

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



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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)

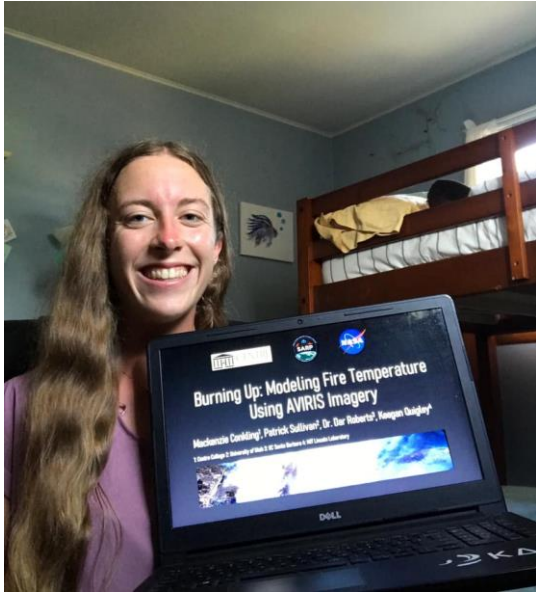
- Develop individual research projects in the atmosphere, oceans and land from data collected onboard aircraft, and from satellites and the field
- Laboratory and data analysis
- Coding and science lectures
- Weekend trips and tours

Week 8 (UC Irvine)

- Formal presentation of results and conclusions
- Submission of top abstracts to AGU scientific sessions

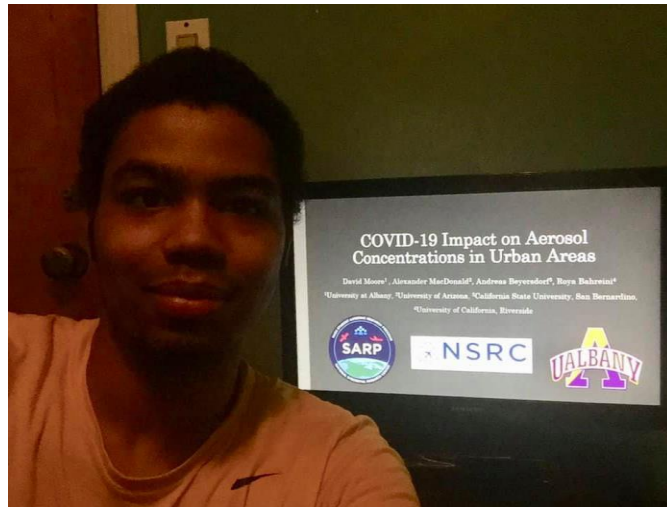


SARP 2020 at Home



2020 Program Elements

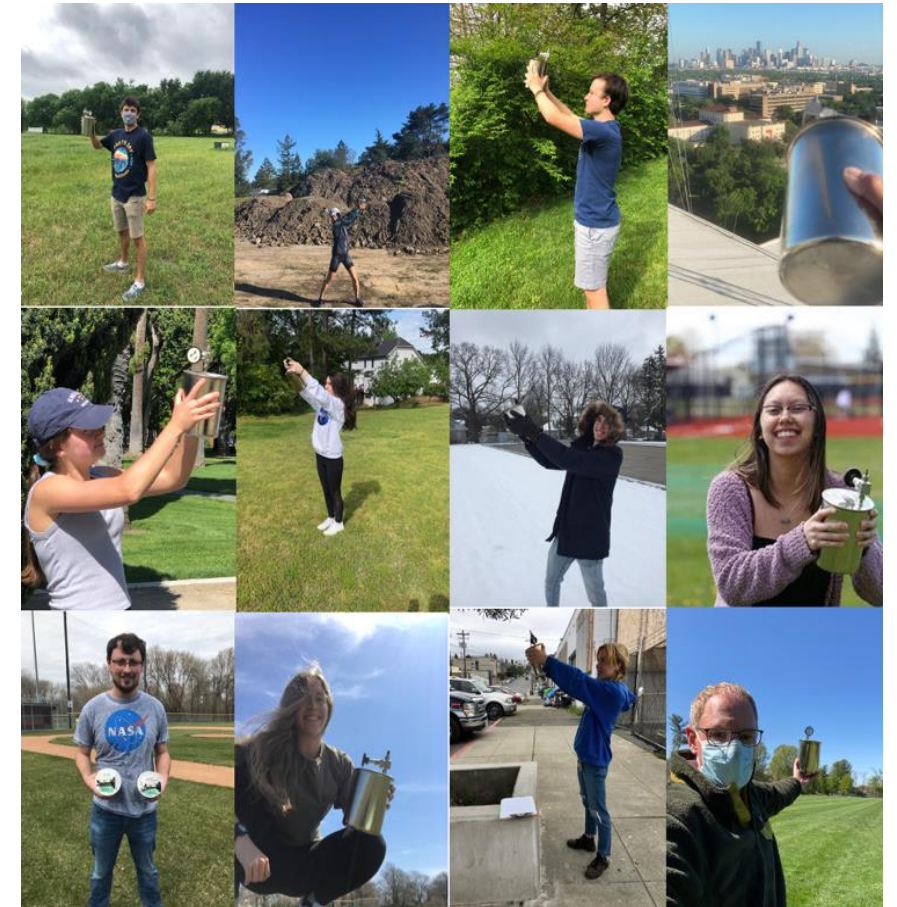
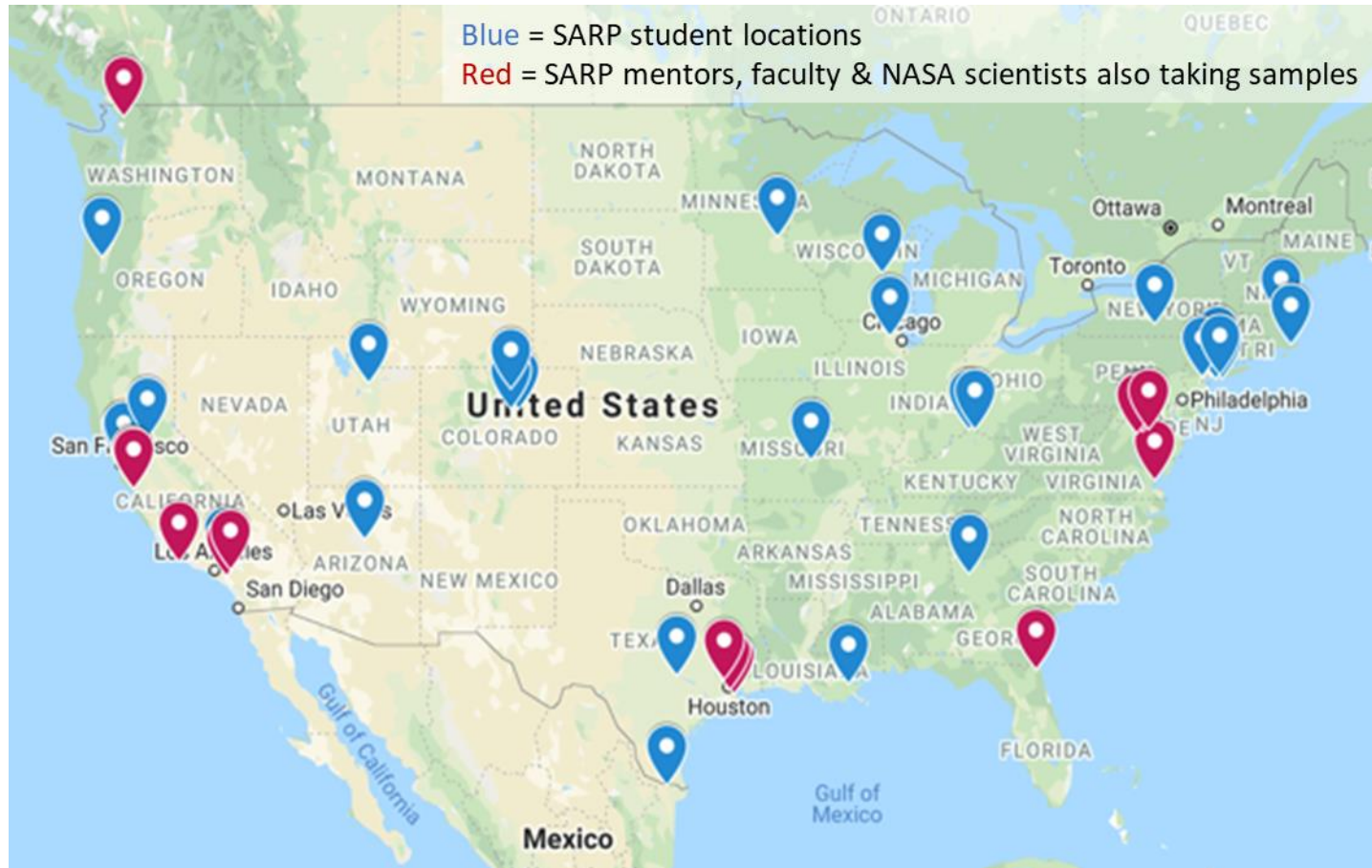
28 individual student research projects using data from 2009-2019 SARP flights, other airborne campaigns, satellites and ground stations



Hands-on at home group projects:

- Whole Air Sampling (WAS)
- Aerosol measurements

SARP at Home: Whole Air Sampling Group Project

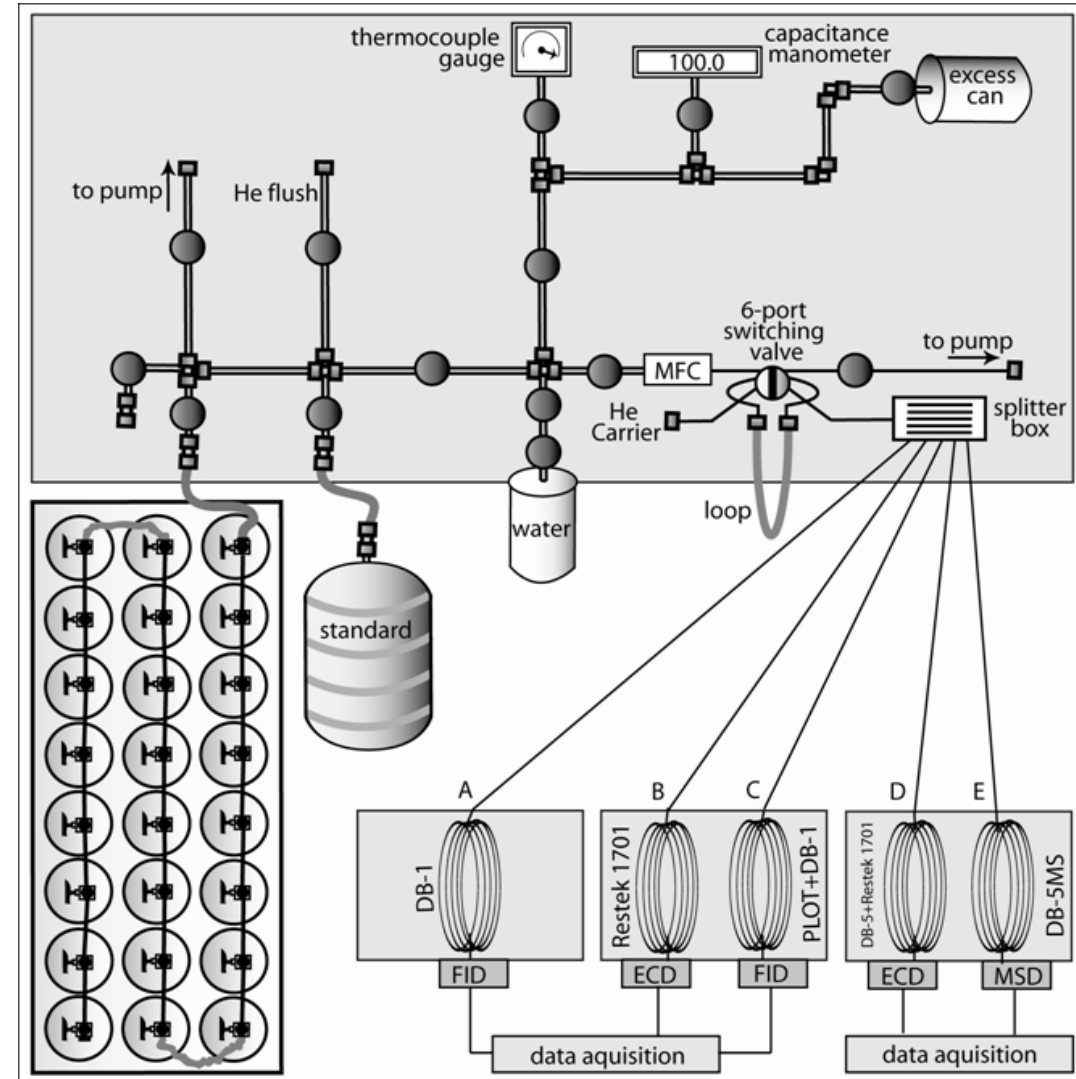


SARP students, mentors, faculty and NASA scientists took air samples near their homes that were subsequently analyzed for nearly 100 different trace gases

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. MeONO₂
20. EtONO₂
21. *i*-PrONO₂
22. *n*-PrONO₂
23. 2-BuONO₂
24. 2-PeONO₂
25. 3-PeONO₂
26. 3-Methyl-2-BuONO₂

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 | 67. HFC-227ea |
| 53. CFC-12 | 68. HFC-365mfc |
| 54. CFC-112 | 69. CH ₃ Cl |
| 55. CFC-113 | 70. CH ₃ Br |
| 56. CFC-114 | 71. CH ₃ I |
| 57. CCl ₄ | 72. CH ₂ Cl ₂ |
| 58. CH ₃ CCl ₃ | 73. CHCl ₃ |
| 59. H-1211 | 74. C ₂ HCl ₃ |
| 60. H-1301 | 75. C ₂ Cl ₄ |
| 61. H-2402 | 76. CH ₂ Br ₂ |
| 62. HCFC-22 | 77. CHBr ₃ |
| 63. HCFC-141b | 78. CHBrCl ₂ |
| 64. HCFC-142b | 79. CHBr ₂ Cl |
| 65. HFC-134a | 80. Ethyl chloride |
| 66. HFC-152a | 81. 1,2-Dichloroethane |

Sulfur Species

82. OCS
83. DMS

Oxygenates

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

Some VOC tracers

Oceans:

- MeONO₂

Biomass burning:

- Ethyne

Urban/industrial:

- C₂Cl₄

Solvents:

- Toluene

Natural gas:

- Ethane

Gas evaporation:

- *i*-Pentane

Vehicle exhaust:

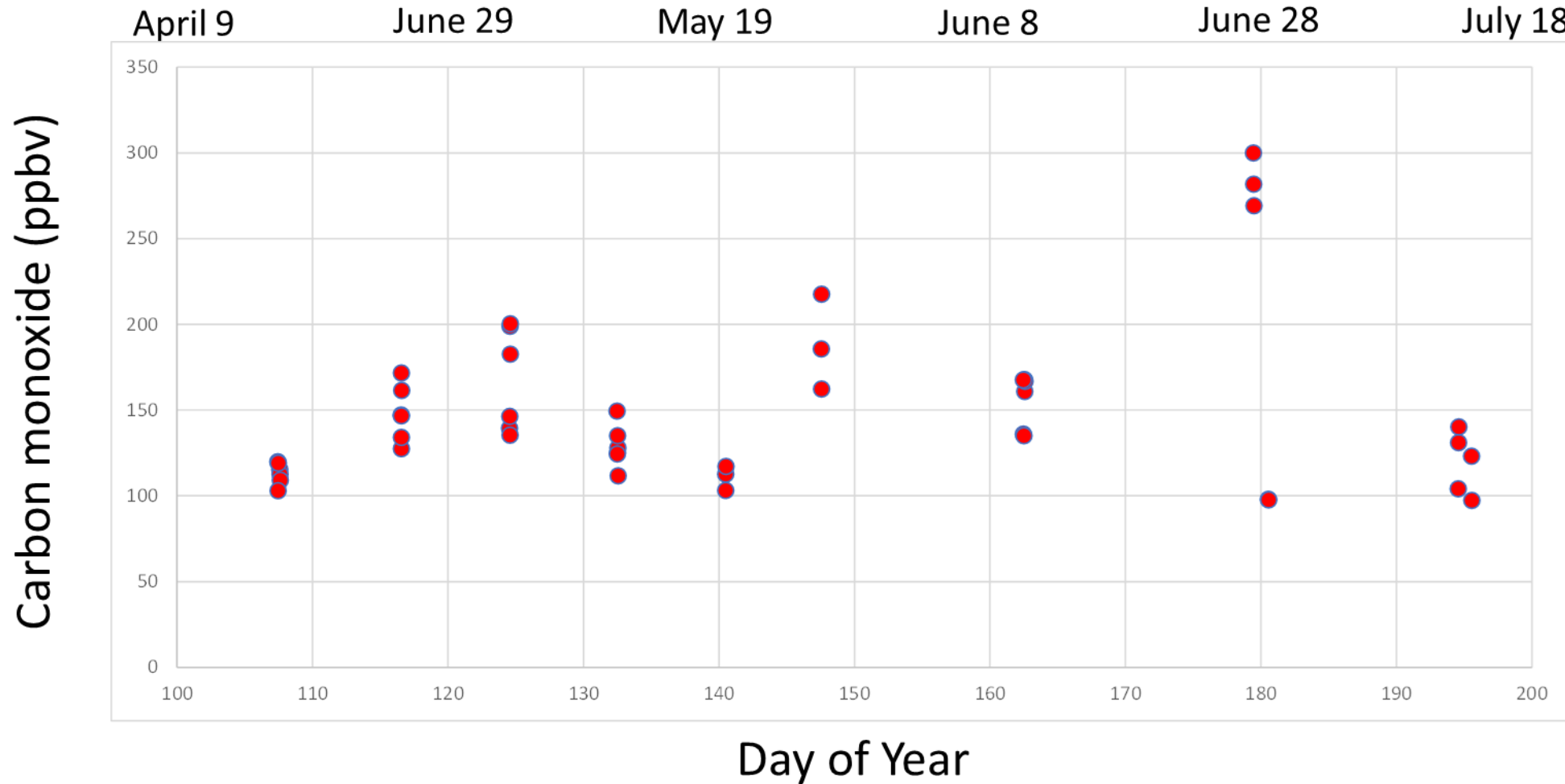
- Ethene

Biogenic:

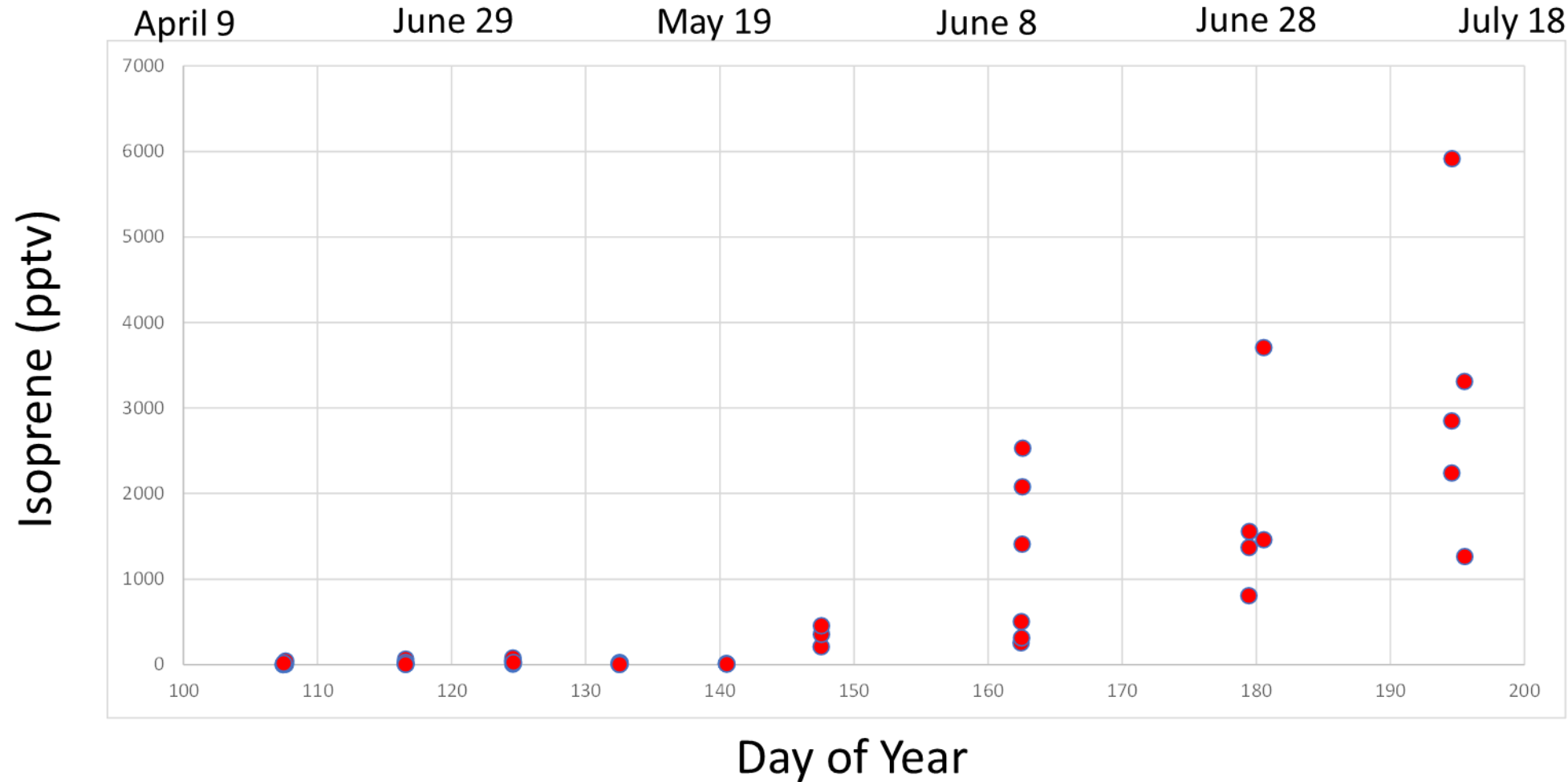
- Isoprene

GHG = greenhouse gas; VOC = volatile organic compound

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

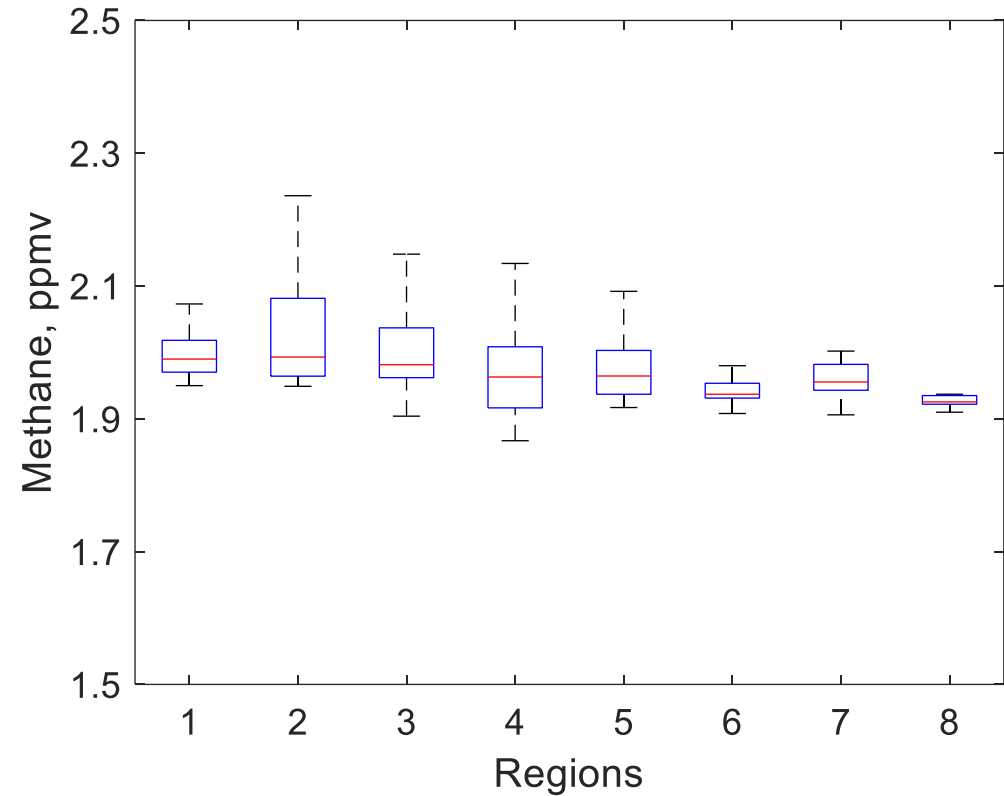
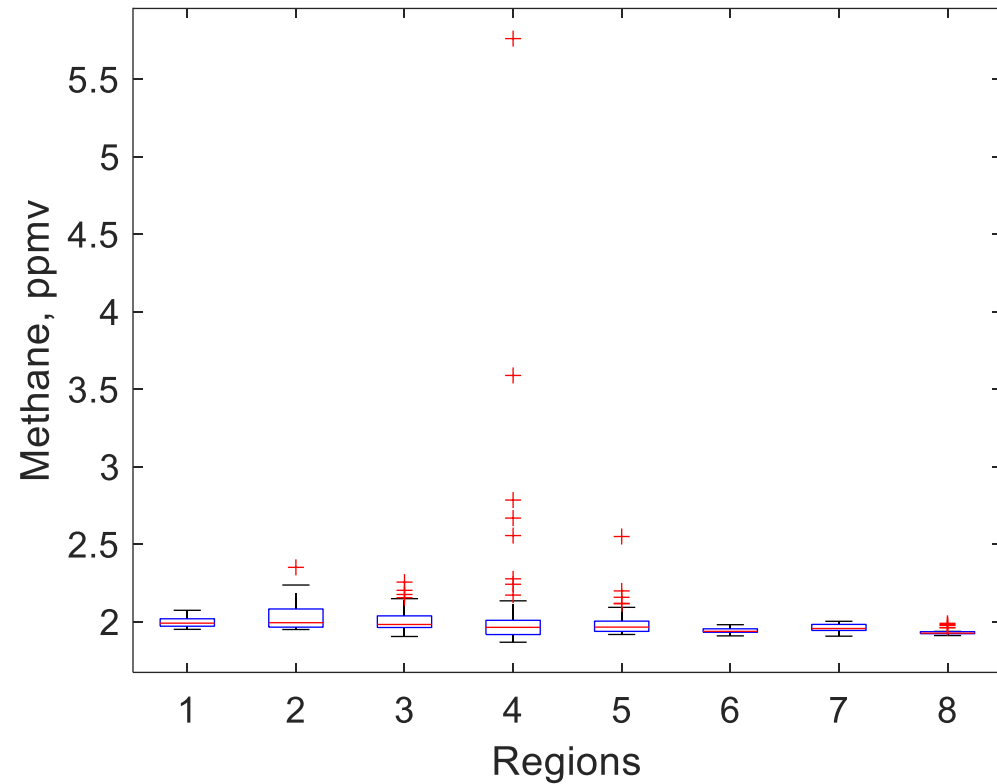


Isoprene time series: New Jersey and Connecticut samples



Methane

SARP 2020 ground samples



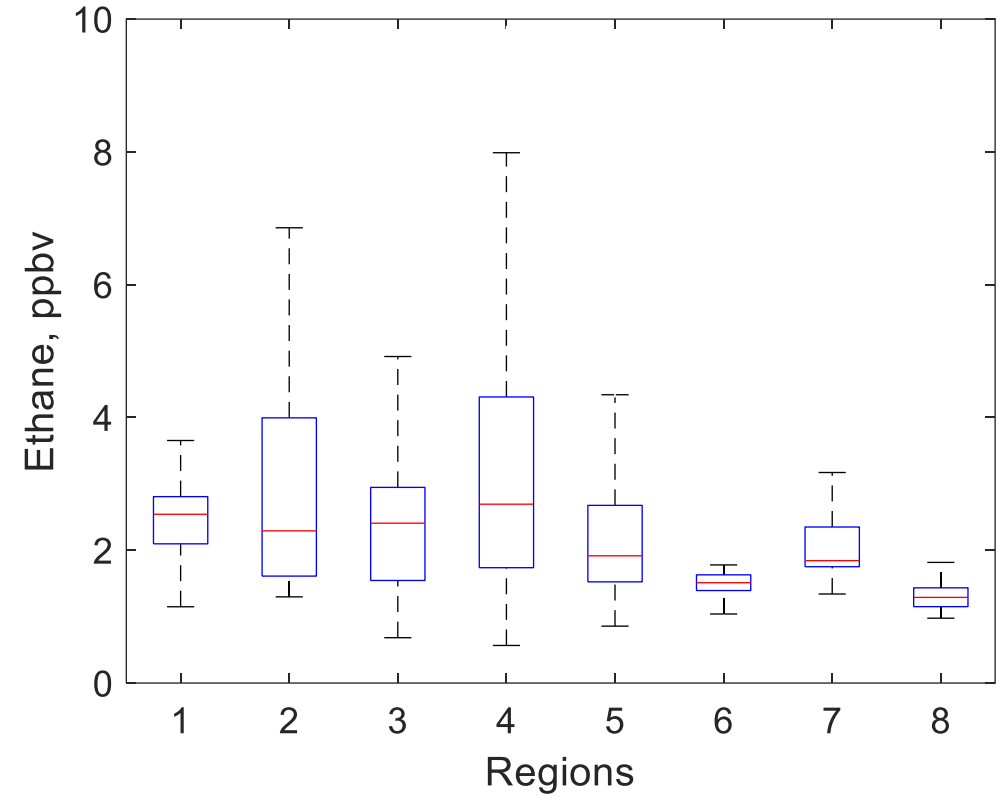
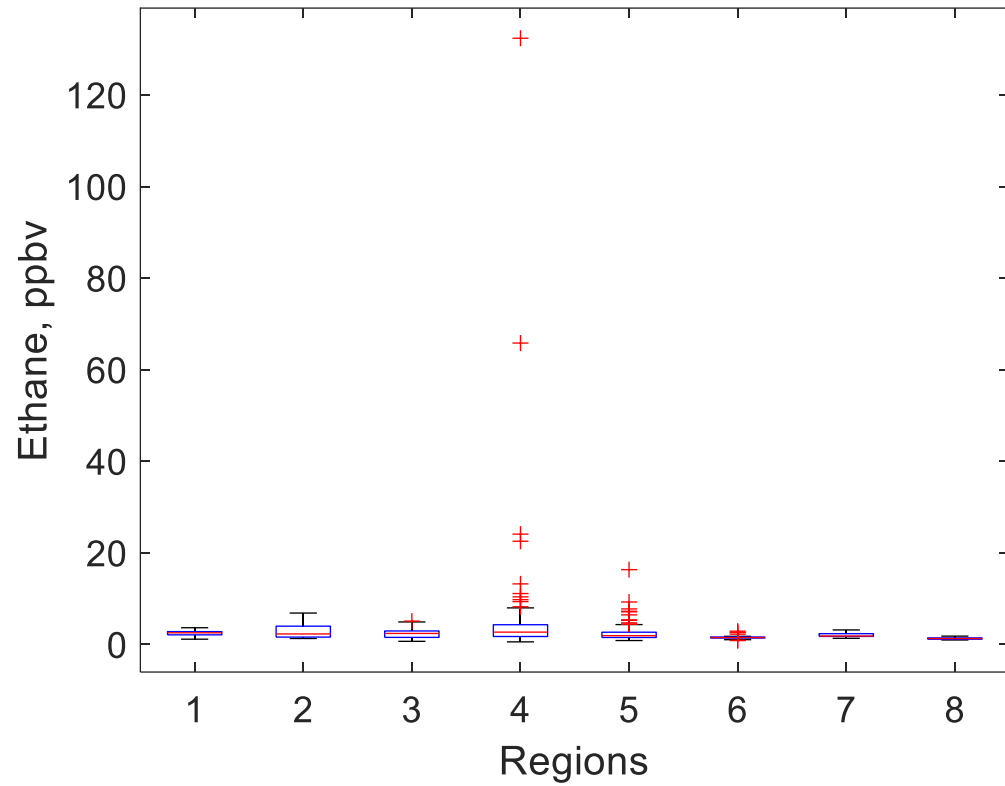
Regions

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



Ethane

SARP 2020 ground samples



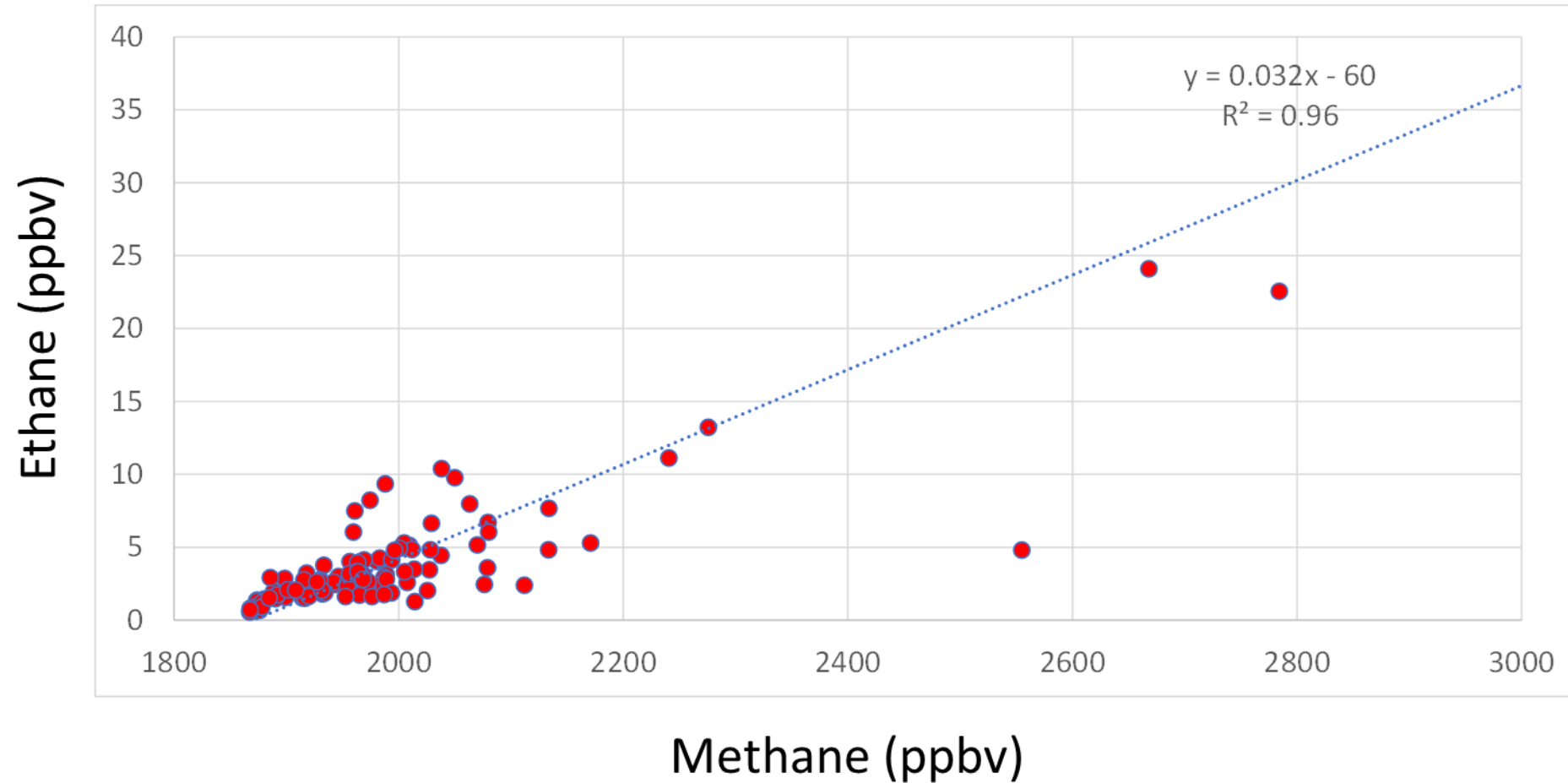
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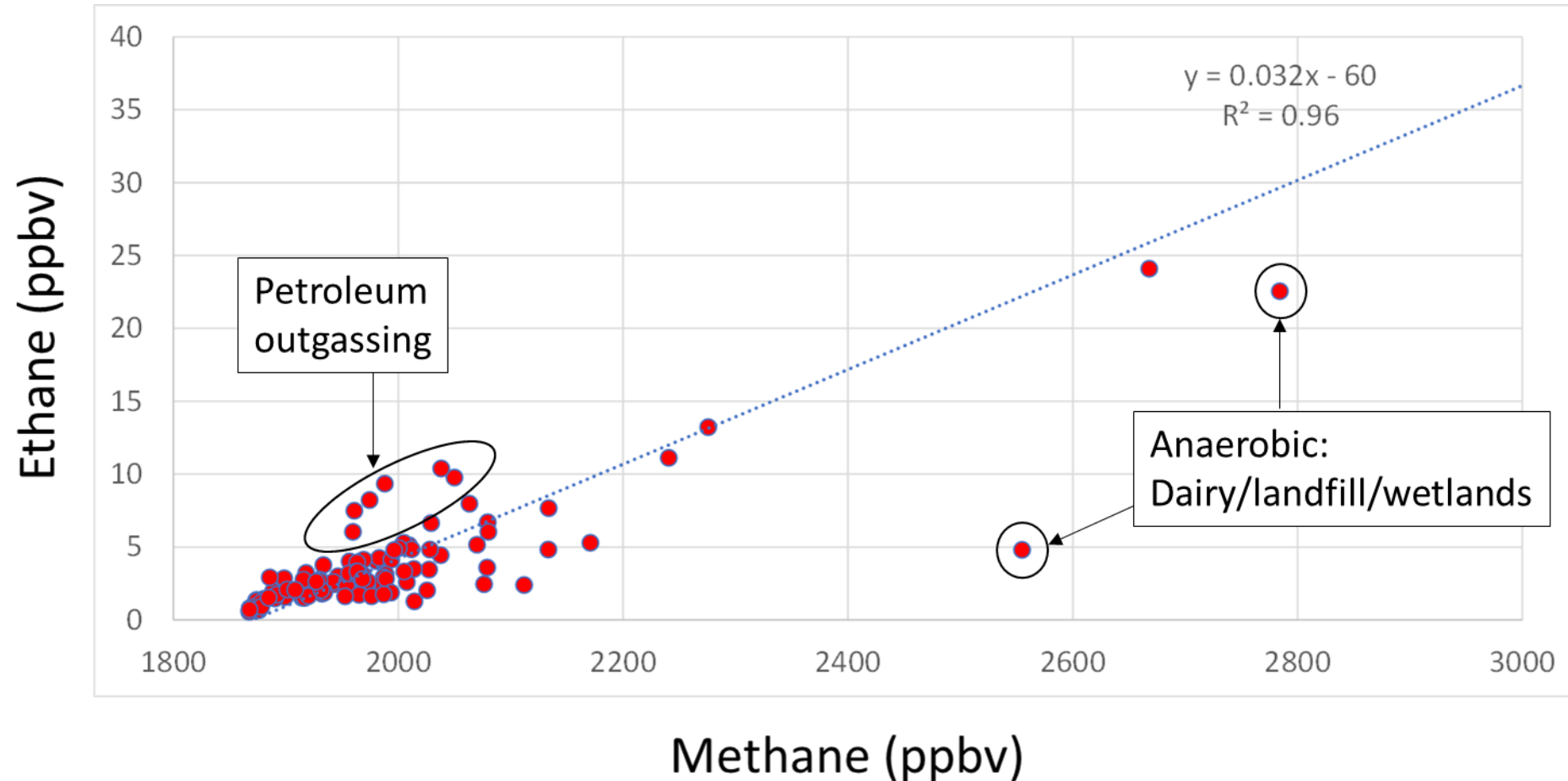
Ethane vs methane for Texas samples:

The slope of ~3% is consistent with natural gas



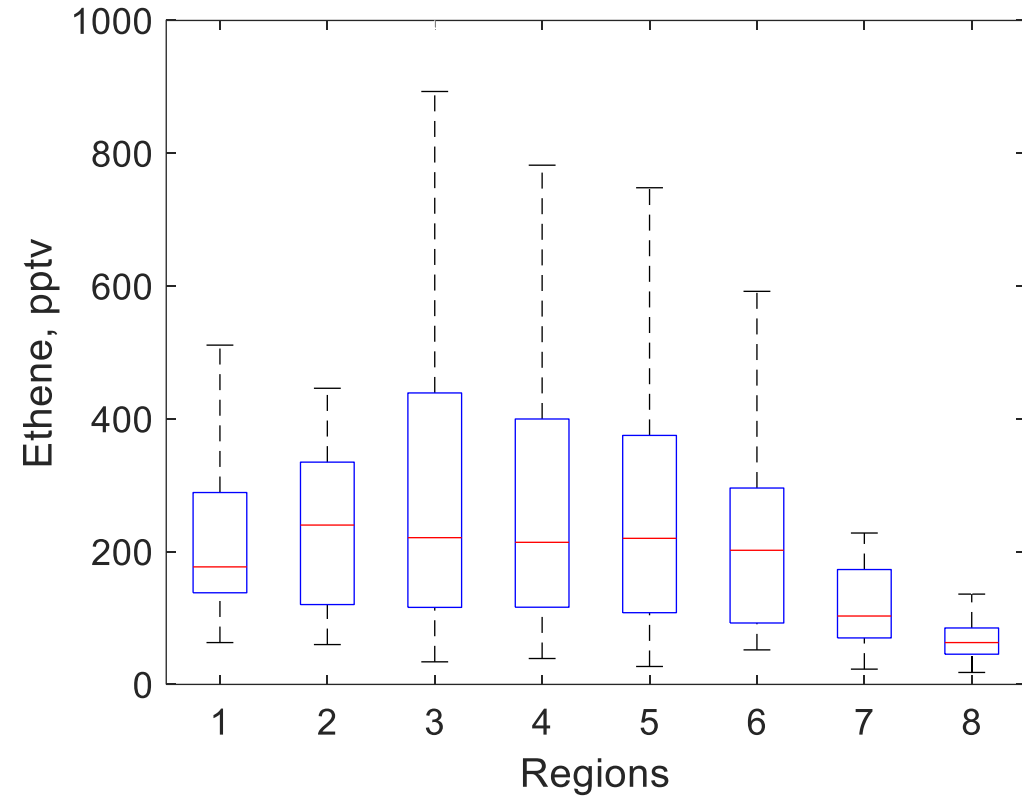
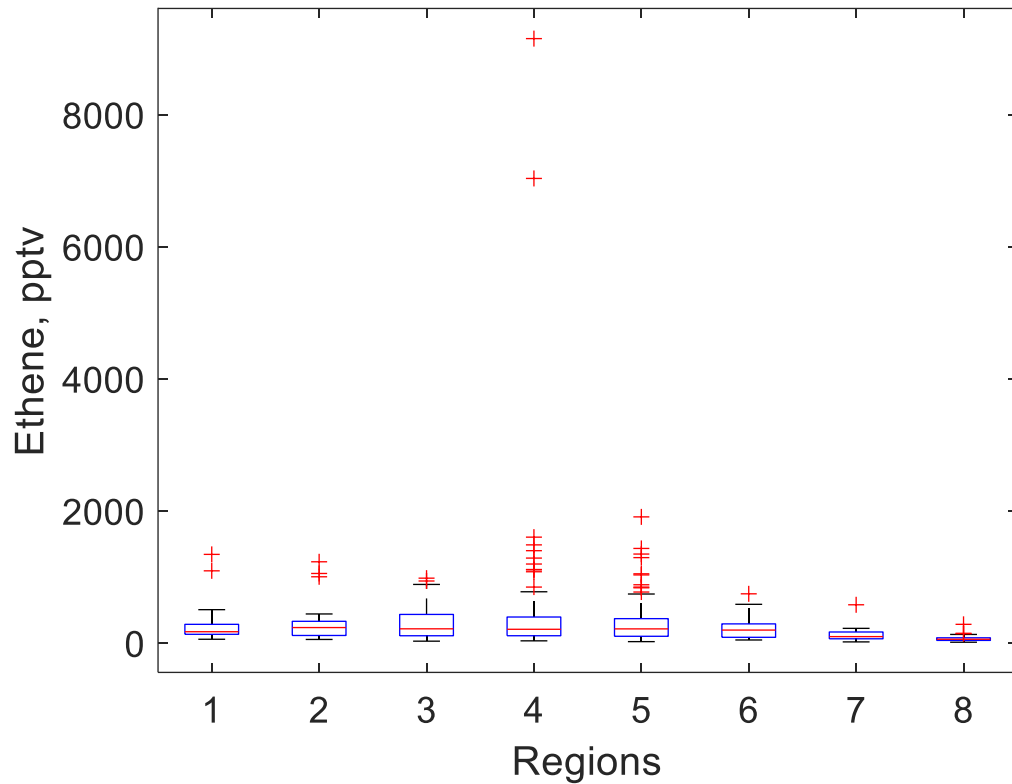
Ethane vs methane for Texas samples:

The slope of ~3% is consistent with natural gas



Ethene

SARP 2020 ground samples



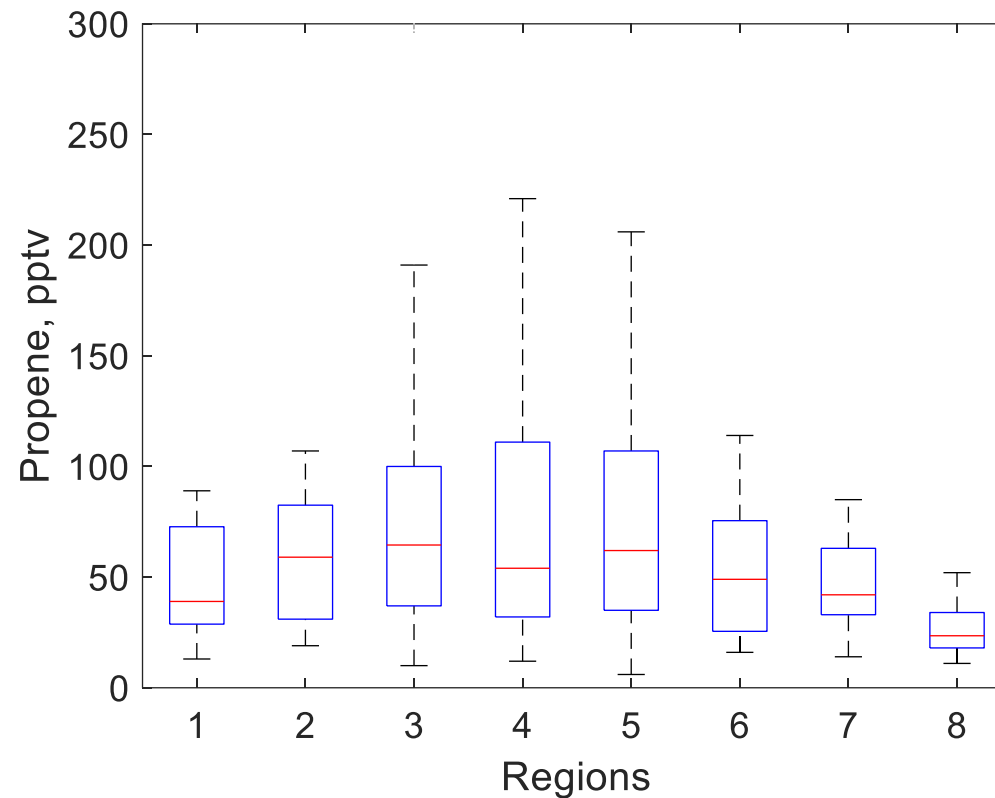
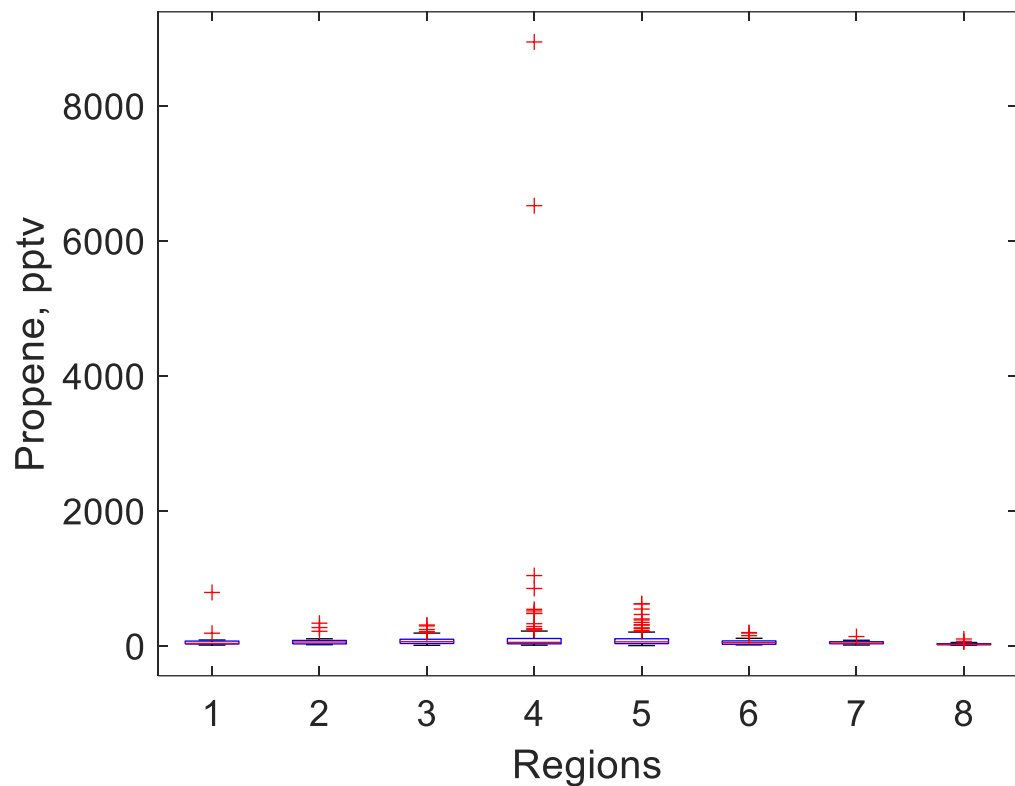
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Propene

SARP 2020 ground samples



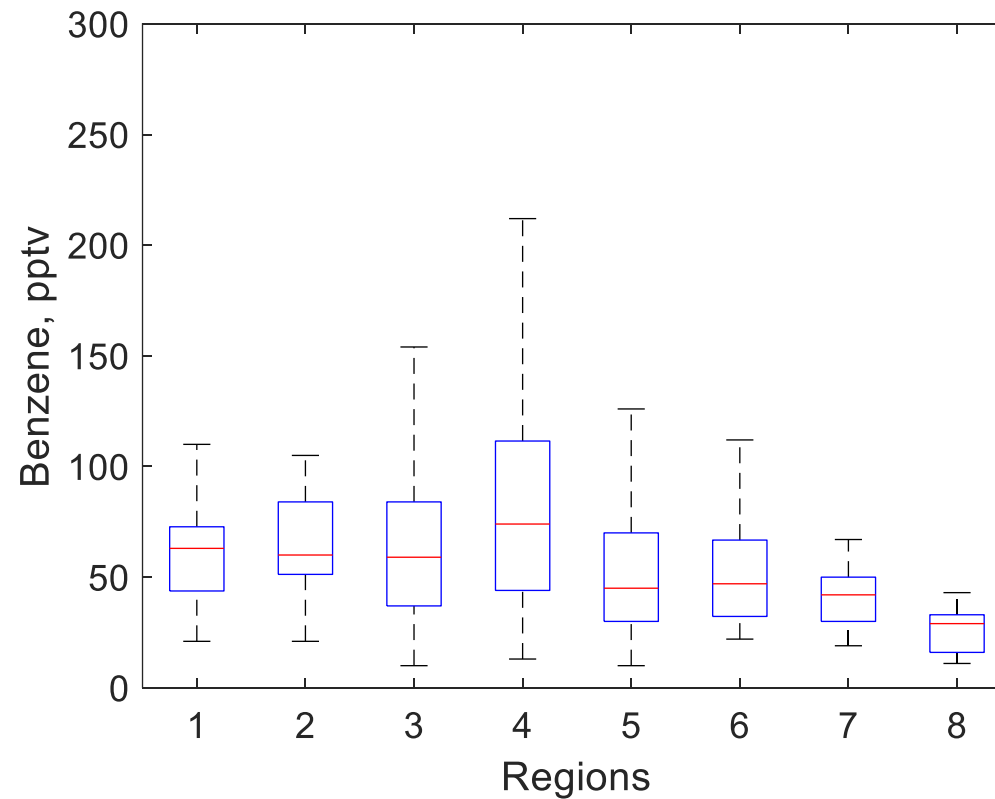
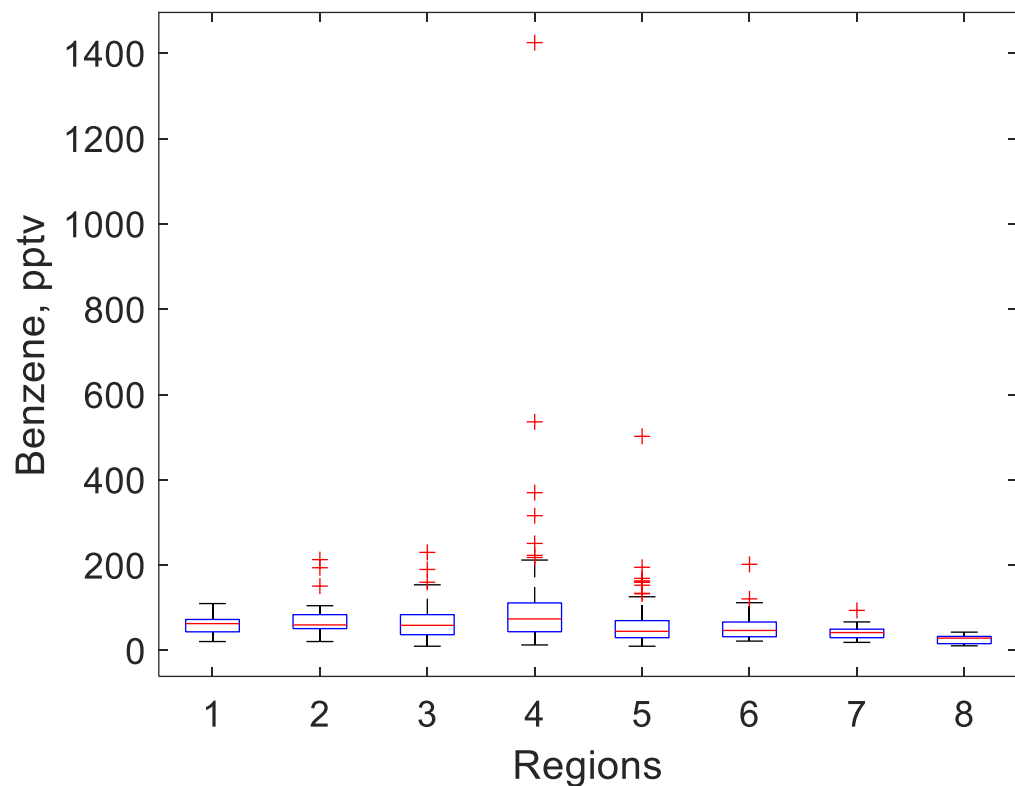
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Benzene

SARP 2020 ground samples



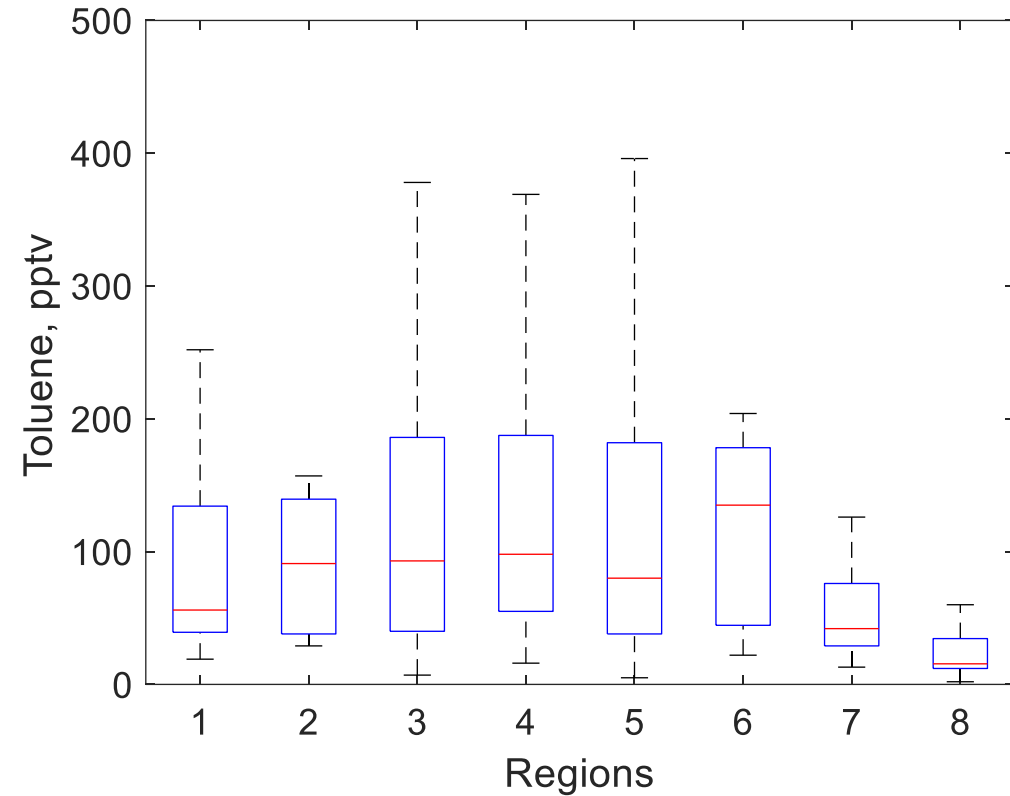
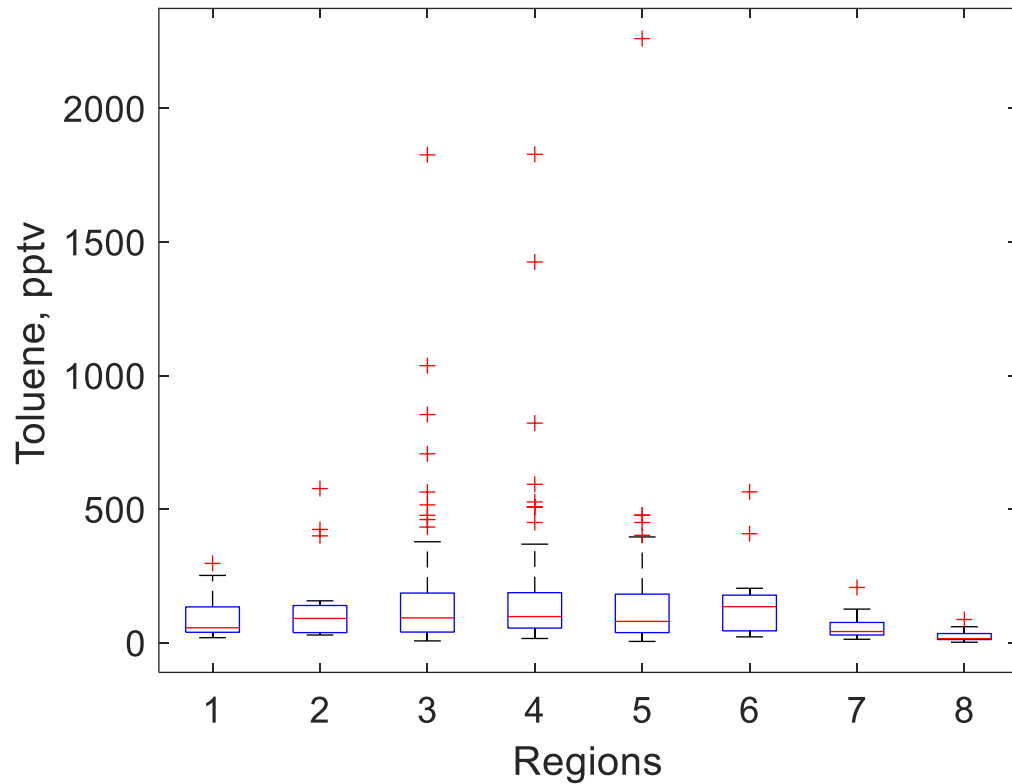
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Toluene

SARP 2020 ground samples



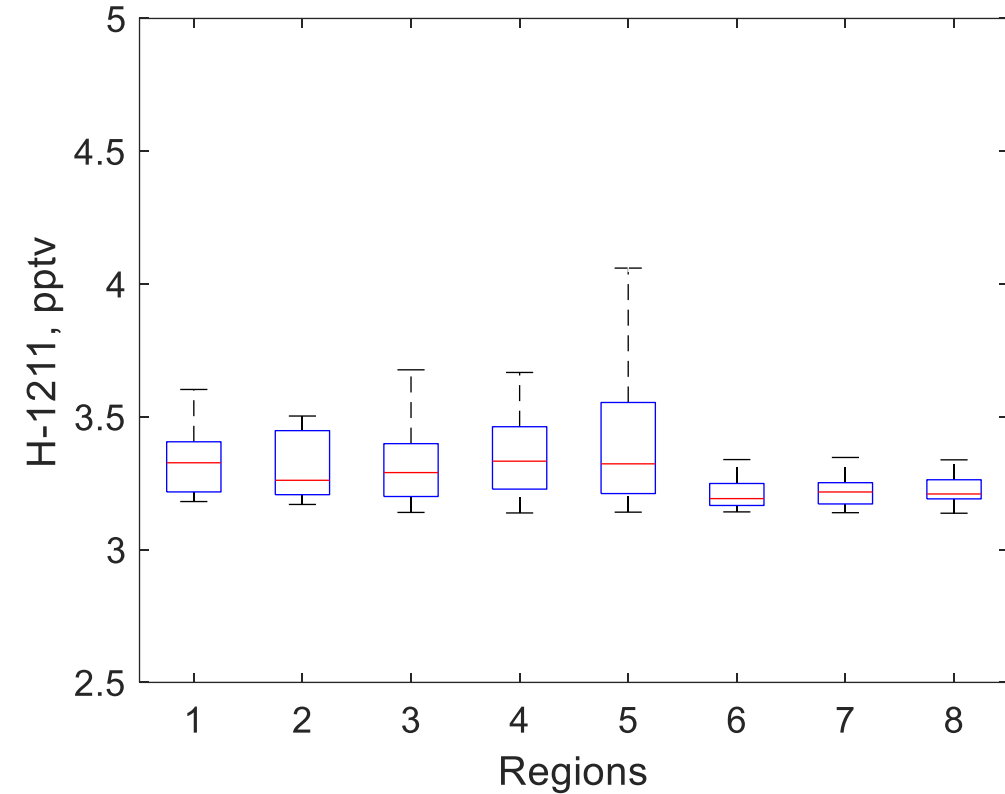
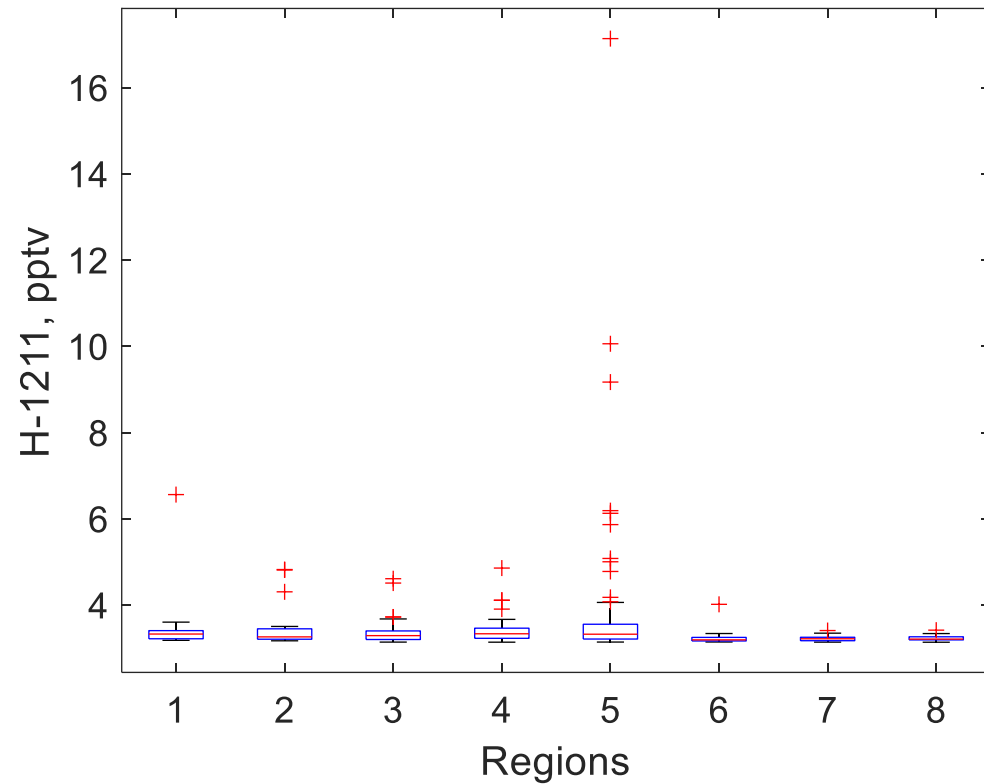
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Halon 1211

SARP 2020 ground samples



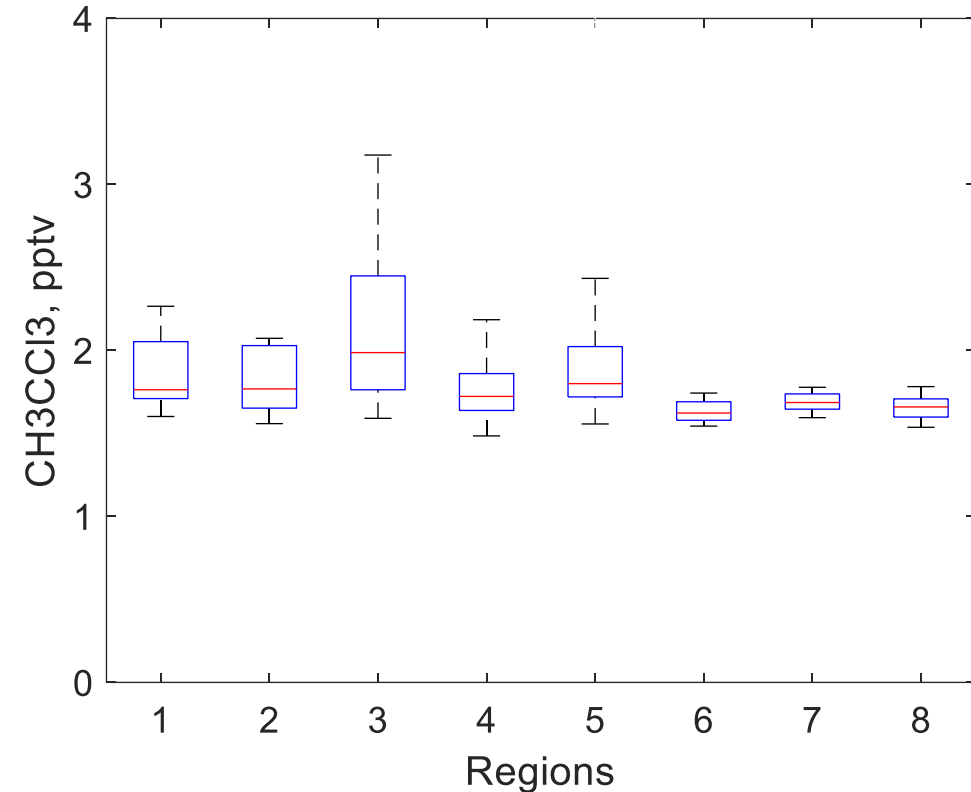
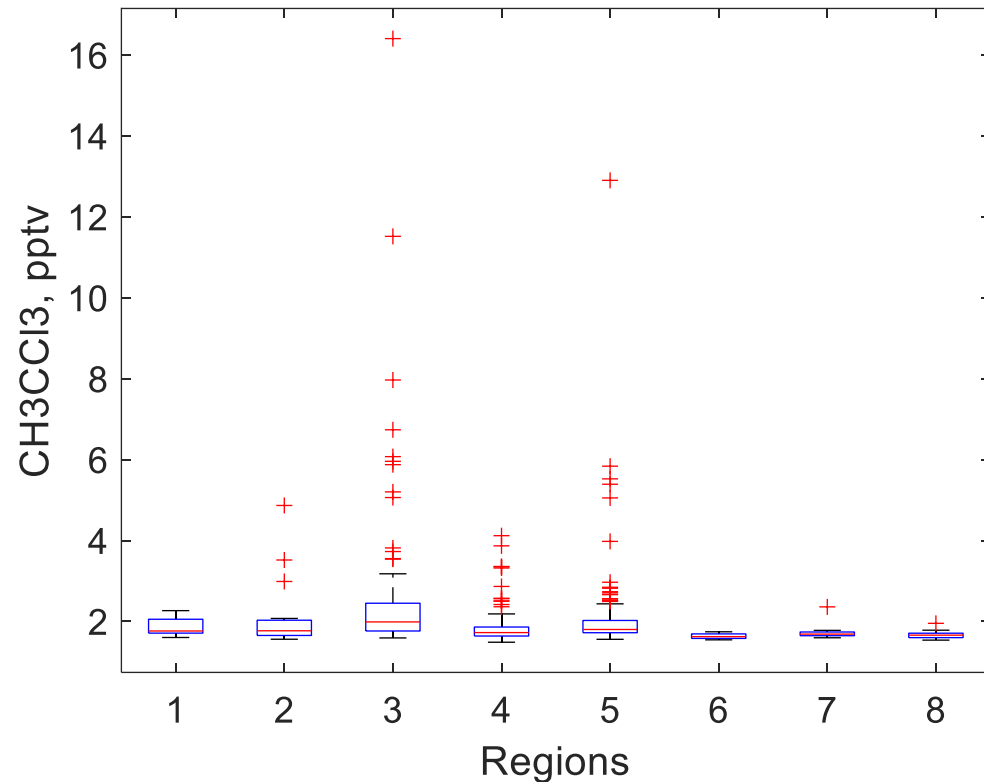
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Methyl chloroform (CH_3CCl_3)

SARP 2020 ground samples

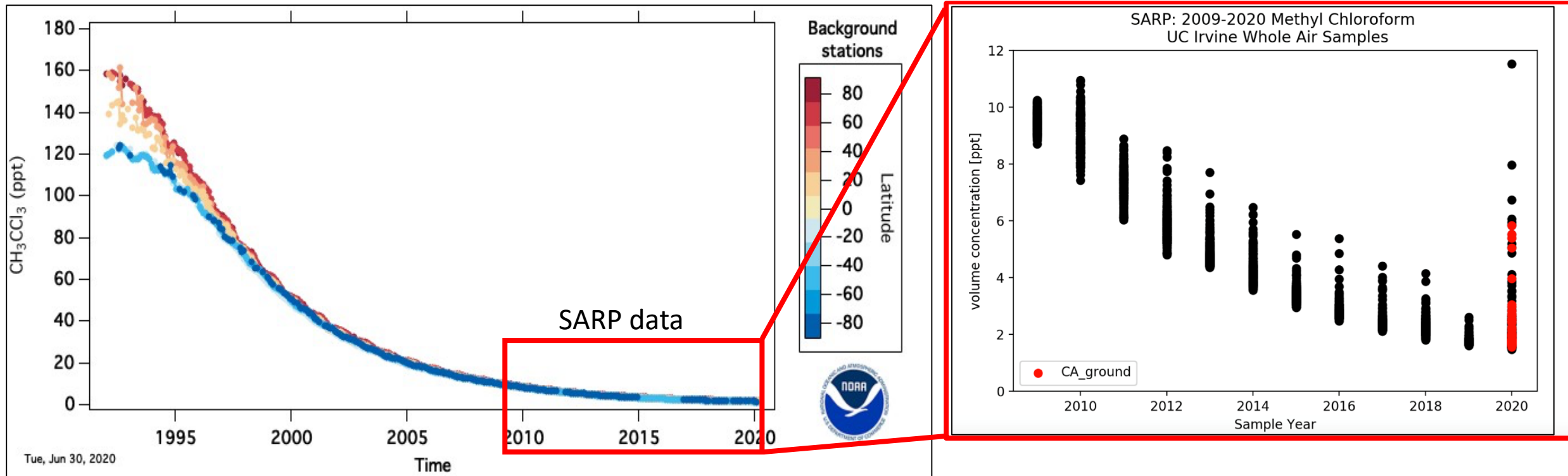


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SARP at Home, Preliminary Results: Methyl chloroform

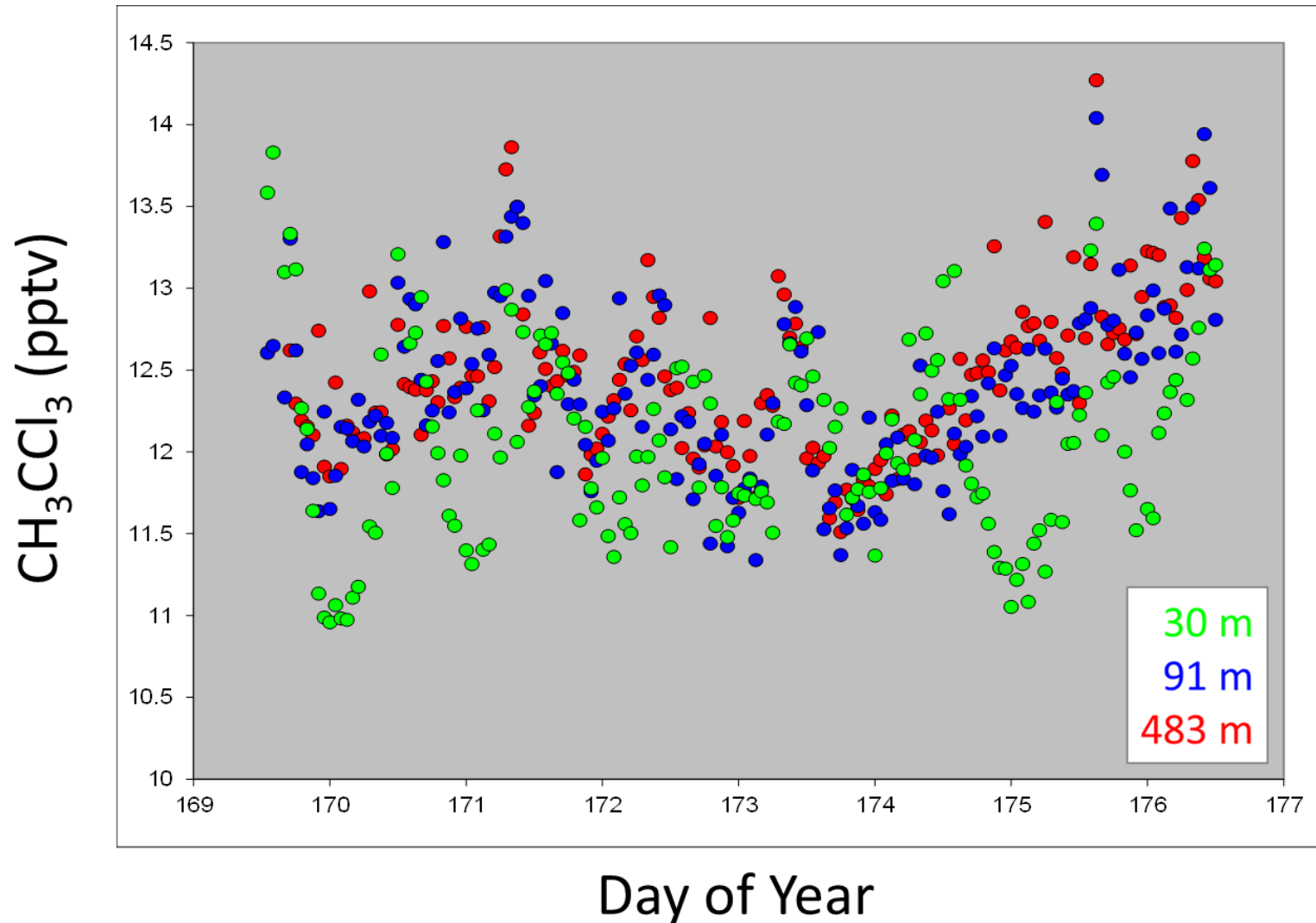


<https://www.esrl.noaa.gov/gmd/hats/gases/CH3CCl3.html>

- 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