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


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2University of California Irvine
3University of California - Irvine
4University of Houston
5Swarthmore College
6Saint John’s University
7Ripon College
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10Vanderbilt University
11University of Colorado - Colorado Springs
12Bowdoin College
13Northern Arizona University
14Missouri University of Science and Technology
15Tulane University
16Stanford University
17University of California - Santa Cruz
18Pomona College
19Amherst College
20University of Albany
21University of Chicago
22Johns Hopkins University
23Harvard University
24University of Connecticut
25Northern Kentucky University
26University of Texas - Rio Grande Valley
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

### 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

### Halocarbons (GHGs)
52. CFC-11
53. CFC-12
54. CFC-112
55. CFC-113
56. CFC-114
57. CCl₄
58. CH₃CCl₃
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

### 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
27. MeONO₂
28. EtONO₂
29. i-PrONO₂
30. n-PrONO₂
31. 2-BuONO₂
32. 2-PeONO₂
33. 3-PeONO₂
34. 3-Methyl-2-BuONO₂

### 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
92. Ethyl chloride
93. 1,2-Dichloroethane

GHG = greenhouse gas; VOC = volatile organic compound

### 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
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
2 = Connecticut
3 = New York
4 = Texas
5 = California
6 = Utah
7 = Missouri
8 = Oregon
Ethane
SARP 2020 ground samples

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

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

[Map of the United States with regions numbered and labeled]
Propene

SARP 2020 ground samples

Regions
1 = New Jersey
2 = Connecticut
3 = New York
4 = Texas
5 = California
6 = Utah
7 = Missouri
8 = Oregon
Benzene
SARP 2020 ground samples

Regions
1 = New Jersey
2 = Connecticut
3 = New York
4 = Texas
5 = California
6 = Utah
7 = Missouri
8 = Oregon
Toluene
SARP 2020 ground samples

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

[Map showing regions with corresponding numbers and states]
Halon 1211
SARP 2020 ground samples

Regions
1 = New Jersey
2 = Connecticut
3 = New York
4 = Texas
5 = California
6 = Utah
7 = Missouri
8 = Oregon
Methyl chloroform (CH$_3$CCl$_3$)
SARP 2020 ground samples

Regions
1 = New Jersey
2 = Connecticut
3 = New York
4 = Texas
5 = California
6 = Utah
7 = Missouri
8 = Oregon
SARP at Home, Preliminary Results: Methyl chloroform

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

https://www.esrl.noaa.gov/gmd/hats/gases/CH3CCl3.html
Hourly CH$_3$CCL$_3$ 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