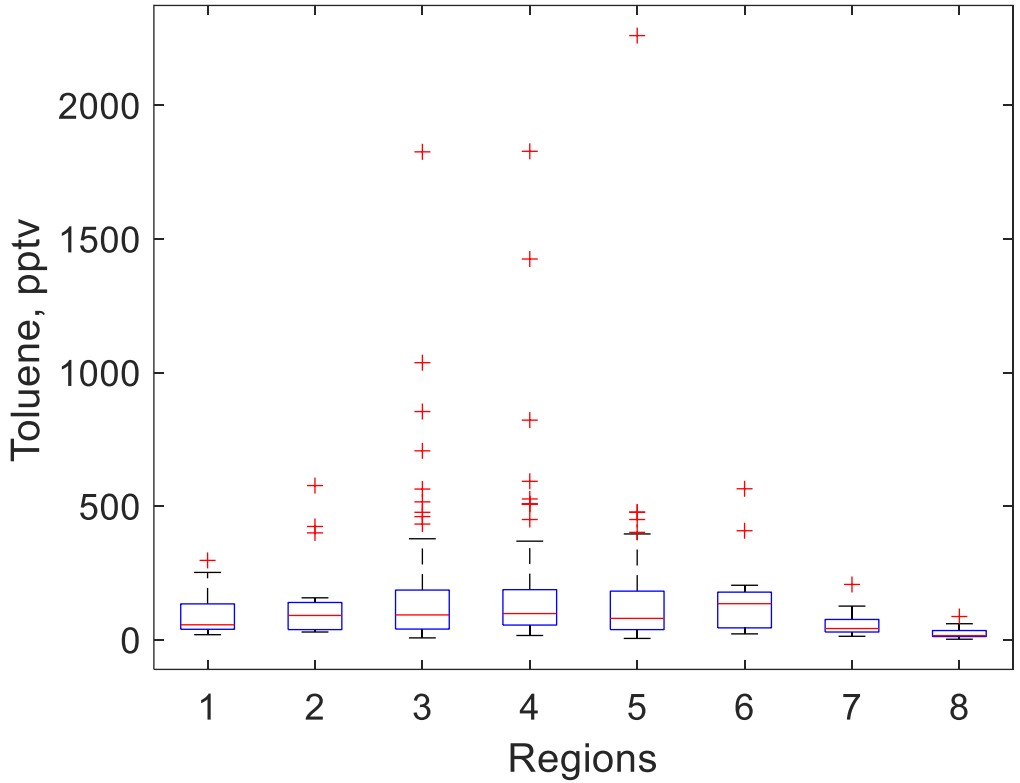


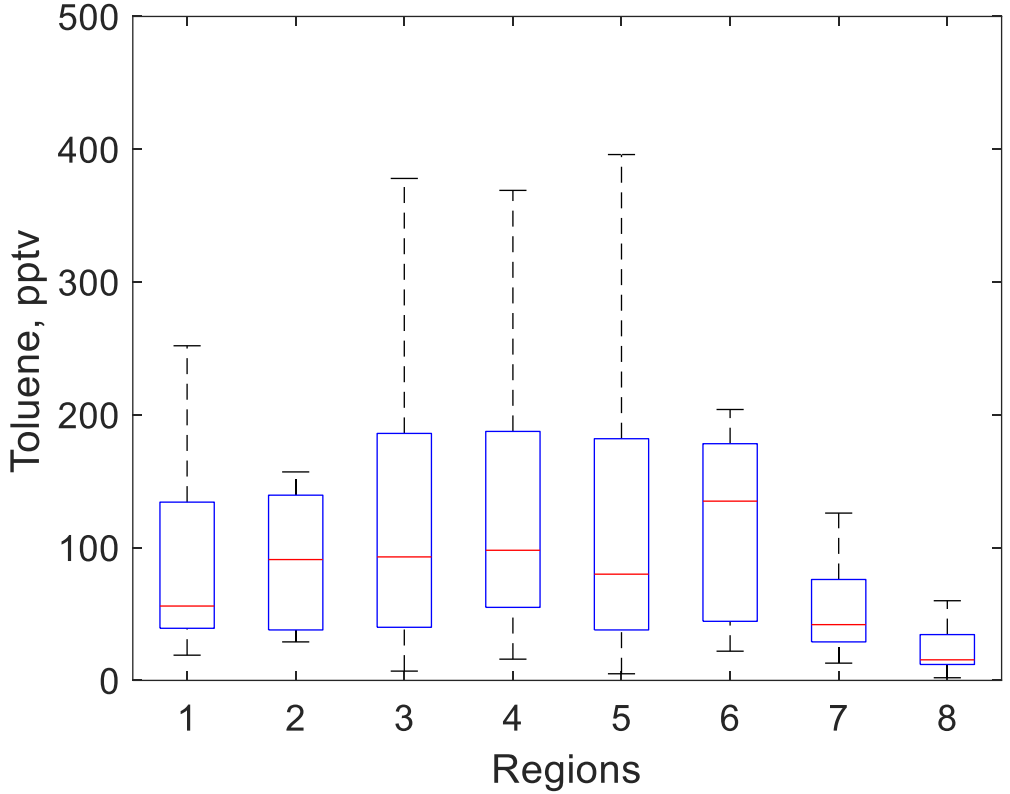


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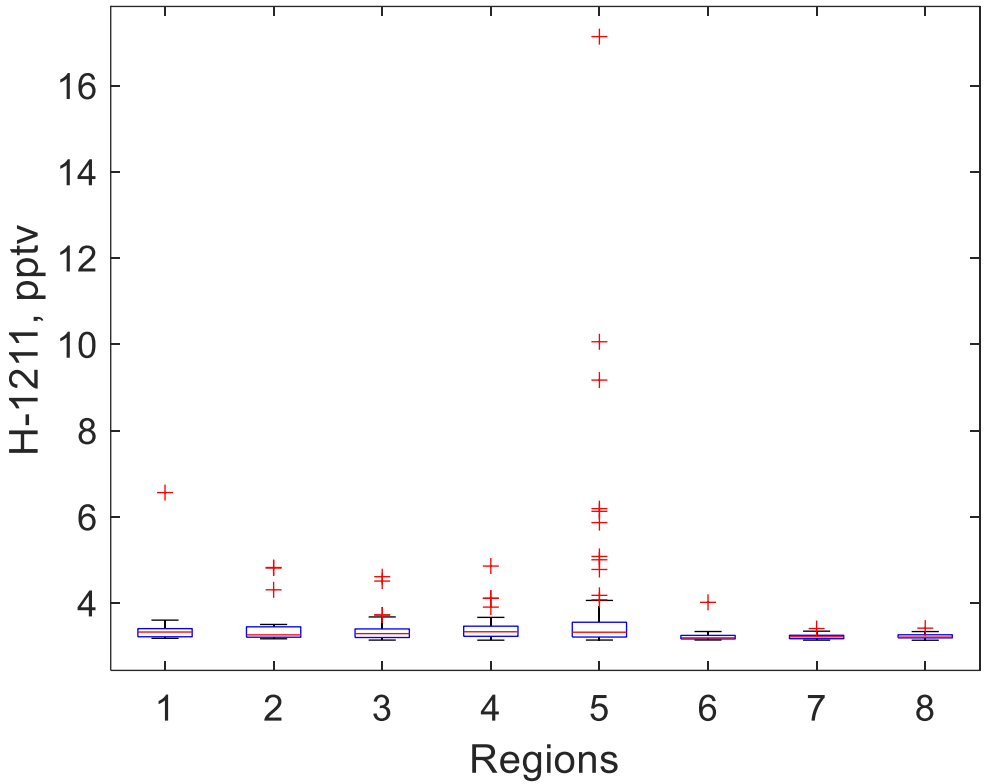
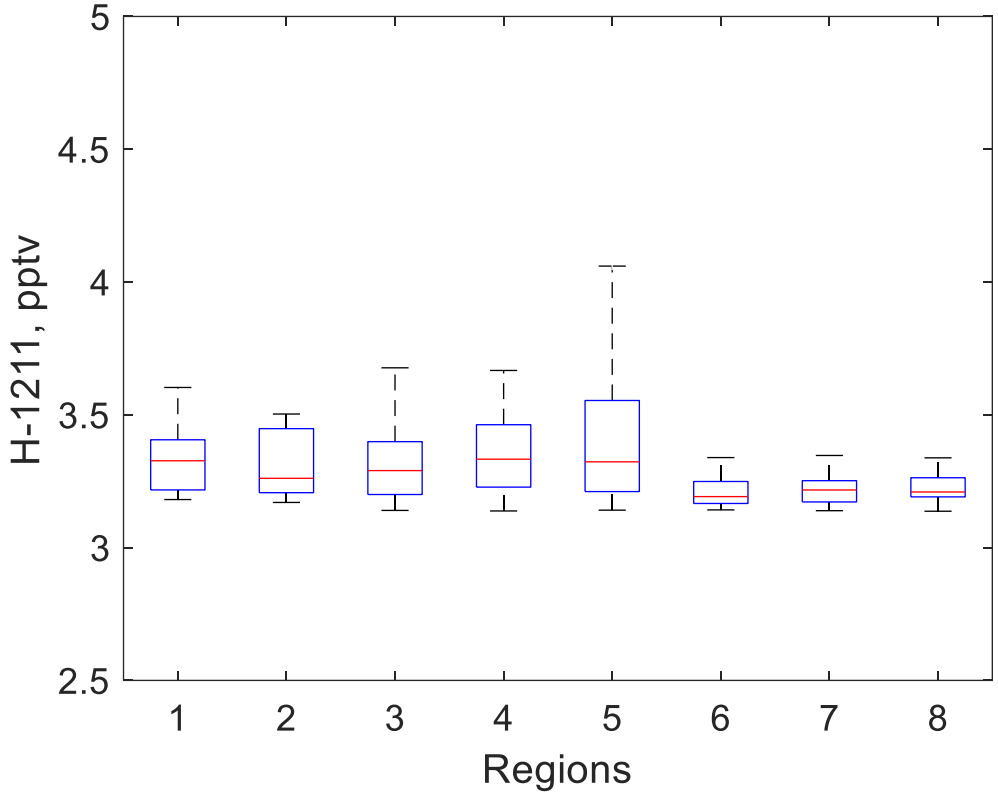
# Halon 1211

## SARP 2020 ground samples

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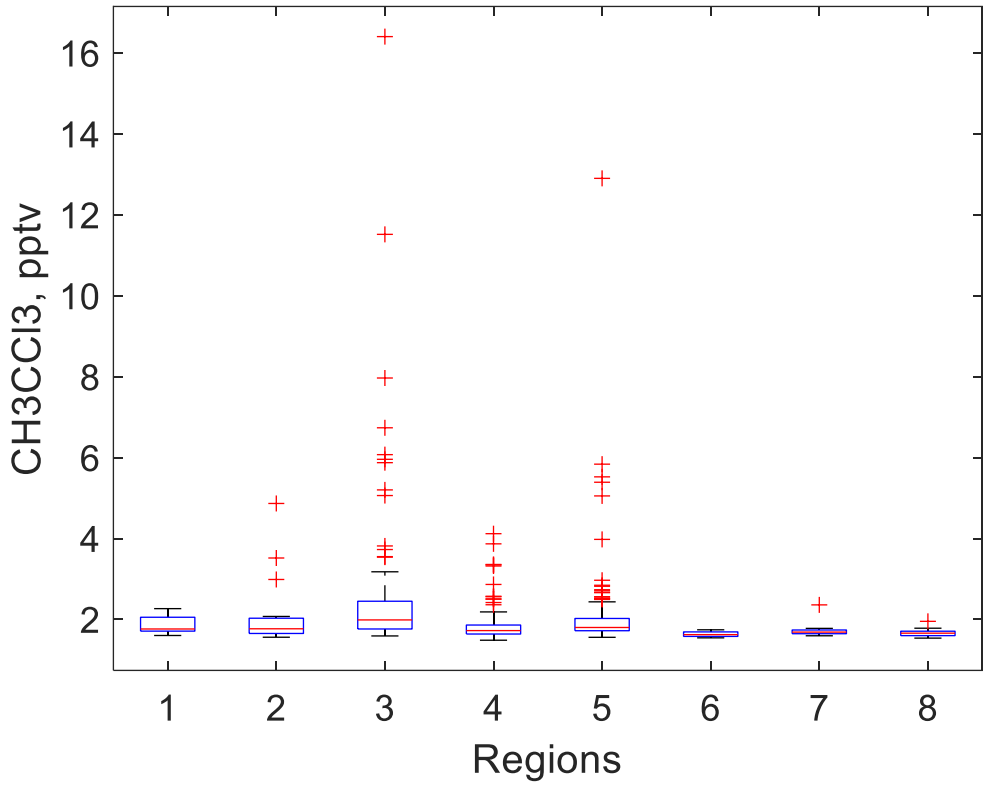
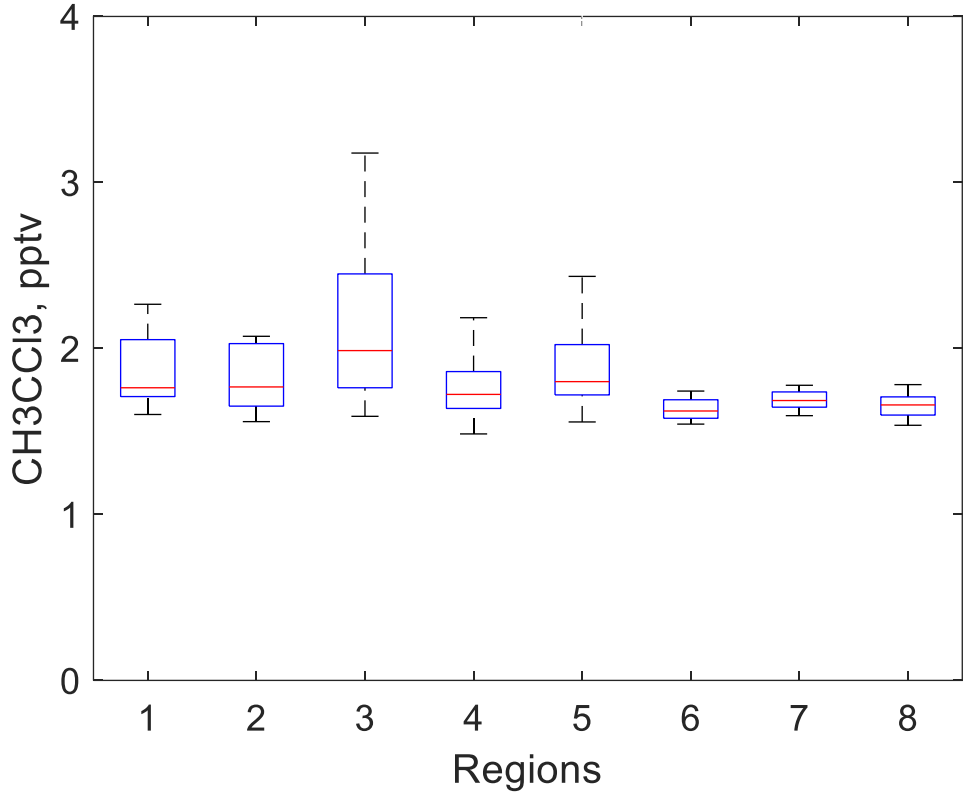
# Methyl chloroform ($CH_3CCl_3$)

## SARP 2020 ground samples

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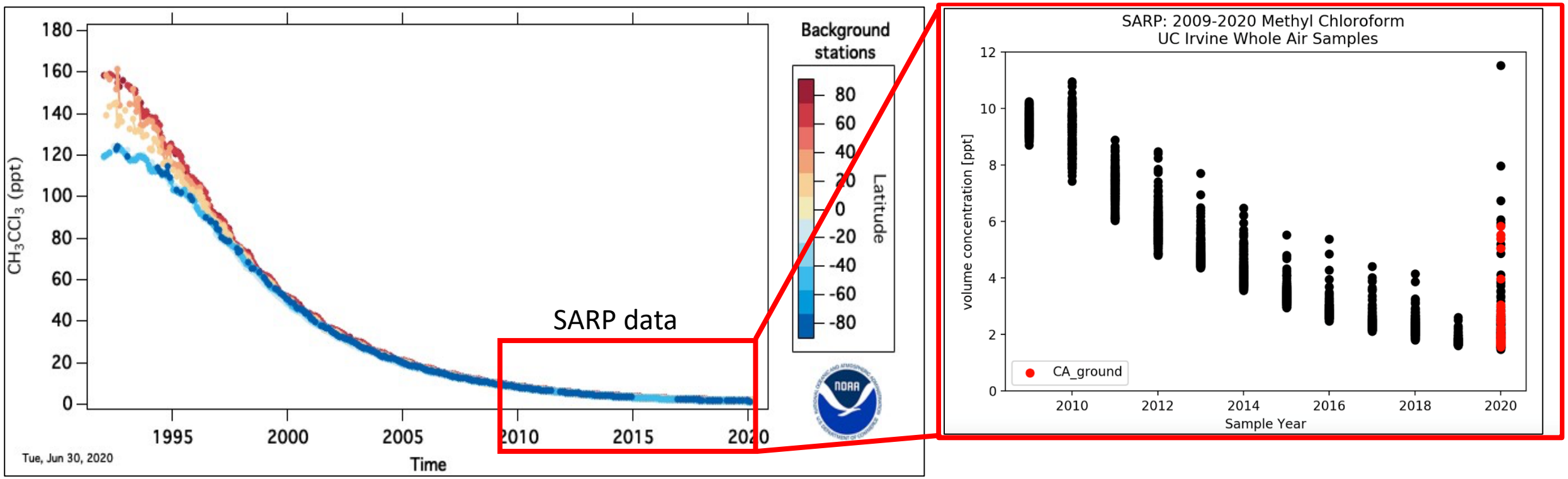
# SARP at Home, Preliminary Results: Methyl chloroform

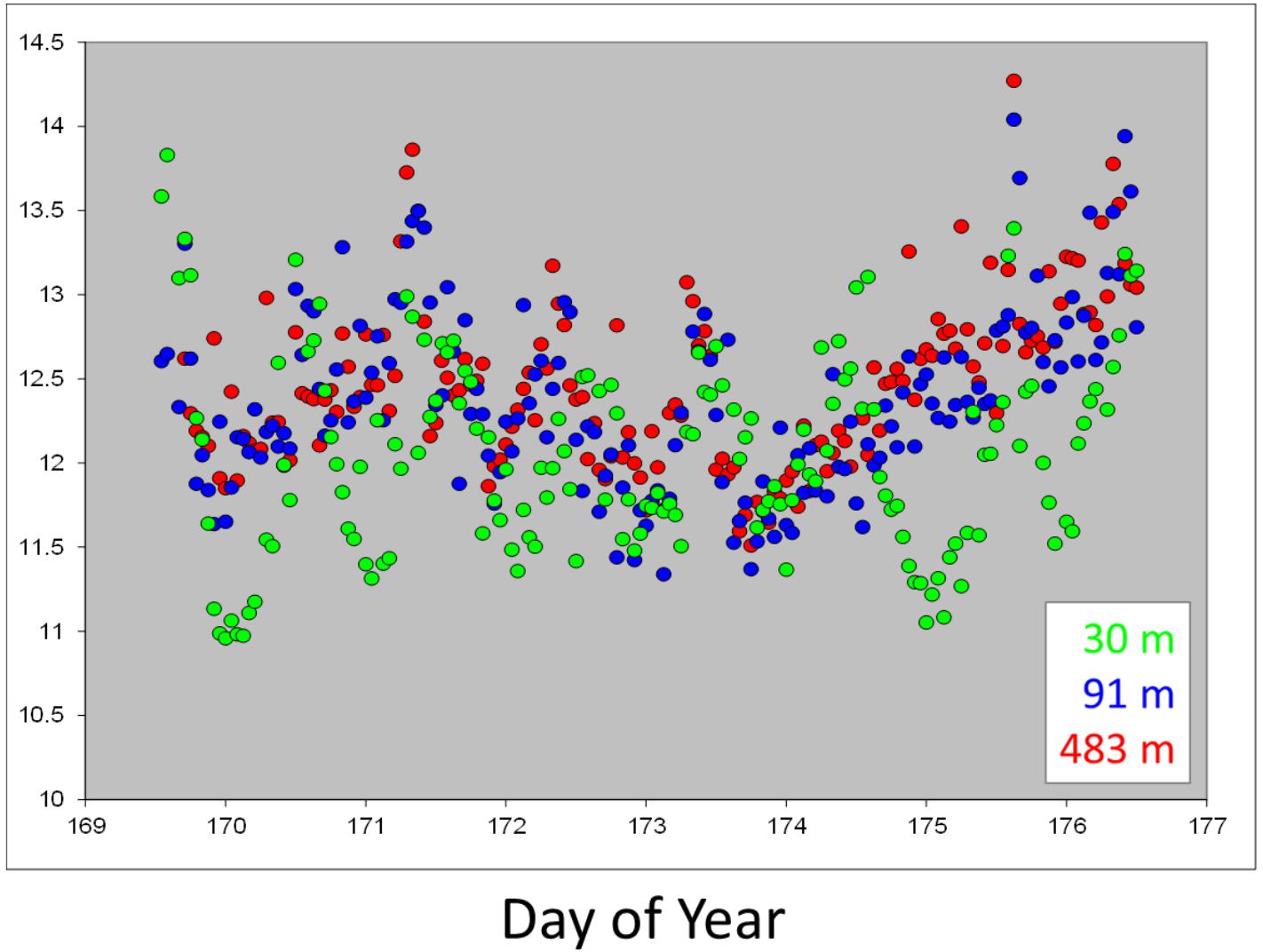



https://www.esrl.noaa.gov/gmd/hats/gases/CH3CCl3.html

- Previously produced industrially in large quantities for use as a solvent
- Regulated by the Montreal Protocol as an ozone-depleting substance

# Hourly $CH_3CCl_3$ mixing ratios

## Walnut Grove Tower, northern Central Valley of CA, June 17-25, 2008




# Conclusions

- Ethane vs methane for Texas samples suggests sources from petroleum, natural gas, and dairy/landfills/wetlands
- Methyl chloroform enhancements are surprising and bothersome
- The study did not identify significant changes in VOC concentrations resulting from reduced traffic from COVID restrictions
- Visit Final Paper Number: A095-0001 for more in-depth discussion