



HEI Research Report 240

Predictive, Source-Oriented Modeling and Measurements to Evaluate Community Exposures to Air Pollutants and Noise from Unconventional Oil and Gas Development

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Additional Materials A: Chapter 3

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Additional Materials A: Chapter 3

Table A-1. Mobile Van Equipment

Instrument	Compounds Measured	Time Resolution of Measurements	Comments
VOCUS 2R PTR-LToF MS	Select hydrocarbons and oxygenated VOCs	1 s	e.g., unsaturated reduced and oxygenated HCs, cyclic, saturated and aromatic compounds
Picarro G2307	Methane (CH ₄), HCHO, H ₂ O	1 s	
QuantAQ Modulair	NO ₂ /NO/NO _x , CO, O ₃	5s	
Thermo	Ozone (O ₃)	1 s	
Thermo	H ₂ S, SO ₂	80 s	
LI-840	CO ₂ , H ₂ O	1 s	
AE33 Magee Aethalometer	Black carbon	1 s	
RMYoung 31000	T winds, p	1 s	
Range finder	Flare distance and height	manual	Derive the height of flares or stack plumes and the distance
T, RH HOBO	RH, T	1 s	
GPS and dashcam	lat/lon/velocity	1 s	van position, CSI

Table A-2. Exponential Time Constants and Averaging Times of B&K 2245

Time Weighting	Time Constant (seconds)	Averaging Time (seconds)
Fast	0.125	0.25
Slow	1	2

Table A-3. Multi-component calibration mixture

Compound	CAS#	Concentration (ppb)	Uncertainty
Methanol	67-56-1	541	±5%
Acetonitrile	75-05-8	491	±5%
Propanal	123-38-6	477	±5%
Benzene	71-43-2	510	±5%
Hexanal	66-25-1	499	±5%
Hexamethylcyclotrisiloxane (D3)	541-05-9	501	±5%
<i>m</i> -Xylene	108-38-3	492	±5%
Styrene	100-42-5	499	±5%
α -Pinene	80-56-8	127	±5%
β -Pinene	18172-67-3	121	±5%
Octamethylcyclotetrasiloxane (D4)	556-67-2	502	±5%
3-Carene	13466-78-9	118	±5%
<i>p</i> -Isopropyltoluene	99-87-6	470	±5%
Limonene	5889-54-8	130	±5%
Acetophenone	98-86-2	482	±5%
Decamethylcyclopentasiloxane (D5)	541-02-6	502	±5%
Dodecamethylcyclohexasiloxane (D6)	540-97-6	181	±5%

Uncertainty is a conservative estimate of the combination of the uncertainties of the gravimetric preparation and analysis.

Table A-4. Enhancement mixing ratios for select VOC markers [ppb], CO₂ [ppm], CH₄ [ppm], and Black Carbon (BC) [ng/m³], along with calculated destruction removal efficiency (DRE) and source location

<i>Chemical Formula</i>	<i>C6H6 OH+</i>	<i>C10H8 OH+</i>	<i>C2H4 OH+</i>	<i>C7H6 OH+</i>	<i>C10H8 OH+</i>	<i>C6H6 +</i>	<i>C7H8 H+</i>	<i>C8H10 OH+</i>	<i>C8H8 H+</i>	<i>C2H6 SH+</i>	<i>C10H16 OH+</i>	<i>C8H8 OH+</i>	<i>CO2</i>	<i>CH4</i>	<i>BC</i>	<i>DRE</i>	<i>LAeq [dB]</i>	<i>LAF max [dB]</i>	<i>LAF min [dB]</i>	<i>Lcpe ak [dB]</i>	<i>Latitude [degrees]</i>	<i>Longitude [degrees]</i>
<i>Flare 1</i>	0.09769	0	2.295	0	0.0009407	1.568	0.9870	2.903	0.03252	0	0	0	11.33	1.135	--	88.08	--	--	--	--	28.866	-97.903
<i>Flare 2</i>	0.06299	0	0.2668	0	0.01731	1.273	0.3993	0.2170	0.001757	0.003642	0.008059	0	27.59	0.3298	--	98.41	--	--	--	--	28.967	-97.826
<i>Flare 3</i>	0.004269	0	0.2072	0	0	0.1120	0.01575	0.01855	0	0	0	0	14.68	0.3375	--	96.99	--	--	--	--	28.968	-97.822
<i>Flare 4</i>	0.1464	0	0.1805	0	0	2.969	1.057	0.9950	0.01863	0.0004583	0.002812	0	7.240	0.04544	--	99.16	--	--	--	--	29.034	-97.811
<i>Flare 5</i>	0.006198	0	0.4174	0	0	0.03576	0.03264	0.2350	0	0.0005482	0	0	19.30	0.4144	--	97.18	--	--	--	--	29.034	-97.819
<i>Flare 2</i>	0.04616	0	0.4016	0.003070	0.01771	0.9811	0.04616	0.09053	0.001060	0.007379	0.004438	0	19.66	4.477	--	76.47	--	--	--	--	28.967	-97.826
<i>Flare 5</i>	0.003834	0	1.377	0.009573	0	0.1313	0.003834	0.1515	0	0.0001413	0.008681	0	49.72	1.070	--	97.18	--	--	--	--	29.034	-97.819
<i>Flare 5</i>	0.01030	0	1.808	0.0002907	0	0.1545	0.01030	0.01743	0	0.0004954	0	0	61.52	1.170	--	97.49	--	--	--	--	29.034	-97.820
<i>Flare 3</i>	0.006767	0	0.4589	0.005900	0.0006704	0.04143	0.02503	0.05009	0.004187	0.003238	0	0	14.80	0.4048	--	96.44	--	--	--	--	28.969	-97.824
<i>Flare 6</i>	0.03270	0	0.006066	0.0001019	0.001149	0.6231	0.05576	0	0	0	0	0	5.457	0.2085	--	95.09	--	--	--	--	29.031	-97.71

																						4
<i>Flare 7</i>	1.196	0.000 2441	16.54	0.009 228	0.139 8	21.27	14.15	20.09	0.557 4	0.027 66	0.003 786	0	30.93	1.067	--	95.55	--	--	--	--	28.93 6	- 97.86 1
<i>Flare 2</i>	0.015 37	0	0.600 7	0	0	0.721 7	0.137 3	0.073 92	0	0.003 147	0.020 50	0	27.44	0.438 6	102.9	97.89	71.17	72.36	69.07	86.27	28.96 6	- 97.82 3
<i>Flare 8</i>	0.011 11	0.000 2362	0.890 7	0.007 883	0.012 52	0.238 2	0.073 48	0.067 92	0	0	0.012 02	0	27.57	1.649	80.27	92.52	68.28	68.63	67.79	97.01	28.94 3	- 97.64 5
<i>Flare 9</i>	0.006 185	0	1.411	0.005 367	0.003 658	0.148 7	0.096 19	0.058 25	0	0	0.000 1295	0	45.48	1.169	19.12	96.64	62.14	63.41	61.79	85.42	28.97 3	- 97.67 4
<i>Flare 10</i>	0.003 668	0	0.959 0	0.001 908	0	0.096 07	0.036 08	0.014 29	0	0.003 115	0.003 343	0	16.02	1.261	142.2	90.39	63.36	63.69	62.53	88.31	28.98 8	- 97.64 2
<i>Flare 11</i>	0.004 468	0	0.586 5	0.002 207	0	0.078 62	0.032 18	0.032 84	0	0.001 471	0	0	22.40	1.442	55.77	92.00	63.37	63.73	63.12	84.01	29.00 1	- 97.65 5
<i>Flare 12</i>	0.018 68	0	0.823 1	0.005 576	0.002 025	0.180 7	0.137 3	0.134 3	0	0	0.034 29	0	51.28	0.608 4	1311 0	98.42	60.16	60.93	59.34	80.76	28.87 1	- 97.89 0
<i>min</i>	0.003 668	0	0.006 066	0	0	0.035 76	0.003 834	0	0	0	0	0	5.457	0.045 44	19.12	76.47	60.16	60.93	59.34	80.76		
<i>max</i>	1.196	0.000 2441	16.54	0.009 573	0.139 8	21.27	14.15	20.09	0.557 4	0.027 66	0.034 29	0	61.52	4.477	1311 0	99.16	71.17	72.36	69.07	97.01		
<i>mean</i>	0.098 38	0	1.719	0.003 006	0.011 52	1.801	1.018	1.479	0.036 21	0.003 017	0.005 768	0	26.61	1.013	2252	94.46	64.75	65.46	63.94	86.96		
<i>median</i>	0.011 11	0	0.600 7	0.001 908	0.000 6704	0.180 7	0.055 76	0.073 92	0	0.000 4954	0.002 812	0	22.40	1.067	91.60	96.64	63.36	63.71	62.82	85.84		

Table A-5. Emission ratios of methane and VOCs observed at the flaring sites (ppmCH₄/ppmCO₂, pptVOC/ppmCO₂)

<i>Chemical Formula</i>	CH₄	C₆H₆O H+	C₁₀H₈O H+	C₂H₄O H+	C₇H₆O H+	C₁₀H₈H +	C₆H₆+ +	C₇H₈H +	C₈H₁₀H +	C₈H₈H +	C₂H₆S H+	C₁₀H₁₆ H+	C₈H₈O H+
<i>Flare 1</i>	0.1002	8.623	0	202.6	0	0.08304	138.4	87.12	256.3	2.870	0	0	0
<i>Flare 2</i>	0.01195	2.283	0	9.668	0	0.6274	46.12	14.47	7.865	0.06369	0.1320	0.2921	0
<i>Flare 3</i>	0.02300	0.2908	0	14.12	0	0	7.631	1.073	1.264	0	0	0	0
<i>Flare 4</i>	0.006275	20.23	0	24.93	0	0	410.1	146.0	137.4	2.573	0.06330	0.3884	0
<i>Flare 5</i>	0.02146	0.3211	0	21.62	0	0	1.852	1.691	12.17	0	0.02840	0	0
<i>Flare 2</i>	0.2278	2.348	0	20.43	0.1561	0.9006	49.91	2.348	4.605	0.05391	0.3754	0.2257	0
<i>Flare 5</i>	0.02151	0.07712	0	27.69	0.1925	0	2.641	0.07712	3.048	0	0.002841	0.1746	0
<i>Flare 5</i>	0.01902	0.1674	0	29.40	0.004725	0	2.511	0.1674	0.2833	0	0.008053	0	0
<i>Flare 3</i>	0.02735	0.4572	0	31.00	0.3986	0.04529	2.799	1.691	3.384	0.2829	0.2187	0	0
<i>Flare 6</i>	0.03821	5.992	0	1.112	0.01867	0.2105	114.2	10.22	0	0	0	0	0
<i>Flare 7</i>	0.03450	38.65	0.007893	534.6	0.2983	4.521	687.7	457.6	649.4	18.02	0.8941	0.1224	0
<i>Flare</i>	0.01598	0.5599	0	21.89	0	0	26.30	5.005	2.694	0	0.1147	0.7470	0

2													
<i>Flare</i>													
8	0.05982	0.4030	0.008568	32.31	0.2860	0.4542	8.641	2.666	2.464	0	0	0.4362	0
<i>Flare</i>													
9	0.02570	0.1360	0	31.03	0.1180	0.08044	3.270	2.115	1.281	0	0	0.002848	0
<i>Flare</i>													
10	0.07869	0.2289	0	59.85	0.1191	0	5.995	2.252	0.8919	0	0.1944	0.2086	0
<i>Flare</i>													
11	0.06437	0.1994	0	26.18	0.09851	0	3.509	1.436	1.466	0	0.06568	0	0
<i>Flare</i>													
12	0.01187	0.3643	0	16.05	0.1087	0.03949	3.524	2.678	2.618	0	0	0.6687	0
<i>min</i>	0.006275	0.07712	0	1.112	0	0	1.852	0.07712	0	0	0	0	0
<i>max</i>	0.2278	38.65	0.008568	534.6	0.3986	4.521	687.7	457.6	649.4	18.02	0.8941	0.7470	0
<i>mean</i>	0.04633	4.784	0.0009683	64.97	0.1058	0.4095	89.12	43.45	63.95	1.404	0.1234	0.1922	0
<i>median</i>	0.02570	0.4030	0	26.18	0.09851	0.03949	7.631	2.348	2.694	0	0.02840	0.1224	0

Table A-6. Limit of detection (LOD), mean, maximum, and minimum concentrations of VOCs measured by the Auto-GC during the spring campaign (March 24 – May 12) and fall campaign (October 16 – November 16)

Compound	LOD [ppb]	<i>Spring Campaign</i>		<i>Fall Campaign</i>	
		Mean [ppb]	Max [ppb]	Mean [ppb]	Max [ppb]
Ethane	0.2	27.13	569.31	41.97	626.05
Propane	0.1	17.83	440.45	25.01	379.52
n-Butane	0.1	8.20	202.97	11.22	185.66
n-Pentane	0.08	2.55	84.52	3.33	61.59
n-Hexane	0.07	0.68	22.92	0.90	18.33
n-Heptane	0.06	0.18	6.53	0.25	5.17
n-Octane	0.05	0.07	2.04	0.11	2.10
n-Nonane	0.04	0.02	0.65	0.19	8.33
n-Decane	0.04	0.02	0.53	0.21	6.46
Propylene	0.1	0.03	1.57	0.14	2.21
Isobutane	0.1	3.94	91.55	5.71	92.56
1,3-Butadiene	0.1	0.03	0.52	0.03	0.28
Cyclopentane	0.08	0.07	2.28	0.10	1.32
Cyclohexane	0.07	0.12	4.40	0.18	2.77
Methylcyclohexane	0.06	0.15	4.25	0.22	3.43
Benzene	0.07	0.09	2.34	0.14	1.58
Toluene	0.06	0.16	2.84	0.21	2.96
Ethylbenzene	0.08	0.01	0.23	0.02	0.49
m/p Xylene	0.05	0.06	1.32	0.10	2.14
o-Xylene	0.05	0.01	0.36	0.02	0.72
Styrene	0.05	0.01	0.72	0.04	8.93
Isoprene	0.08	0.03	0.41	0.03	0.60

Table A-7. Limit of detection (LOD), mean, maximum, and minimum concentrations of VOCs measured by the Vocus during its stationary period from April 3-27

*Limit of detection varied over time due to changing instrument sensitivity, so the campaign average is shown.

Compound	LOD* [ppb]	Mean [ppb]	Max [ppb]
Benzaldehyde	0.01	0.013	7.2
Acetophenone	0.1	0.058	0.980.35
Naphthalene	0.002	0.0045	1.0
Total Naphthols	0.001	0.00084	0.96
Total Monoterpenes	0.02	0.025	1.5
Acetaldehyde	0.04	0.75	47
Dimethylsulfide	0.001	0.074	9.6
Phenol	0.03	0.14	2.2
Styrene	0.02	0.026	9.0
Benzene	0.02	0.17	32
Toluene	0.02	0.15	2.4
Total C8 Alkyl-Aromatic	0.008	0.0082	0.50

Table A-8. Limit of detection (LOD), mean, maximum, and minimum concentrations of VOCs measured by the CH₄/HCHO/H₂O gas analyzer during its stationary periods in the spring (March 30 – May 12) and fall (October 20 – November 16)

Compound	LOD [ppb]	<i>Spring Campaign</i>		<i>Fall Campaign</i>	
		Mean [ppb]	Max [ppb]	Mean [ppb]	Max [ppb]
Methane	1	2.13	4.04	2.23	5.41
Formaldehyde	0.5	0.73	21.05	1.30	27.93

Table A-9. Limit of detection (LOD), mean, maximum, and minimum concentrations of VOCs measured by the Vocus during its mobile periods from March 24 – April 2 and November 8 to November 16

*Limit of detection varied over time due to changing instrument sensitivity, so the campaign average is shown.

Compound	LOD* [ppb]	Mean [ppb]	Max [ppb]
Benzaldehyde	0.004	0.019	1.8
Acetophenone	0.045	0.025	2.0
Naphthalene	0.002	0.006	0.5
Total Naphthols	0.001	0.001	0.03
Total Monoterpenes	0.006	0.09	31.2
Acetaldehyde	0.018	1.08	84.6
Dimethylsulfide	0.001	0.02	0.5
Phenol	0.009	0.085	13.0
Styrene	0.008	0.061	8.5
Benzene	0.032	0.81	105
Toluene	0.005	0.44	45.8
Total C8 Alkyl-Aromatic	0.007	0.51	46.4

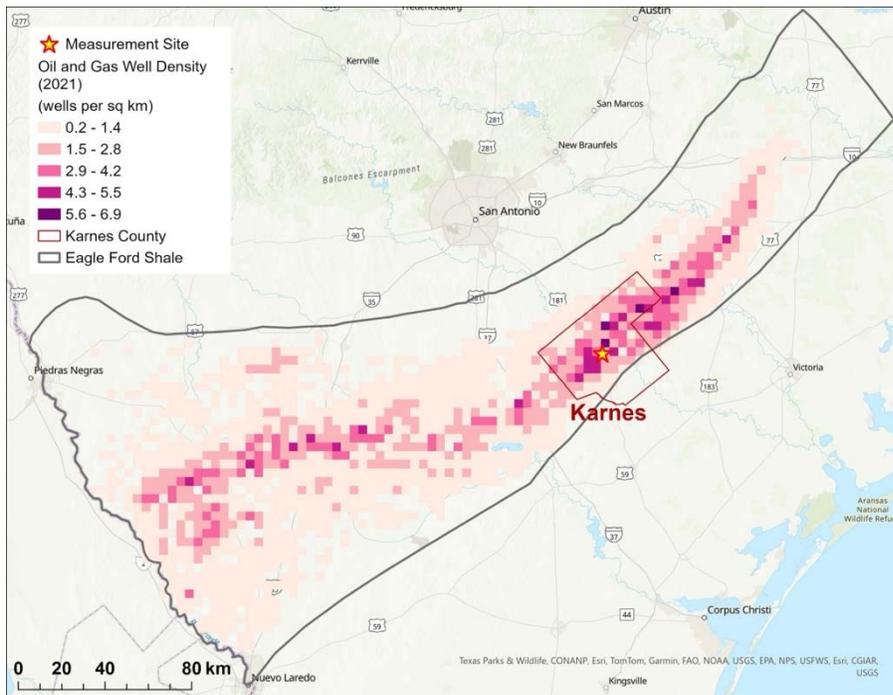
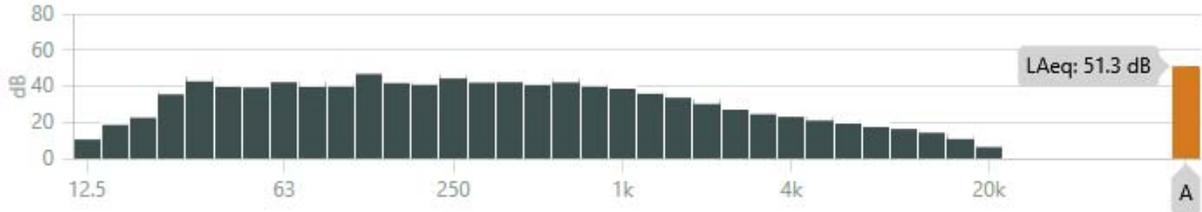
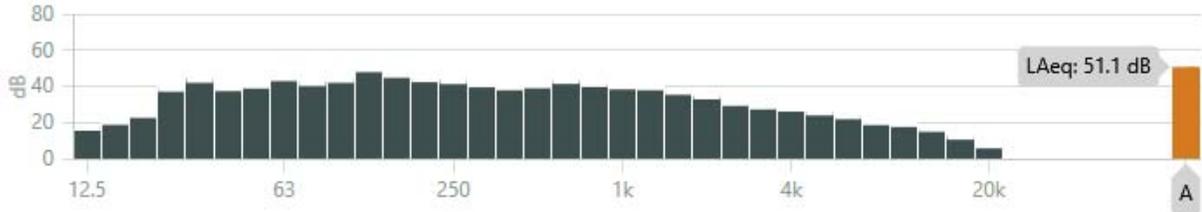


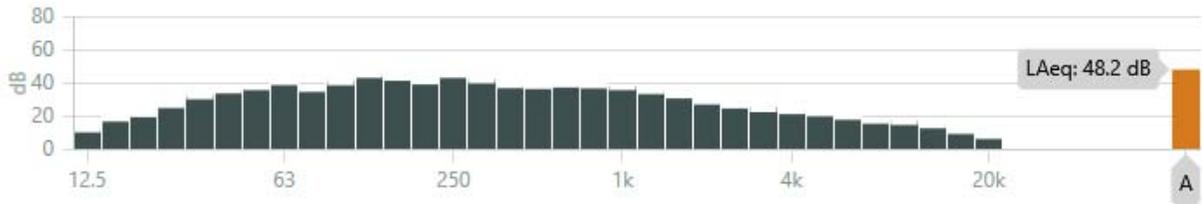
Figure A-1. Oil and gas well density in the Eagle Ford Shale.



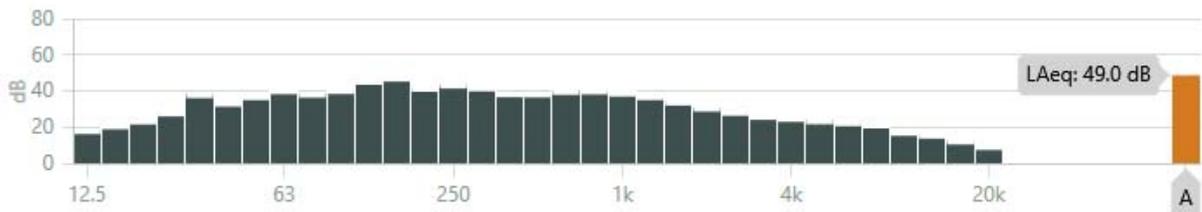
Average Frequency Spectrum at Stationary Site Nov. 15, 2023, 02:00-03:00



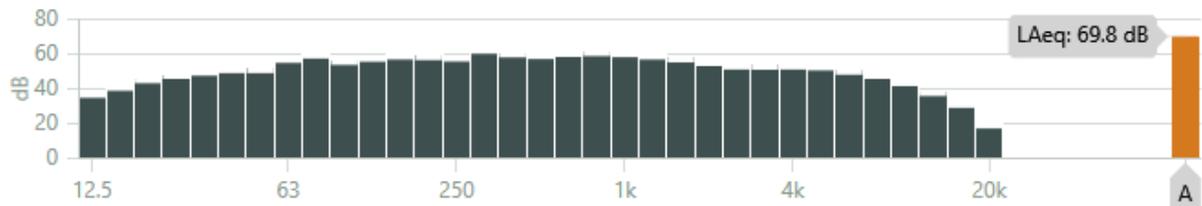
Average Frequency Spectrum at Stationary Site Nov. 15, 2023, 09:00-10:00



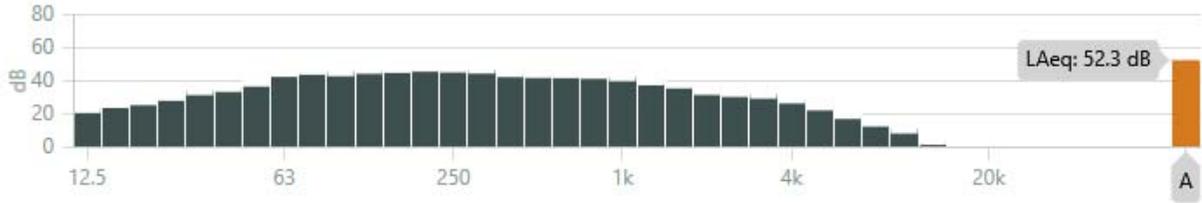
Average Frequency Spectrum at Stationary Site Nov. 16, 2023, 02:00-03:00



Average Frequency Spectrum at Stationary Site Nov. 16, 2023, 09:00-10:00



Average Frequency Spectrum during Stationary Near Site Period Nov. 15, 2023, 14:34-14:44



Average Frequency Spectrum Away from Site Nov. 15, 2023, 13:20-13:30

Figure A-2. Average frequency spectra away from source locations (frequency plotted on horizontal axis).

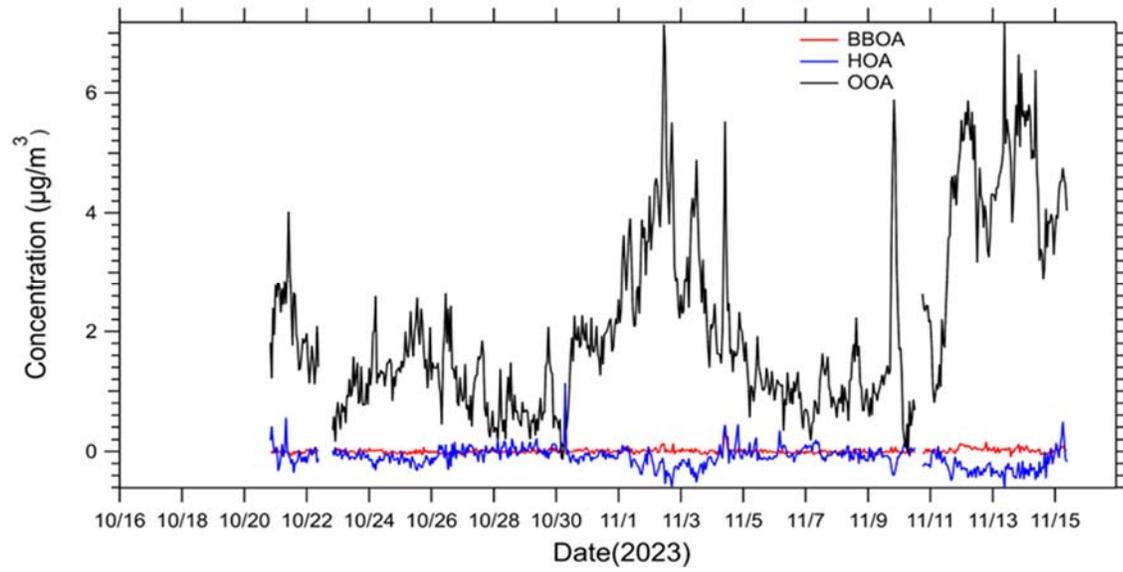


Figure A-3. Time series of oxygenated organic aerosol (OOA), hydrocarbon-like organic aerosol (HOA), and biomass burning organic aerosol (BBOA) in Fall 2023.

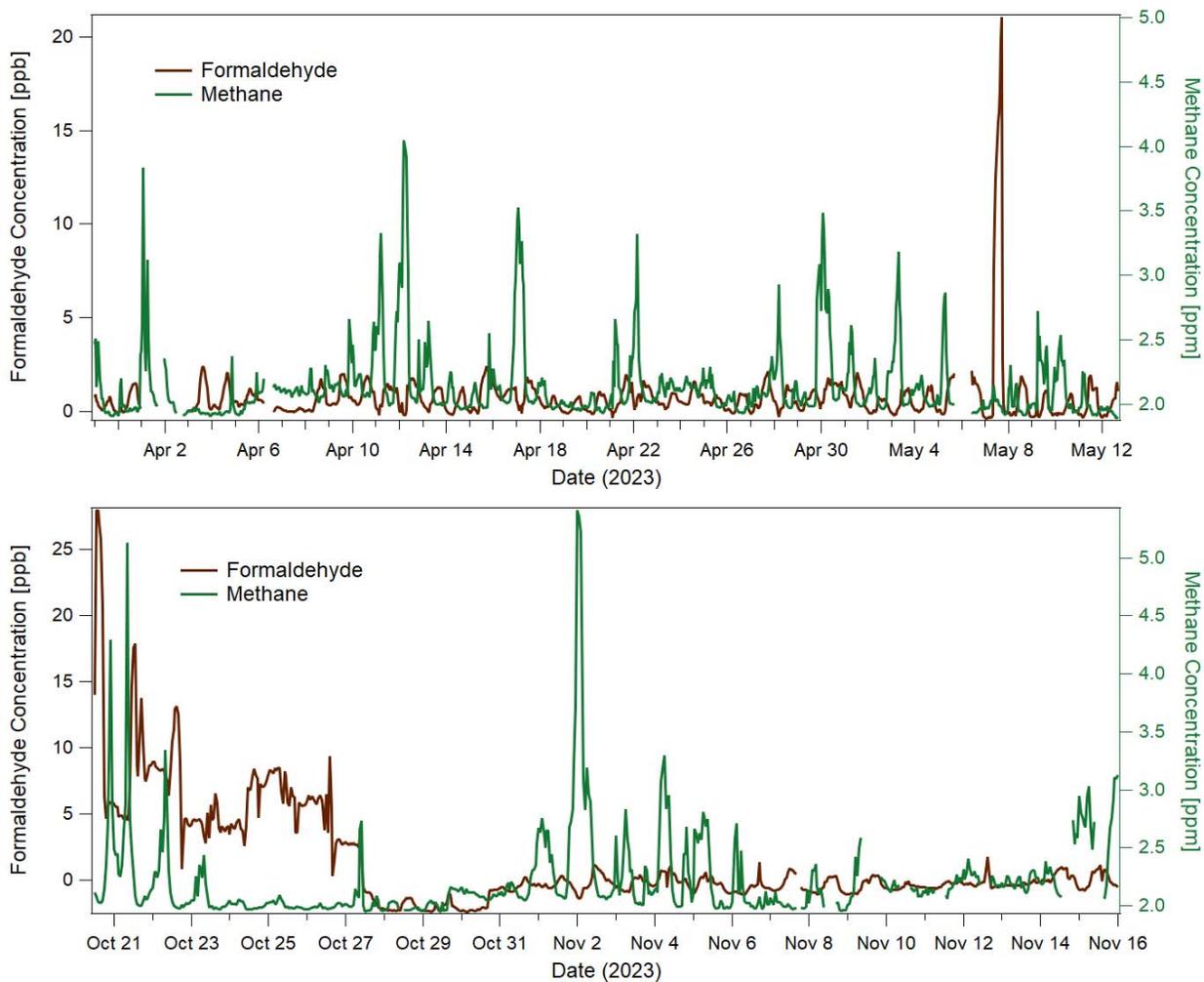


Figure A-4. Formaldehyde and methane concentrations from the spring (March 30 – May 12; top) and fall (October 20 – November 16; bottom).

During the spring, the average formaldehyde concentration was 0.7 ppb, with a campaign maximum of 21 ppb. During the fall, the average formaldehyde concentration was 1.3 ppb, with a campaign maximum of 28 ppb. Methane had a spring campaign average of 2.1 ppb, with a maximum of 4.04 ppb. In the fall, the campaign average was 2.2 ppb with a maximum of 5.41 ppb.

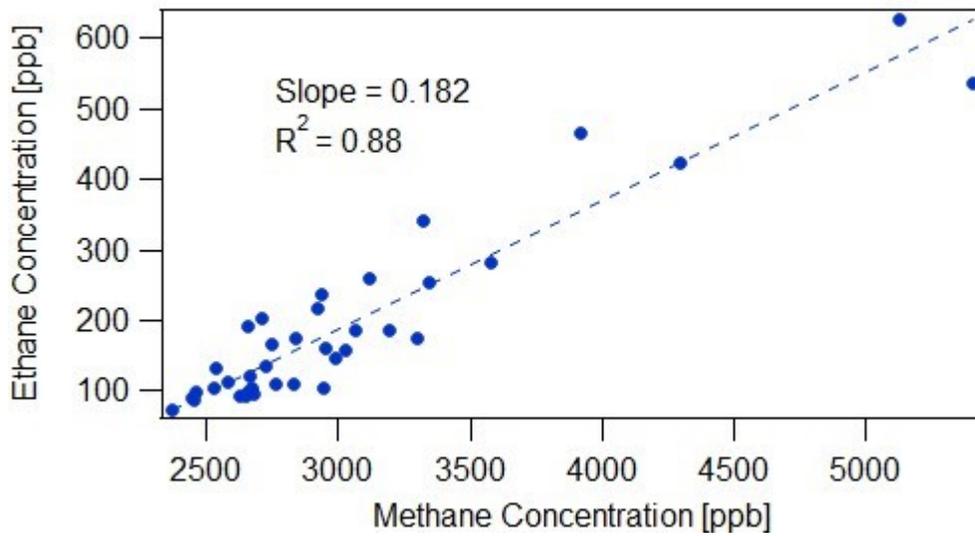


Figure A-5. Ratio of ethane to methane for times when the sum of ethane, propane, and n-butane was over 100 ppb (indicating a plume) during the spring and fall campaigns.

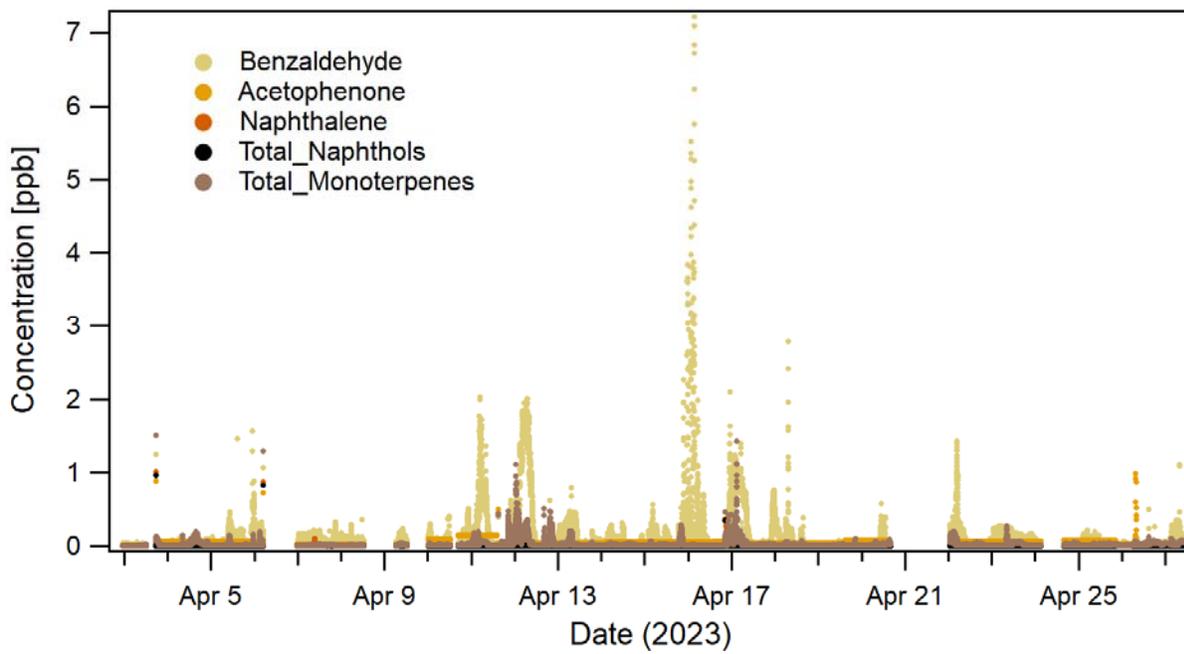


Figure A-6. Time series of benzaldehyde, acetophenone, naphthalene, total naphthols, and total monoterpenes during the stationary Vocus period from April 3-27.

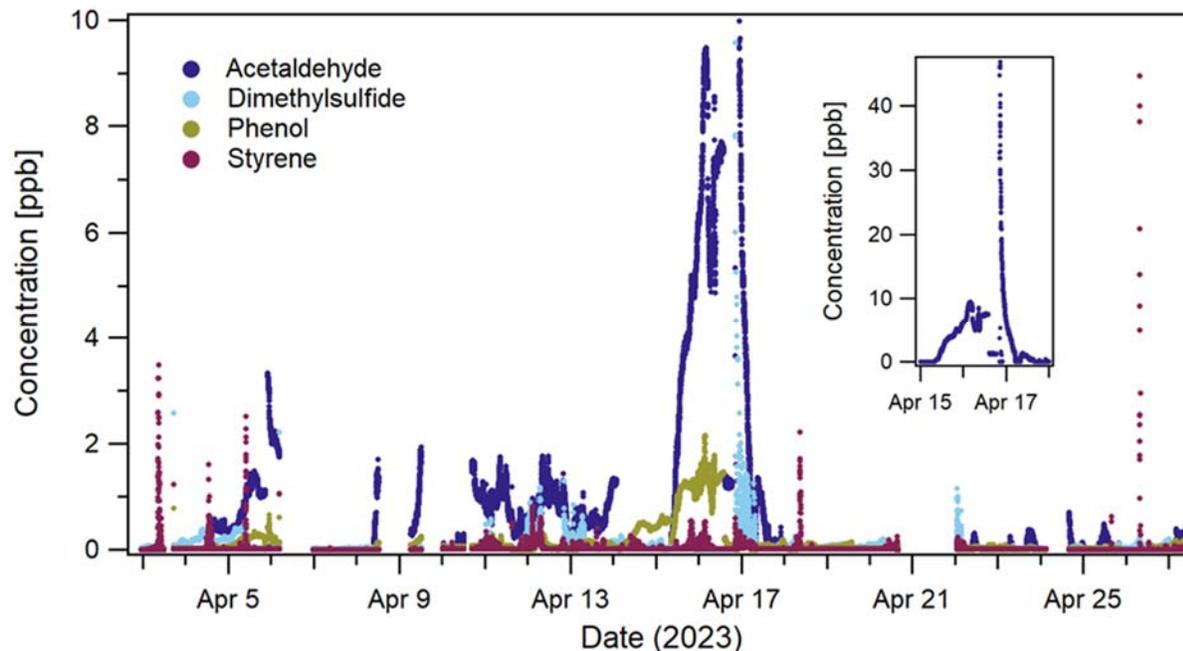


Figure A-7. Time series of acetaldehyde, dimethylsulfide, phenol, and styrene during the stationary Vocus period from April 3 to 27. The inset shows acetaldehyde from April 15 to 18, when the concentration reached a maximum 47 ppb.

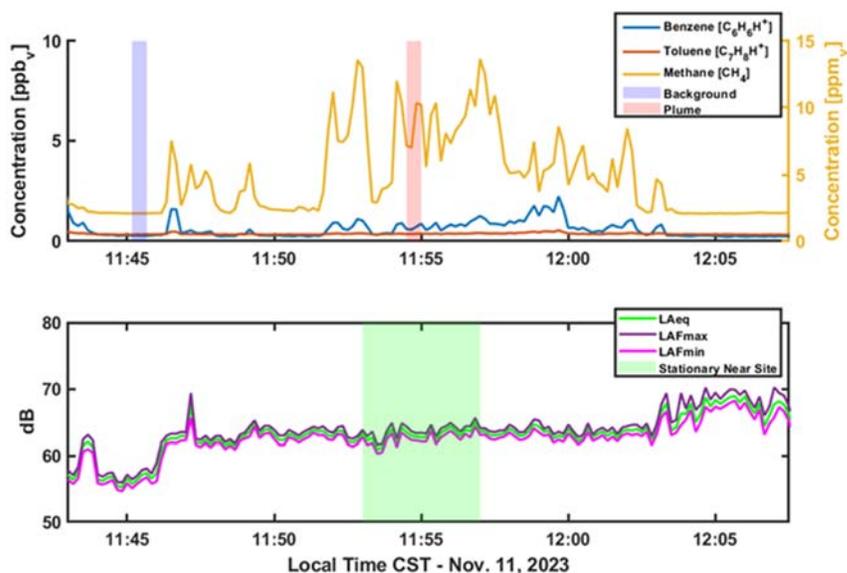


Figure A-8. Corresponding Time Series of Benzene, Toluene, and Methane Concentration, and Sound Levels Detected near an Active Flaring Site on November 11, 2023.

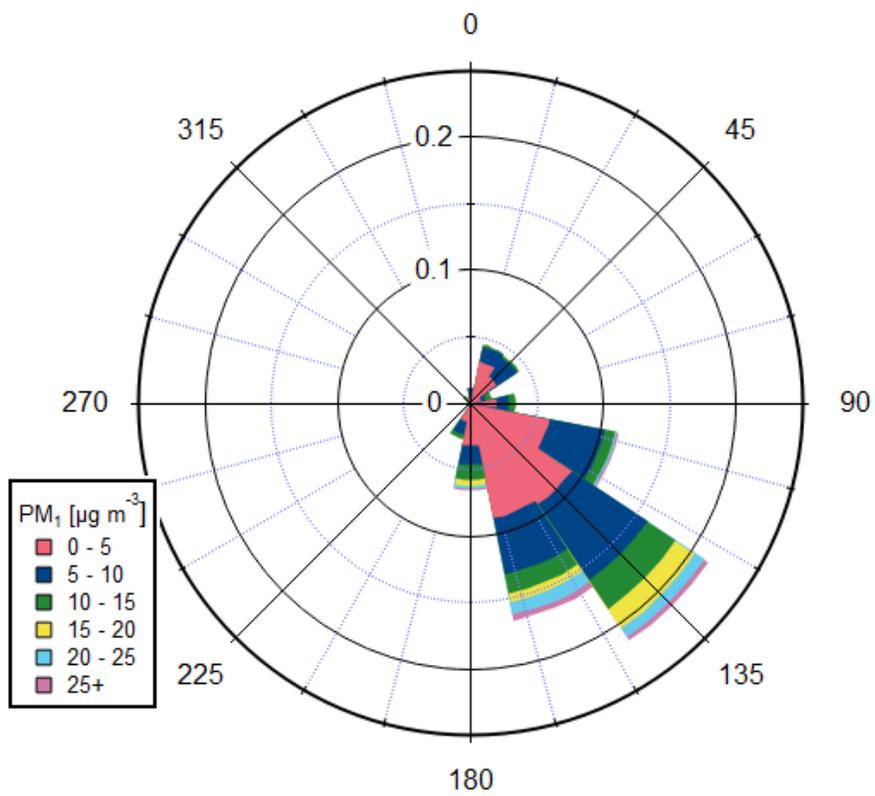


Figure A-9. Pollution rose of PM₁ over the portion of the campaign where SEMS data are available.

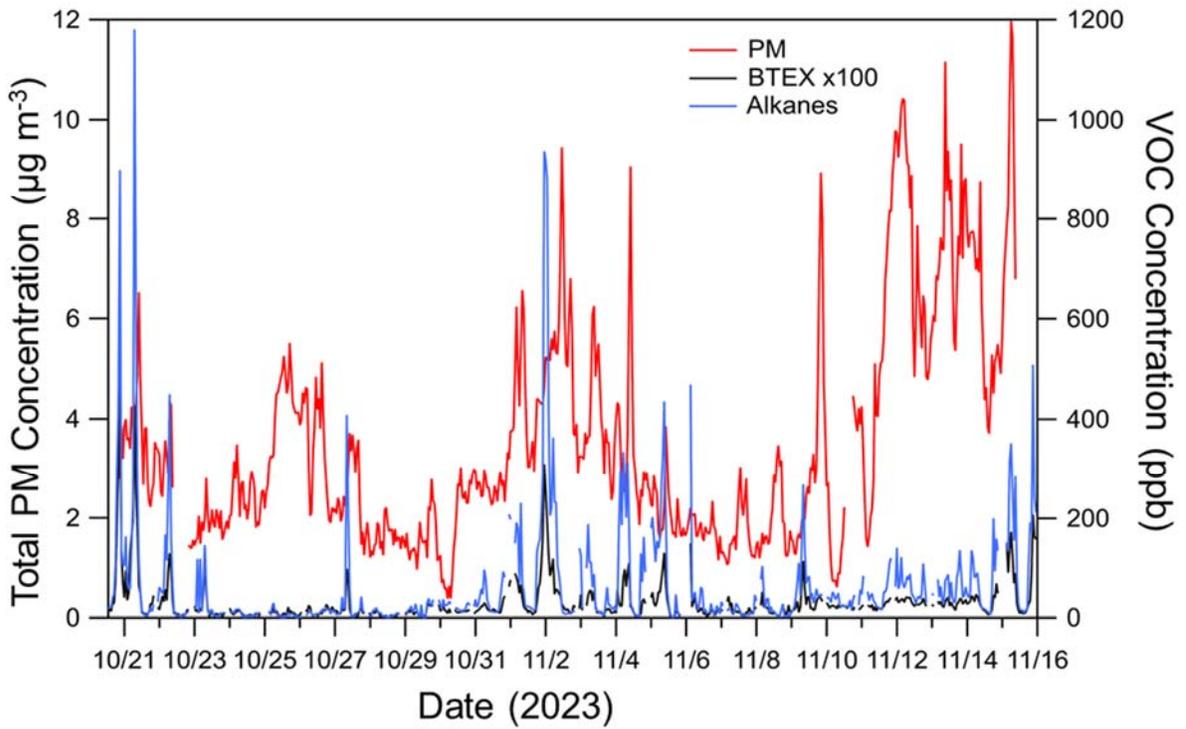


Figure A-10. Time series of total PM concentration ($\mu\text{g m}^{-3}$) and VOC concentration (ppb) in Fall 2023 showing VOCs peaking before PM peaks.

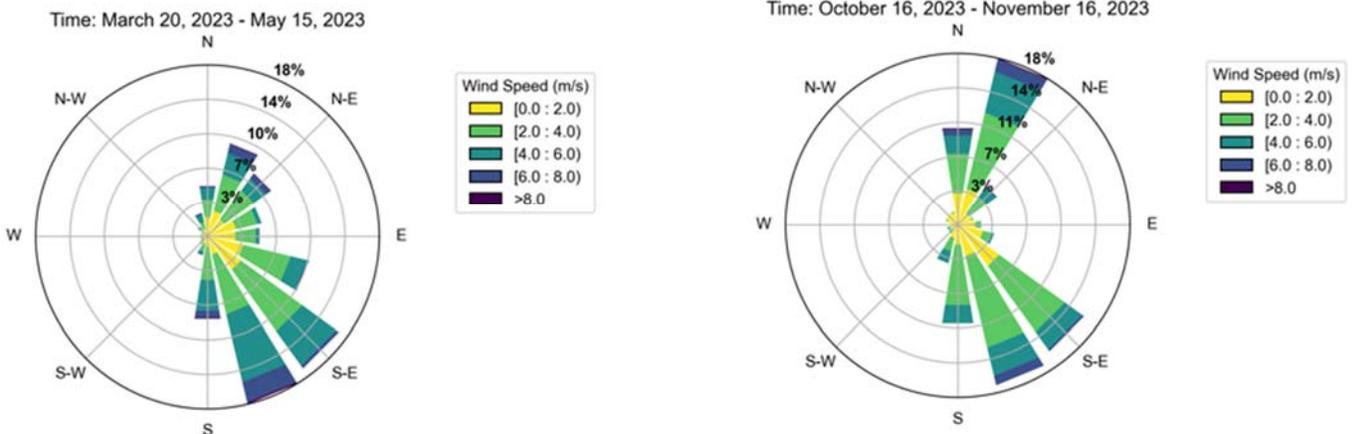


Figure A-11. Wind Roses of Spring 2023 and Fall 2023.

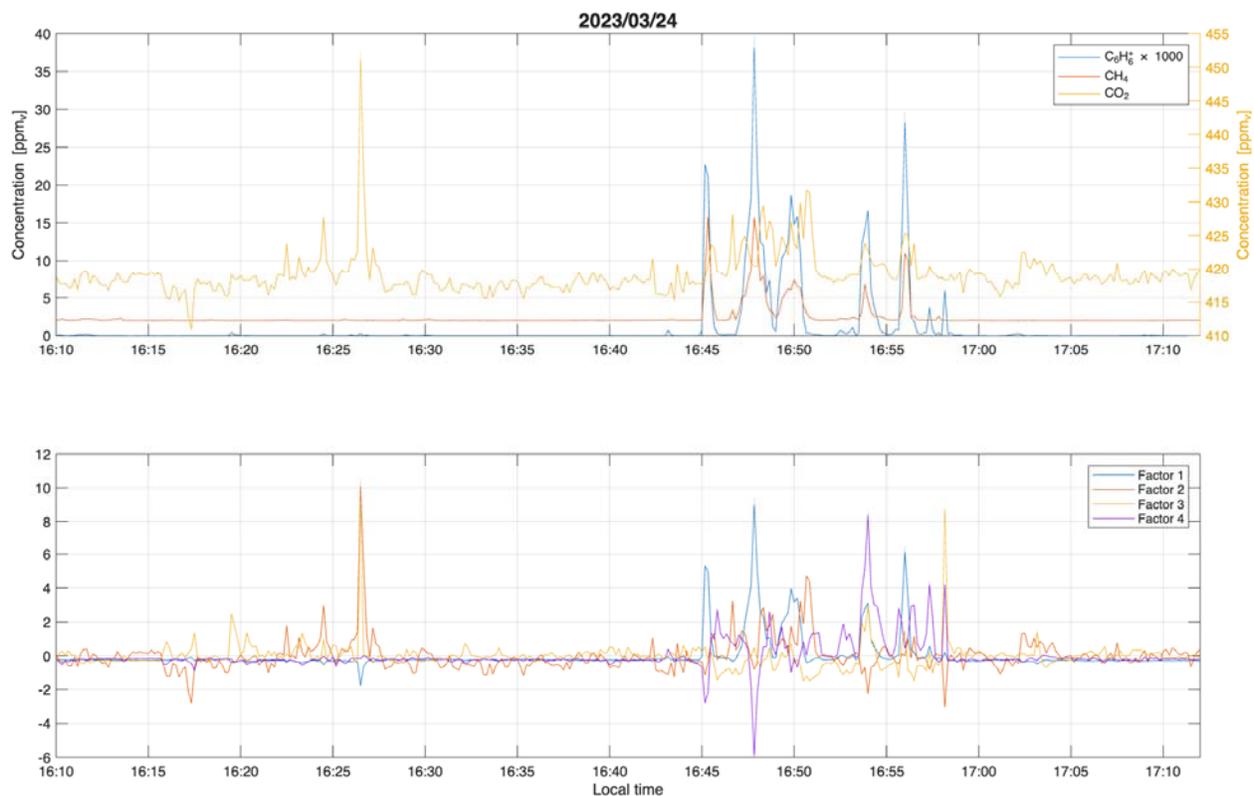


Figure A-12. Plume variability and multivariate factor analysis for Flare 1 on March 24,

2023. **Table A-10.** Factor loadings table for Flare 1 on March 24, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4
C6H6OH+	0.150	0.991			
C10H8OH+	0.001				
C2H4OH+	0.626	0.530			
C7H6OH+	0.002		0.524	0.464	
C10H8H+	0.004	0.492		0.516	
C6H6+	1.761	0.992			
C7H8H+	1.211	0.990			
C8H10H+	2.124	0.955			
C8H8H+	0.061	0.936			
C2H6SH+	0.005	0.966			
C10H16H+	0.026			0.536	
C8H8OH+	0.034				
CO2	419.126		0.918		
CH4	2.407	0.934			

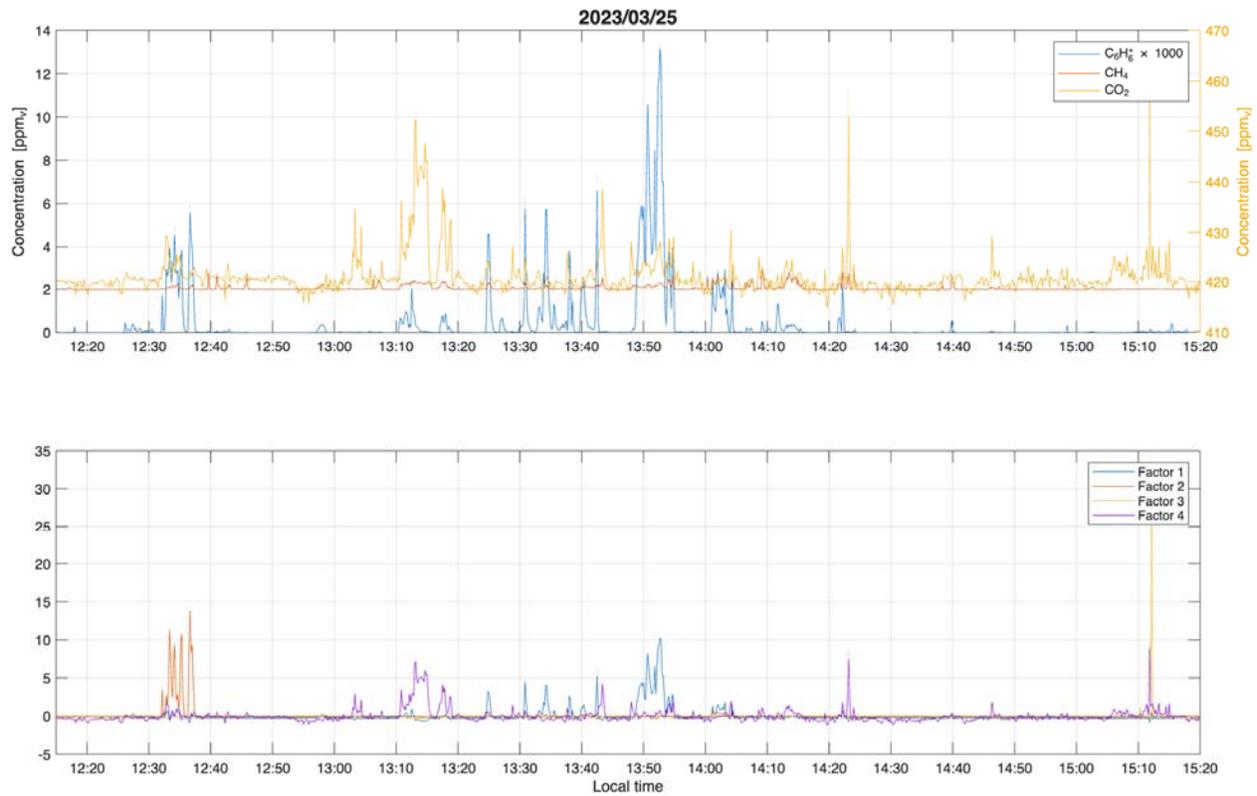


Figure A-13. Plume variability and multivariate factor analysis for Flares 2, 3, 4, and 5 on March 25, 2023.

Table A-11. Factor loadings table for Flares 2, 3, 4, and 5 on March 25, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4
C6H6OH+	0.093	0.962			
C10H8OH+	0.001				
C2H4OH+	0.141	0.564			
C7H6OH+	0.002			0.996	
C10H8H+	0.005		0.974		
C6H6+	1.206	0.994			
C7H8H+	0.412	0.942			
C8H10H+	0.450		0.946		
C8H8H+	0.025		0.853	0.512	
C2H6SH+	0.007	0.915			
C10H16H+	0.015		0.593		
C8H8OH+	0.034				
CO2	421.038				0.901
CH4	2.052				0.424

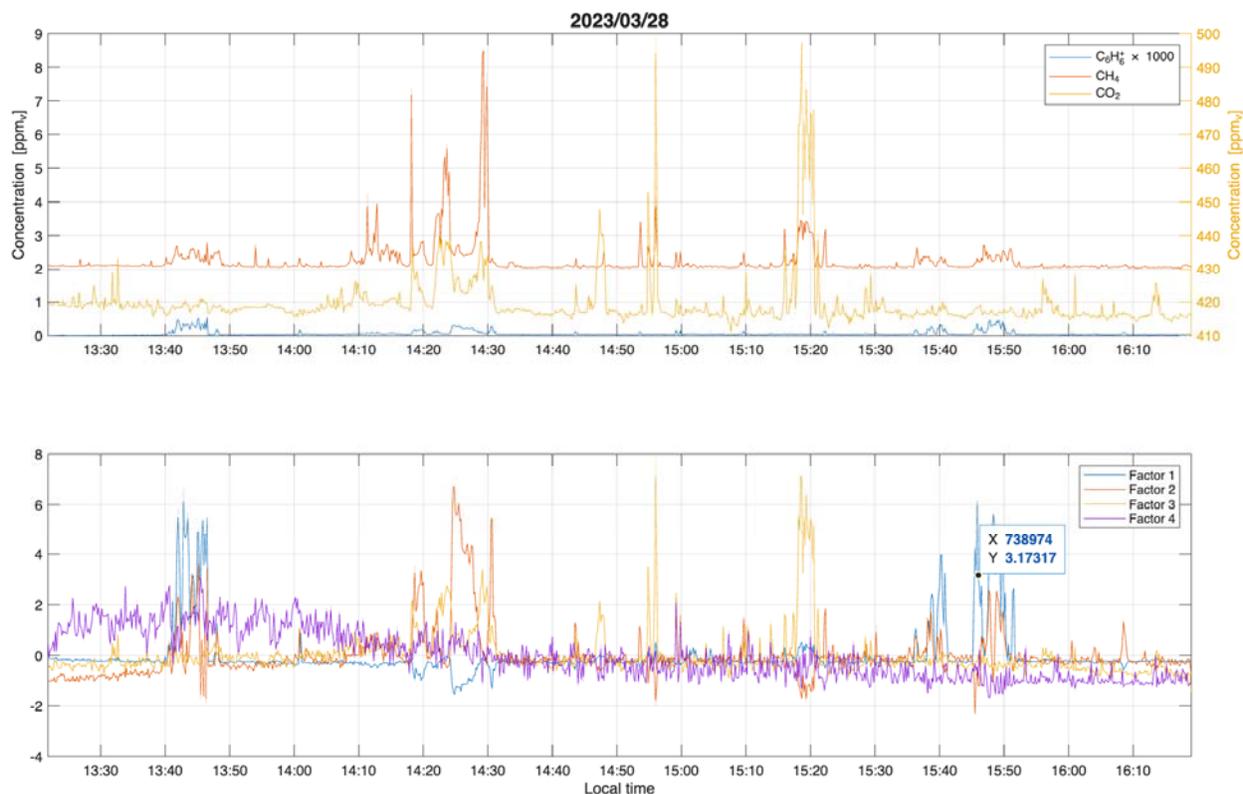


Figure A-14. Plume variability and multivariate factor analysis for Flares 2 and 5 on March 28, 2023.

Table A-12. Factor loadings table for Flares 2 and 5 on March 28, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C6H6OH+	0.067	0.745	0.659			
C10H8OH+	0.001					
C2H4OH+	1.309			0.661	0.562	
C7H6OH+	0.011				0.934	
C10H8H+	0.003		0.488			
C6H6+	0.643	0.531	0.803			
C7H8H+	0.067	0.745	0.659			
C8H10H+	0.503	0.950				
C8H8H+	0.015	0.970				
C2H6SH+	0.014	0.478			0.544	
C10H16H+	0.010					
C8H8OH+	0.006					
CO2	419.590			0.855		
CH4	2.246			0.549		

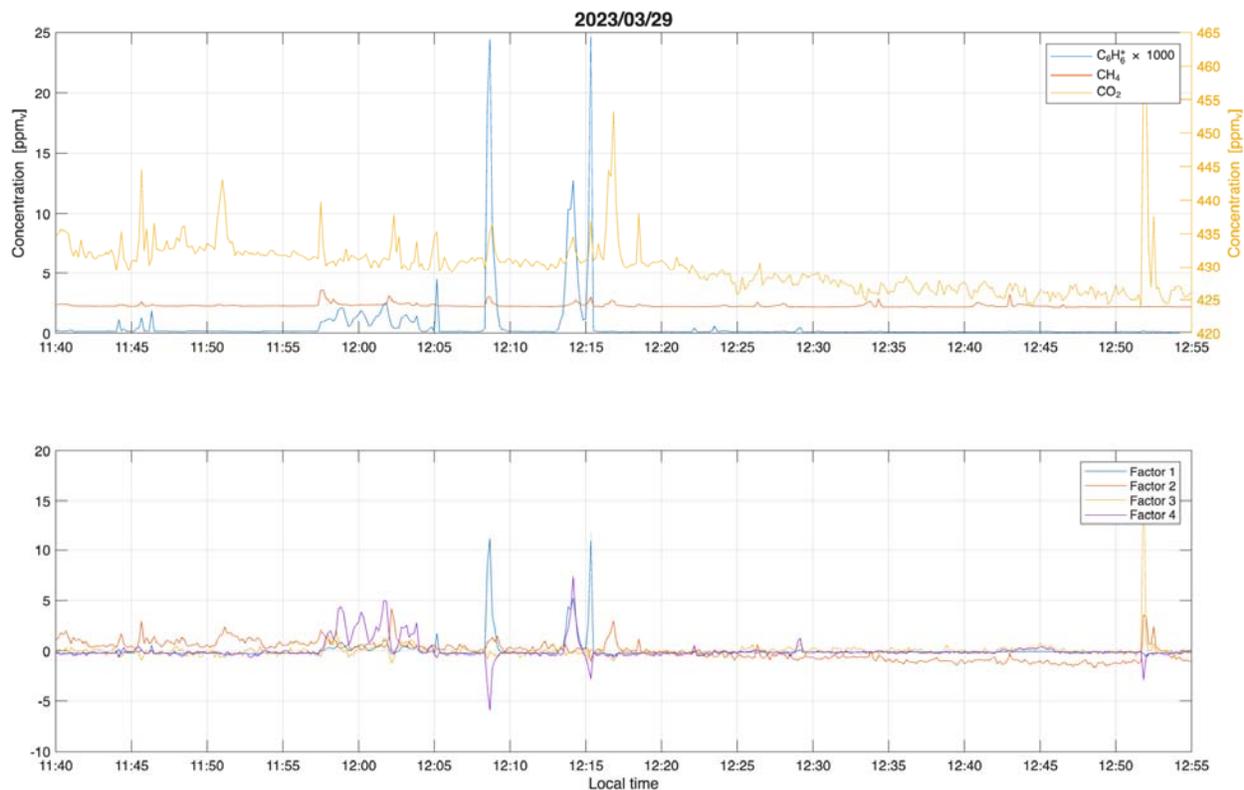


Figure A-15. Plume variability and multivariate factor analysis for Flare 3 on March 29, 2023.

Table A-13. Factor loadings table for Flare 3 on March 29, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C6H6OH+	0.144	0.993				
C10H8OH+	0.001					
C2H4OH+	2.601		0.846			
C7H6OH+	0.041		0.726			
C10H8H+	0.005		0.524	0.617		
C6H6+	0.899	0.989				
C7H8H+	0.572	0.995				
C8H10H+	0.358	0.971				
C8H8H+	0.014	0.856				
C2H6SH+	0.014	0.965				
C10H16H+	0.033					
C8H8OH+	0.005			0.829		
CO2	430.015		0.761			
CH4	2.288	0.420				



Figure A-16. Plume variability and multivariate factor analysis for Flare 6 on March 29, 2023.

Table A-14. Factor loadings table for Flare 6 on March 29, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
C6H6OH+	0.122	0.961				
C10H8OH+	0.001					
C2H4OH+	2.048	0.486		0.570	0.600	
C7H6OH+	0.023				0.486	
C10H8H+	0.002					
C6H6+	1.013	0.972				
C7H8H+	0.290	0.865	0.448			
C8H10H+	0.142		0.904			
C8H8H+	0.005		0.840			
C2H6SH+	0.013	0.951				
C10H16H+	0.021				0.608	
C8H8OH+	0.005					
CO2	426.000			0.674		
CH4	2.307			0.607		

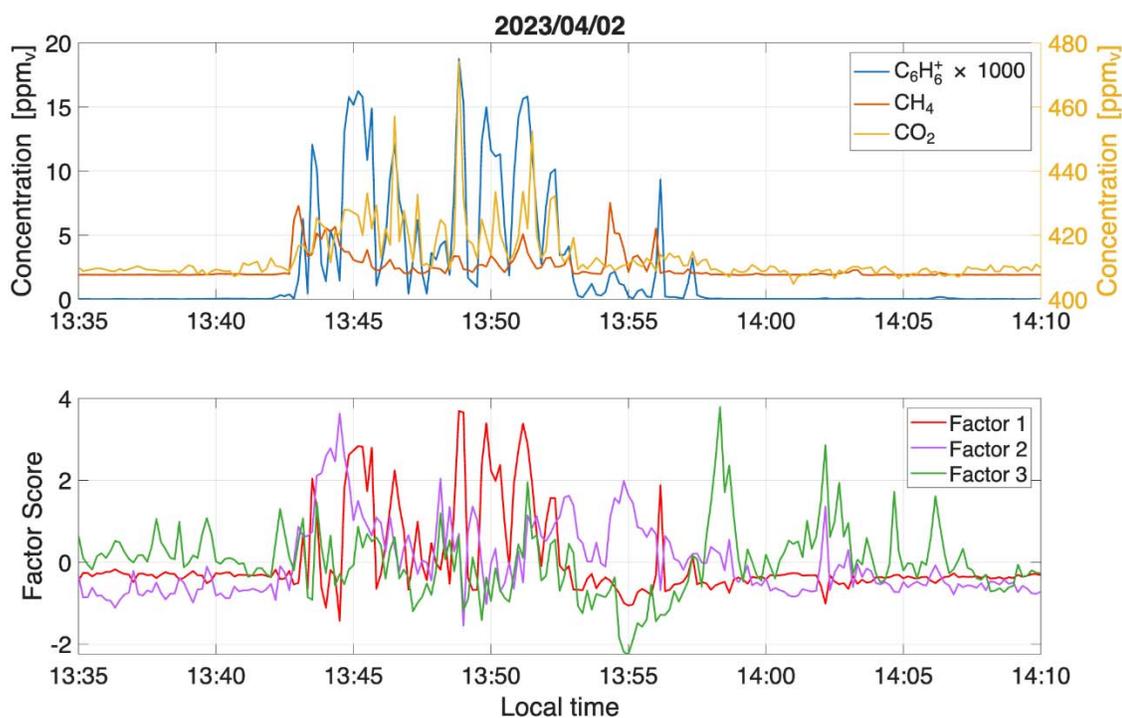


Figure A-17. Plume variability and multivariate factor analysis for Flare 7 on April 2, 2023.

Table A-15. Factor loadings table for Flare 7 on April 2, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C ₆ H ₆ OH ⁺	0.266	0.939				
C ₁₀ H ₈ OH ⁺	0.001					
C ₂ H ₄ OH ⁺	7.656	0.5622	0.6853			
C ₇ H ₆ OH ⁺	0.007	0.5474	0.5856			
C ₁₀ H ₈ H ⁺	0.025	0.9393				
C ₆ H ₆ ⁺	3.654	0.9399				
C ₇ H ₈ H ⁺	2.300	0.9471				
C ₈ H ₁₀ H ⁺	3.221	0.951				
C ₈ H ₈ H ⁺	0.092	0.9444				
C ₂ H ₆ SH ⁺	0.048	0.8155				
C ₁₀ H ₁₆ H ⁺	0.025			0.6521		
C ₈ H ₈ OH ⁺	0.004					
CO ₂	413.170	0.6821				
CH ₄	2.425		0.5505			



Figure A-18. Plume variability and multivariate factor analysis for Flare 2 on November 10, 2023.

Table A-16. Factor loadings table for Flare 2 on November 10, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C6H6OH+	0.069	0.967				
C10H8OH+	0.001					
C2H4OH+	0.548		0.787			
C7H6OH+	0.014					
C10H8H+	0.003			0.641		
C6H6+	1.874	0.973				
C7H8H+	0.361	0.937				
C8H10H+	0.194					
C8H8H+	0.011					
C2H6SH+	0.030	0.924				
C10H16H+	0.115					
C8H8OH+	0.053					
CO2	434.879		0.958			
CH4	2.233	0.666	0.531			

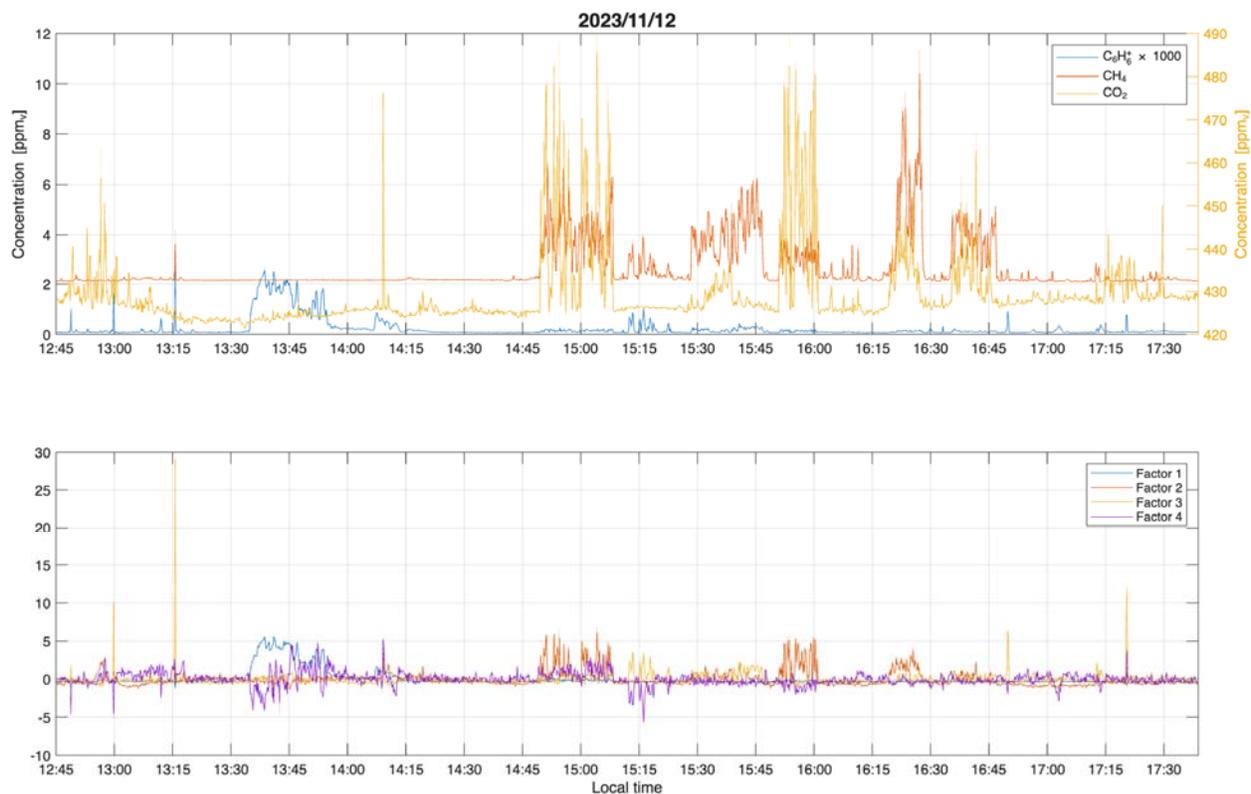


Figure A-19. Plume variability and multivariate factor analysis for Flares 8, 9, 10, and 11 on November 12, 2023.

Table A-17. Factor loadings table for Flares 8, 9, 10, and 11 on November 12, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C6H6OH+	0.025	0.969				
C10H8OH+	0.001	0.660				
C2H4OH+	0.415	0.521	0.850			
C7H6OH+	0.009	0.468				
C10H8H+	0.011	0.994				
C6H6+	0.270	0.406		0.867		
C7H8H+	0.231	0.944				
C8H10H+	0.364	0.988				
C8H8H+	0.097	0.995				
C2H6SH+	0.014	0.455				
C10H16H+	0.121	0.938				
C8H8OH+	0.040					
CO2	429.235		0.833			
CH4	2.630		0.481			

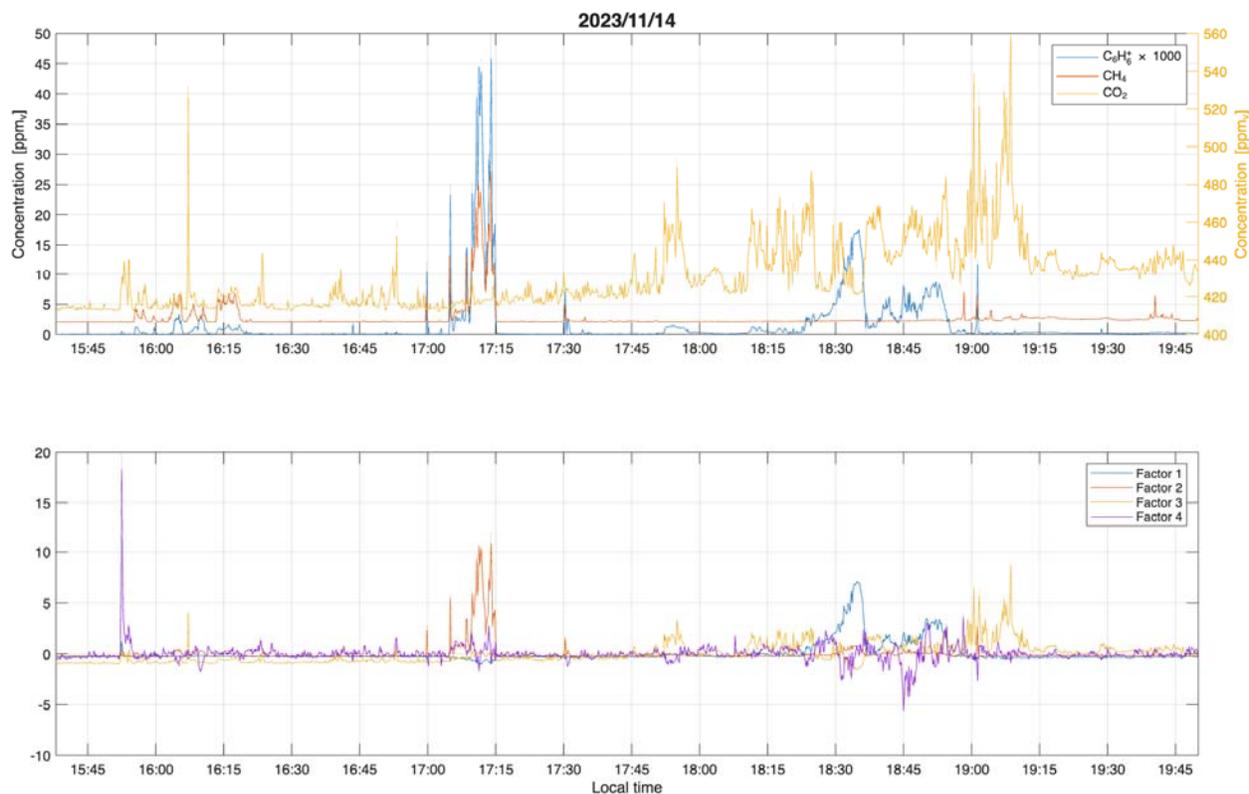


Figure A-20. Plume variability and multivariate factor analysis for Flare 12 on November 14, 2023.

Table A-18. Factor loadings table for Flare 12 on November 14, 2023.

Analyte	Average Concentration	Factor 1	Factor 2	Factor 3	Factor 4	
C6H6OH+	0.172	0.446	0.894			
C10H8OH+	0.002	0.704			0.415	
C2H4OH+	1.069	0.806				
C7H6OH+	0.018	0.520				
C10H8H+	0.027	0.994				
C6H6+	1.523		0.998			
C7H8H+	1.557		0.915			
C8H10H+	2.119	0.909				
C8H8H+	0.350	0.991				
C2H6SH+	0.032			0.846		
C10H16H+	0.273	0.964				
C8H8OH+	0.035					
CO2	430.358			0.945		
CH4	2.689		0.901			