

Saturation Air Toxics Monitoring in Davis County, Utah

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1. Introduction

The North Salt Lake- Woods Cross-West Bountiful- Bountiful-Centerville area in Davis County, Utah, has a large industrial complex with multiple industries and several small emission sources. These include oil refineries, industrial gas companies as well as metal processing, recycling, painting/coating manufacturing and electricity generation facilities. Several roadways, railroads and highways also run through this area. Given their close proximity to and mostly downwind location from these sources, communities in this area are at a high risk of exposure to Hazardous Air Pollutants (HAPs) emissions, particularly formaldehyde, acetaldehyde and dichloromethane.

A study conducted by the Utah Division of Air Quality (UDAQ) and the University of Utah, where 24-hr time-integrated air samples were collected every third day at three different sites during 2015, showed high levels of certain air toxics at Bountiful Viewmont (BV) site, which is a National Air Toxics Trends Station (NATTS) located in Davis County and operated by UDAQ¹. Levels of formaldehyde and acetaldehyde, in particular, peaked during winter and were greatest at BV site compared to two other UDAQ stations located in less industrialized Salt Lake and Utah Counties. Measured concentrations during this period as well as previous years were also overall associated with a high cancer risk, exceeding the one-in-a-million cancer risk threshold. Moreover, high levels of dichloromethane, often exceeding its cancer risk screening value, were also recorded. However, while this study helped identify high-concentration and -risk HAPs, it lacked information on their sources and spatial variation. Sample collection was limited to one sampling location. Given the significant health risk from formaldehyde, acetaldehyde and dichloromethane, UDAQ, in collaboration with the University of Utah, conducted a saturation monitoring study to help identify sources of these air pollutants and characterize their spatial distribution.

2. Methodology

2.1. Sampling sites

To characterize the spatial distribution and sources of carbonyls and VOCs in the North Salt Lake- Woods Cross-West Bountiful- Bountiful-Centerville area, sampling was conducted at 34 sampling sites for 6 weeks (01/16/2017-02/25/2017) during winter and 7 weeks (06/05/2017-07/17/2017) during summer. The sampling sites, which included BV-NATTS site (S4), were selected to

¹ <https://documents.deq.utah.gov/air-quality/planning/technical-analysis/research/air-toxics/study-2/DAQ-2017-016653.pdf>

represent varying spatial scales relative to emission sources, where different factors were considered in the sites' selection. These included typical wind patterns, distance from busy roadways and freeways, site accessibility as well as location of residential areas and potential sources of air toxics emissions. For better source characterization, seven sites were re-located during the summer. This was based on an analysis of results from the winter campaign.

A map of the sampling sites is provided in Figures 1a-b.

2.2. Sample collection

To determine the concentration of carbonyls and VOCs, two different samples were concurrently collected at each sampling site using Radiello passive diffusive samplers. VOCs were collected using stainless steel net cartridges filled with activated charcoal (code 130) while carbonyls were collected using stainless steel net cartridges filled with 2,4-dinitrophenylhydrazine (2,4-DNPH) coated florisol (code 165). Factors, including analytes' detection limit and samplers' applicability for the temperature, wind speed and relative humidity conditions in the sampling area, were considered in the selection of the samplers. Moreover, RAD165 samplers were particularly selected for carbonyls measurements since these cartridges, which are packed with coated florisol, are less prone to losses of carbonyls compounds by chemical reactions with ozone. Ozone may react directly with the 2,4-DNPH reagent, making the DNPH unavailable for derivatizing carbonyl compounds into dinitrophenylhydrazones. It may also react with the carbonyl-hydrazones on the sampled cartridge to degrade these compounds, leading to an underestimation of carbonyl concentrations. Degradation of these compounds, however, only becomes important at ozone concentrations greater than 100 ppb, when averaged over the entire exposure period. All ozone concentrations were lower than 100 ppb throughout this study, as indicated by ozone measurements taken at select sites during the summer.

Sampling was conducted for 6 weeks (01/16/2017-02/25/2017) during winter and 7 weeks (06/05/2017-07/17/2017) during summer. With the exception of winter sites S2, S3, S10, S11, S4, S12, S5 and S6, samplers were deployed for five consecutive days. To account for the effect of meteorology on levels of air toxics, two different sets of samples were collected at sites S2, S3, S10, S11, S4, S12, S5 and S6 during the winter. These included daytime and overnight samples, which were collected from ~7:30 am to 5:30 pm and 5:30 pm to 7:30 am, respectively. Time periods were selected based on an analysis of historical wind data collected in the sampling area, which showed that wind shifts direction between these two time periods. Given that no high concentrations were observed overnight during the winter, only daytime samples were collected at sites S2, S3, S10, S11, S4, S12, S5 and S6, during the summer. Three sets of samples were also collected at select sites over the weekend during each sampling phase.

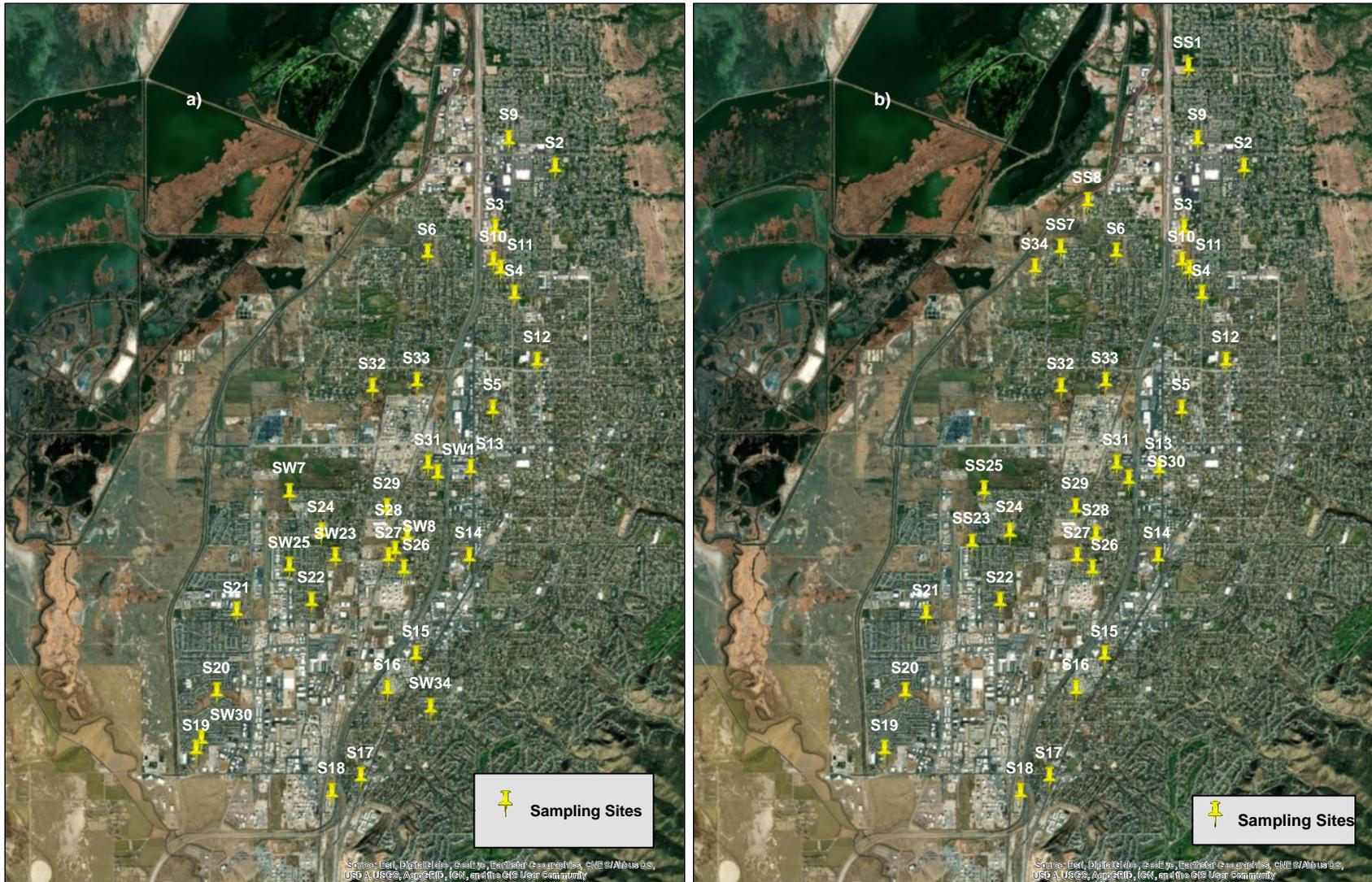


Figure 1. Location of sampling sites during a) winter and b) summer sampling campaigns.

2.3. Sample analysis

Following sample collection, samples were sent to Desert Research Institute (DRI) laboratory for analysis. All VOC passive samples were extracted with carbon disulfide followed by analysis using capillary gas chromatography and FID detection. Samples were analyzed for dichloromethane, benzene, toluene, ethylbenzene, m+p-xylene and o-xylene. Carbonyl samples were extracted with acetonitrile then analyzed by HPLC and UV detection. Species measured included formaldehyde, acetaldehyde, acrolein, proaldehyde, butanal, valeraldehyde, hexaldehyde and benzaldehyde. Due to potential interference between the acrolein and butyraldehyde analytical peak measurements, concentrations of these two compounds are not reported.

3. Community Collaboration

The Utah Division of air Quality worked closely with the Davis County Health Department, who was instrumental in helping UDAQ reach out to community members and secure sampling sites. UDAQ also relied greatly on help from city officials, Davis school district, local fire departments as well as community members who offered their businesses for some of the sampling sites.

4. Air Quality Overview

24-hr PM_{2.5} concentrations varied during the sampling study. A few exceedances of the 35 $\mu\text{g}/\text{m}^3$ 24-hr National Ambient Air Quality Standard (NAAQS) for PM_{2.5} were observed during the winter while no exceedances were recorded during the summer at the Bountiful Viewmont site (Figures 2 and 3).

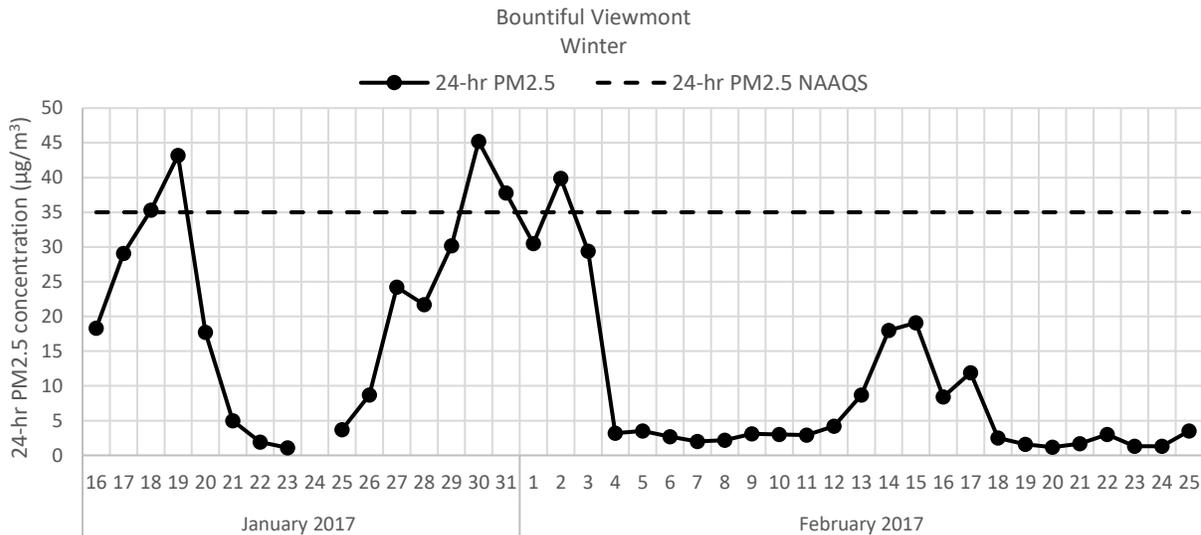


Figure 2. 24-hr PM_{2.5} concentration ($\mu\text{g}/\text{m}^3$) at Bountiful Viewmont station during the winter phase of the study (January – February 2017).

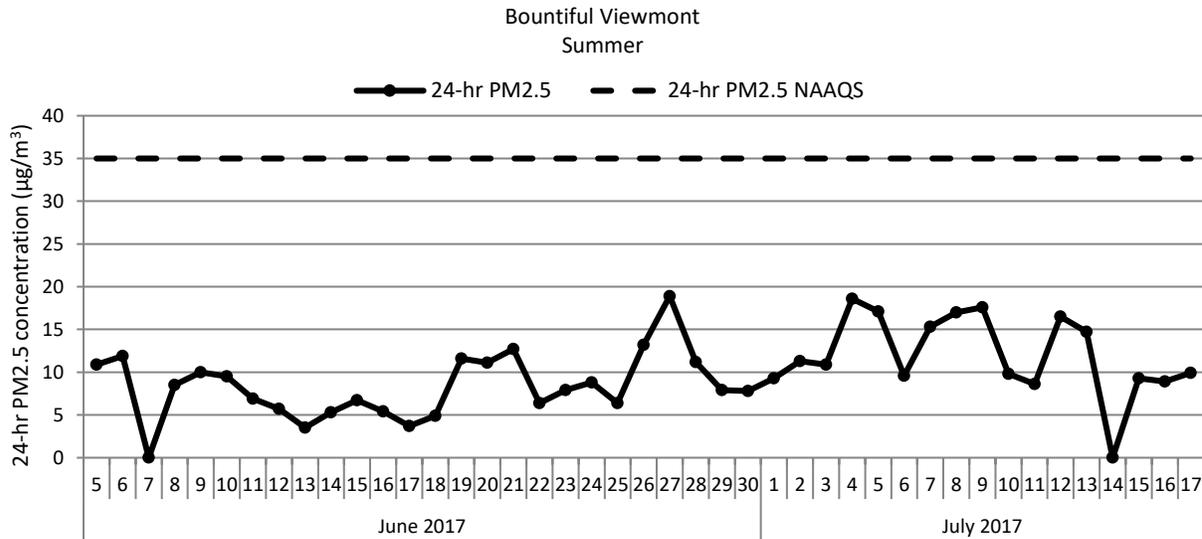


Figure 3. 24-hr PM2.5 concentration ($\mu\text{g}/\text{m}^3$) at Bountiful Viewmont station during the summer phase of the study (June – July 2017).

5. Results

5.1. Seasonal Variation in Concentrations

The concentration of formaldehyde, acetaldehyde and dichloromethane varied across sampling seasons and sites (Table 1). Formaldehyde concentrations were generally higher at all sampling sites over the summer than winter. Acetaldehyde followed a similar trend, displaying overall higher levels in the summer than winter and a strong correlation with formaldehyde at almost all sites and during both seasons (R overall greater than 0.8, Tables 2 and 3). Dichloromethane concentrations, on the other hand, were higher during winter than summer at sampling sites S2-S6 and S10-S12, which are located in the northern part of the sampling area. At almost all of the remaining sites, levels of dichloromethane were comparable or lower during the summer.

Table 1. Average (Minimum-Maximum) of formaldehyde, acetaldehyde and dichloromethane concentrations (ppb at local conditions) over all sampling weekdays during winter (January - February) and summer (June - July) 2017. Values shown in bold represent measurements taken during daytime (about 7:30 am – 5:30 pm) only.

SiteID	Average (Min-Max) (ppb/C)					
	Winter			Summer		
	Dichloromethane	Formaldehyde	Acetaldehyde	Dichloromethane	Formaldehyde	Acetaldehyde
SS1				0.08 (0.05-0.14)	2.81 (1.67-5.86)	1.53 (0.99-2.91)
SW1	0.05(0.03-0.08)	1.31(0.34-2.39)	0.77(0.18-1.34)			
S2	0.15 (0.04-0.41)	1.1 (0.26-1.95)	1.24 (0.69-2.18)	0.06 (0.03-0.08)	2.55 (1.79-3.07)	1.33 (1.11-1.74)
S3	0.1 (0.05-0.16)	1.01 (0.24-2.14)	1.17 (0.12-2.19)	0.07 (0.05-0.1)	2.27 (1.66-2.78)	1.28 (1.08-1.55)
S4	0.15 (0.07-0.27)	1.1 (0.24-2.05)	1.4 (0.72-2.22)	0.08 (0.05-0.11)	2.58 (1.98-3.18)	1.39 (1.06-1.66)
S5	0.15 (0.04-0.43)	1.37 (0.71-2.55)	1.31 (0.61-2.59)	0.07 (0.05-0.09)	2.38 (1.87-3.19)	1.37 (1.11-1.55)
S6	0.14 (0.05-0.4)	1.04 (0.38-1.82)	1.23 (0.55-2.12)	0.07 (0.05-0.1)	2.47 (1.73-3.52)	1.35 (0.96-1.57)
SS7				0.09 (0.05-0.15)	2.36 (1.76-3.22)	1.34 (0.99-1.74)
SW7	0.04(0.03-0.07)	0.96(0.57-1.41)	0.75(0.39-1.01)			
SS8				0.08 (0.05-0.09)	2.93 (1.84-6.31)	1.68 (1.04-3.71)
SW8	0.05(0.03-0.07)	1.05(0.68-1.72)	0.76(0.33-1.21)			
S9	0.05(0.03-0.08)	0.99(0.25-1.61)	0.75(0.17-1.22)	0.06(0.04-0.09)	2.01(1.52-2.57)	1.21(1.01-1.44)
S10	0.09 (0.05-0.11)	1.12 (0.35-2.32)	1.36 (0.7-2.32)	0.06(0.05-0.08)	2.1(1.41-2.54)	1.28(0.95-1.78)
S11	0.08 (0.05-0.11)	1.15 (0.35-2.15)	1.4 (0.68-2.26)	0.06(0.04-0.08)	2.19(1.66-2.73)	1.35(1-1.75)
S12	0.12 (0.06-0.18)	1.48 (0.86-2.37)	1.53 (0.6-2.43)	0.05(0.04-0.07)	1.75(1.29-2.48)	1.08(0.79-1.49)
S13	0.06(0.03-0.09)	1.18(0.44-2.17)	0.97(0.39-1.49)	0.07(0.04-0.14)	1.83(1.13-2.95)	1.24(0.91-1.67)
S14	0.05(0.02-0.07)	1.18(0.34-2.13)	0.88(0.18-1.45)	0.05(0.03-0.06)	2.04(1.49-2.69)	1.31(1.01-1.73)
S15	0.06(0.03-0.08)	1.11(0.32-1.95)	0.85(0.23-1.31)	0.05(0.04-0.06)	1.88(1.38-2.35)	1.23(1.02-1.58)
S16	0.05(0.03-0.07)	1.15(0.33-1.94)	0.87(0.22-1.25)	0.06(0.05-0.09)	2.09(1.52-2.66)	1.39(1.05-1.8)
S17	0.05(0.03-0.07)	1.07(0.45-1.85)	0.8(0.28-1.25)	0.05(0.04-0.07)	1.88(1.39-2.62)	1.3(1.1-1.88)
S18	0.06(0.03-0.11)	1.17(0.54-2.04)	0.83(0.41-1.36)	0.06(0.05-0.08)	2.09(1.49-2.68)	1.56(1.33-1.95)
S19	0.04(0.02-0.07)	1.01(0.62-1.43)	0.62(0.31-1.09)	0.06(0.04-0.07)	2.05(1.44-2.44)	1.31(0.64-1.69)
S20	0.05(0.02-0.08)	0.85(0.3-1.42)	0.59(0.17-0.86)	0.06(0.05-0.07)	2.11(1.85-2.4)	1.37(1.21-1.68)
S21	0.09(0.02-0.25)	1.17(0.32-2.28)	0.72(0.2-1.12)	0.07(0.05-0.1)	2.23(1.81-2.53)	1.49(1.27-1.87)
S22	0.06(0.04-0.08)	1.09(0.54-1.8)	0.68(0.27-1.2)	0.08(0.05-0.13)	1.98(1.72-2.28)	1.36(1.16-1.66)
SS23				0.06(0.04-0.07)	2.67(1.94-3.57)	1.58(1.24-1.91)
SW23	0.06(0.03-0.14)	0.86(0.3-1.52)	0.68(0.25-1.18)			
S24	0.06(0.03-0.1)	0.96(0.54-1.52)	0.76(0.38-1.12)	0.06(0.04-0.09)	2.3(2.01-2.72)	1.55(1.27-2.08)
SS25				0.05(0.03-0.06)	1.95(1.55-2.35)	1.39(1.1-1.76)
SW25	0.05(0.03-0.08)	0.99(0.35-1.66)	0.67(0.22-1.2)			
S26	0.05(0.03-0.13)	1.03(0.37-1.84)	0.73(0.22-1.21)	0.07(0.04-0.14)	2.2(1.79-2.56)	1.6(1.35-2.04)
S27	0.05(0.03-0.13)	1.2(0.71-2.09)	0.83(0.38-1.15)	0.07(0.05-0.08)	2.17(1.4-2.76)	1.51(0.63-1.92)
S28	0.04(0.02-0.08)	1.11(0.7-1.78)	0.77(0.38-1.29)	0.06(0.04-0.09)	2.41(1.91-2.99)	1.59(1.36-2.04)
S29	0.05(0.03-0.08)	1.26(0.73-1.66)	0.82(0.36-1.17)	0.07(0.04-0.11)	2.11(1.72-2.47)	1.43(1.19-1.83)
SS30				0.06(0.04-0.09)	2.04(1.45-2.58)	1.43(1.19-1.7)
SW30	0.04(0.02-0.08)	0.93(0.28-1.53)	0.6(0.18-1.12)			
S31	0.05(0-0.09)	1.02(0.31-1.84)	0.79(0.21-1.32)	0.07(0.04-0.09)	2.2(1.74-2.73)	1.59(1.22-1.93)
S32	0.05(0.02-0.09)	0.86(0-1.46)	0.62(0-1.13)	0.05(0.04-0.06)	2.09(1.77-2.46)	1.55(1.34-1.96)
S33	0.05(0.03-0.09)	1.15(0.71-1.6)	0.84(0.39-1.25)	0.05(0.04-0.07)	2.04(1.56-2.84)	1.42(1.13-1.8)
SS34				0.06(0.03-0.12)	2.32(1.83-2.84)	1.53(1.27-1.88)
SW34	0.05(0.03-0.08)	0.86(0.31-1.16)	0.68(0.18-1.04)			

Table 2. Pearson correlation coefficient (R) between formaldehyde and other measured species during winter (January - February) 2017. Correlation coefficients with select aldehydes are not reported since most measured values were below detection limit and the number of data points was less than 6. Correlation coefficients exceeding 0.7 are highlighted in light red.

	Site	Pearson Correlation Coefficient R								
		Dichloromethane	Benzene	Toluene	Ethylbenzene	m+p-xylene	o-xylene	Formaldehyde	Acetaldehyde	Proaldehyde
Formaldehyde	S2	0.13	0.89	0.65	0.29	0.66	0.67	1.00	0.80	0.17
	S3	0.08	0.87	0.78	0.43	0.77	0.80	1.00	0.83	0.11
	S10	0.02	0.59	0.62	0.47	0.57	0.57	1.00	0.60	0.12
	S11	0.16	0.92	0.91	0.62	0.89	0.89	1.00	0.83	-0.04
	S4	0.06	0.79	0.74	0.54	0.75	0.80	1.00	0.78	0.08
	S12	0.09	0.96	0.77	0.41	0.84	0.73	1.00	0.88	0.04
	S5	0.21	0.81	0.60	0.57	0.73	0.68	1.00	0.92	0.08
	S6	-0.05	0.68	0.45	0.42	0.39	0.33	1.00	0.79	-0.31
	S9	0.80	0.93	0.74	0.80	0.85	0.90	1.00	0.87	0.15
	S33	0.92	0.75	0.51	0.56	0.42	0.51	1.00	0.83	-
	S32	0.83	0.57	0.35	0.49	0.44	0.55	1.00	0.95	-
	S31	0.88	0.71	0.23	0.53	0.43	0.63	1.00	0.94	0.34
	SW1	0.75	0.67	0.20	0.56	0.30	0.48	1.00	0.98	0.37
	SW7	0.97	0.74	0.41	0.47	0.57	0.56	1.00	0.83	0.53
	S29	0.73	0.92	0.91	0.42	0.96	0.87	1.00	0.85	-
	S24	0.25	0.76	0.40	0.09	0.66	0.65	1.00	0.84	-
	S28	0.76	0.76	0.37	0.36	0.61	0.69	1.00	0.94	-
	SW8	0.97	0.83	0.48	0.33	0.68	0.69	1.00	0.85	-
	S27	0.98	0.88	0.68	0.47	0.83	0.78	1.00	0.66	-
	S26	0.89	0.88	0.60	0.54	0.80	0.84	1.00	0.88	-
	SW23	0.65	0.73	0.43	0.37	0.63	0.68	1.00	0.92	-
	SW25	0.33	0.67	0.39	0.49	0.63	0.61	1.00	0.92	-
	S22	0.24	0.79	0.56	0.56	0.67	0.66	1.00	0.90	-
	S21	-0.03	0.91	0.79	0.72	0.93	0.92	1.00	0.93	-
	S20	0.75	0.84	0.58	0.45	0.60	0.60	1.00	0.87	-
	SW30	0.89	0.93	0.70	0.68	0.80	0.80	1.00	0.93	-
	S19	0.97	0.87	0.73	0.74	0.82	0.84	1.00	0.84	-
	S18	-0.10	0.83	0.71	0.59	0.89	0.88	1.00	0.85	-
	S17	0.28	0.87	0.64	0.37	0.85	0.96	1.00	0.93	-
	SW34	0.39	0.77	0.61	0.59	0.68	0.75	1.00	0.97	-
S16	0.12	0.88	0.61	0.55	0.86	0.91	1.00	0.88	-	
S15	0.26	0.90	0.90	0.62	0.96	0.92	1.00	0.91	-	
S14	0.34	0.86	0.57	0.40	0.71	0.78	1.00	0.89	-	
S13	0.48	0.84	0.60	0.43	0.79	0.81	1.00	0.92	-	

Table 3. Pearson correlation coefficient (R) between formaldehyde and other measured species during summer (June - July) 2017. Correlation coefficients with aldehydes other than acetaldehyde are not reported since most measured values were below detection limit and the number of data points was less than 6. Correlation coefficients exceeding 0.7 are highlighted in light red.

	Site	Pearson Correlation Coefficient R							
		Dichloromethane	Benzene	Toluene	Ethylbenzene	m+p-Xylene	o-Xylene	Formaldehyde	Acetaldehyde
Formaldehyde	SS1	0.18	0.32	0.21	-0.01	0.19	0.17	1.00	0.93
	S2	0.17	0.44	0.31	0.11	0.24	0.27	1.00	0.88
	S3	0.63	-0.40	-0.47	-0.40	-0.42	-0.42	1.00	0.58
	S4	-0.06	0.36	0.47	0.07	0.16	0.14	1.00	0.94
	S5	0.15	0.34	0.43	0.56	0.54	0.56	1.00	0.66
	S6	-0.03	0.75	0.60	0.66	0.56	0.66	1.00	0.96
	SS7	-0.38	0.65	0.63	0.69	0.63	0.64	1.00	0.96
	SS8	0.38	0.70	0.76	0.84	0.66	0.77	1.00	0.94
	S9	0.44	0.82	0.84	0.87	0.85	0.86	1.00	0.99
	S10	0.28	0.85	0.89	0.86	0.84	0.85	0.97	0.99
	S11	0.09	0.88	0.88	0.59	0.63	0.66	0.86	0.83
	S12	0.04	0.99	0.86	0.98	0.98	0.98	1.00	0.99
	S13	0.37	0.75	0.86	0.92	0.79	0.87	1.00	0.97
	S14	0.02	0.72	0.76	0.75	0.72	0.77	1.00	1.00
	S15	0.36	0.76	0.73	0.76	0.75	0.75	1.00	0.98
	S16	0.10	0.85	0.97	0.99	0.90	0.95	1.00	0.98
	S17	-0.04	0.89	0.92	0.92	0.93	0.94	1.00	0.99
	S18	0.24	0.97	0.98	0.95	0.96	0.95	1.00	0.99
	S19	-0.40	0.95	0.98	0.97	0.99	0.99	1.00	1.00
	S20	0.37	0.76	0.78	0.80	0.77	0.78	1.00	1.00
	S21	-0.05	0.95	0.97	0.98	0.97	0.97	1.00	1.00
	S22	-0.18	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	SS23	0.39	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	S24	0.22	0.09	0.09	0.13	0.09	0.13	1.00	0.59
	SS25	-0.49	-0.05	-0.16	-0.04	-0.16	-0.10	1.00	0.61
	S26	0.24	0.48	0.53	0.48	0.48	0.56	1.00	0.64
	S27	0.33	0.21	0.63	0.60	0.61	0.60	1.00	0.96
	S28	-0.34	0.19	0.18	0.05	0.06	0.09	1.00	0.50
	S29	-0.02	0.35	0.34	0.42	0.45	0.54	1.00	0.66
	SS30	-0.47	0.45	0.60	0.55	0.62	0.62	1.00	0.81
	S31	-0.25	0.55	0.65	0.60	0.60	0.63	1.00	0.92
	S32	0.08	0.67	0.62	0.58	0.49	0.47	1.00	0.42
	S33	-0.30	0.51	0.61	0.78	0.78	0.77	1.00	0.93
	SS34	0.52	0.86	0.70	0.63	0.56	0.53	1.00	0.88

5.2. Spatial Variation in Concentrations

5.2.1. Formaldehyde

Formaldehyde concentrations exhibited limited variation across the sampling sites, particularly during winter, with average wintertime concentration ranging between 0.85 and 1.48 ppb across sites. These results are consistent with 24-hr data collected during the sampling period at BV site, where air toxics data is routinely collected as part of EPA's NATTS measurements. Levels, however, were much lower than previously observed 24-hr concentrations. Levels as high as 36.9 ppb were measured during July 2003 and March 2018 at BV. The difference in concentrations could be partly attributed to the longer sampling durations during the current study. Formaldehyde was also strongly correlated with acetaldehyde (R ranging between 0.60 and 0.98) and benzene (R ranging between 0.57 and 0.96), likely suggesting their common source(s), such as fuel emissions. The relatively limited spatial variation in wintertime formaldehyde concentrations also possibly suggests a mix of source emissions. More spatial variation was observed during the summer, when

photochemical activity is stronger, with daytime concentrations peaking during week 7 (07/17/2017-07/21/2017 or 07/22/2017) at SS1 and SS8 at 5.9 and 6.3 ppbv, respectively (Figure 4).

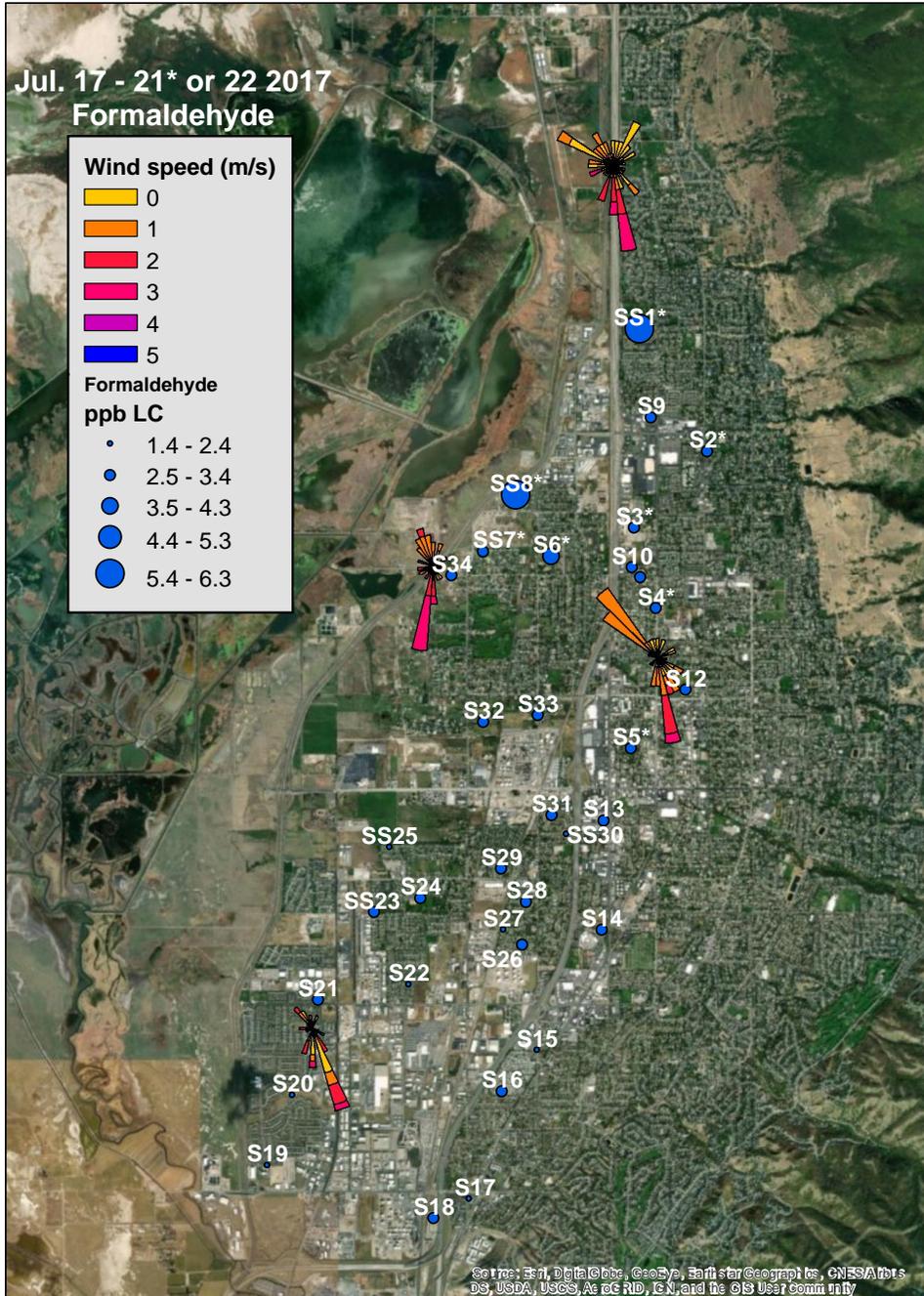


Figure 4. Wind roses and spatial variation in formaldehyde concentration (ppb LC) during July 17-21 or 17-22 2017. * represents sites where samples were collected during daytime (7:30 am – 5:30 pm) only.

5.2.2. Dichloromethane

Dichloromethane concentrations varied across sampling weeks and sampling sites. Levels of dichloromethane were below its one-in-a-million cancer risk threshold of 0.3 ppb during sampling weeks 2, 3, 4 and 6, reaching a maximum of 0.27 ppb. Daytime concentrations were also overall higher than overnight concentrations (Figures 5a-f).

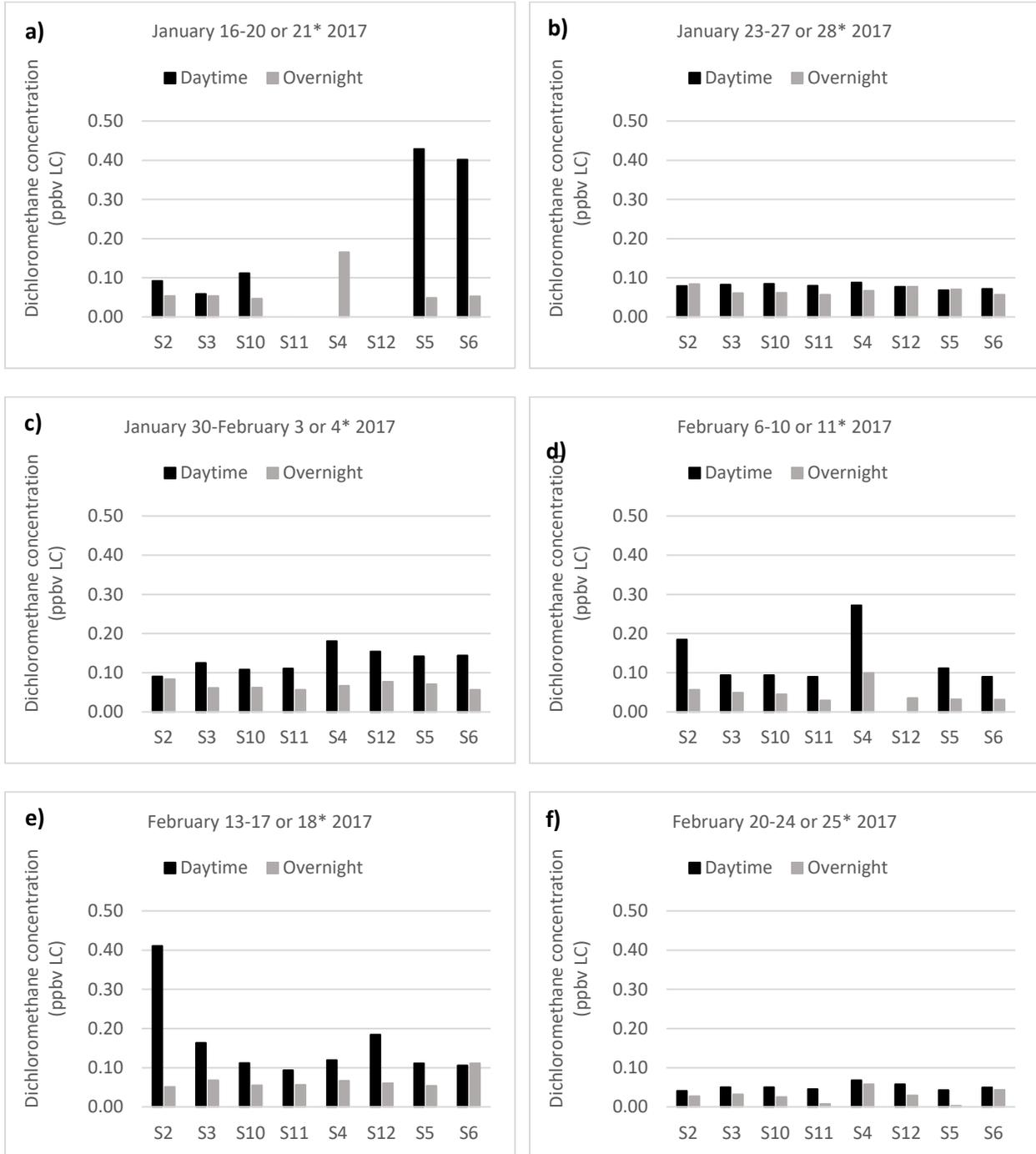


Figure 5. Daytime and overnight dichloromethane concentrations (ppb at local conditions) at select sites during winter (January - February) 2017.

Higher concentrations and spatial variation were observed during sampling weeks 1 (Jan. 16-20) and 5 (Feb. 13-17). Dichloromethane exhibited significant spatial variation during the first week of sampling, when winds were generally weak, with highest daytime concentrations being observed at S6 and S5 (Figure 6). It is noteworthy that data collected at S4, S11 and S12 was lost due to mishandling of the collected samples. Concentrations then increased at almost all of S2-S6 and S10-S12 sites over the weekend, when winds were stronger and predominantly southerly and southeasterly, peaking at S6, where dichloromethane levels exceeded its one-in-a-million cancer risk screening value (Figure 7). During the fifth week of sampling, dichloromethane concentration peaked at S2, rather than S5 and S6, even though the winds were overall weak with a westerly component, similarly to those observed during the first week of sampling (Figure 8). The relatively large spatial variation in dichloromethane concentrations suggests the influence of emission hotspots.

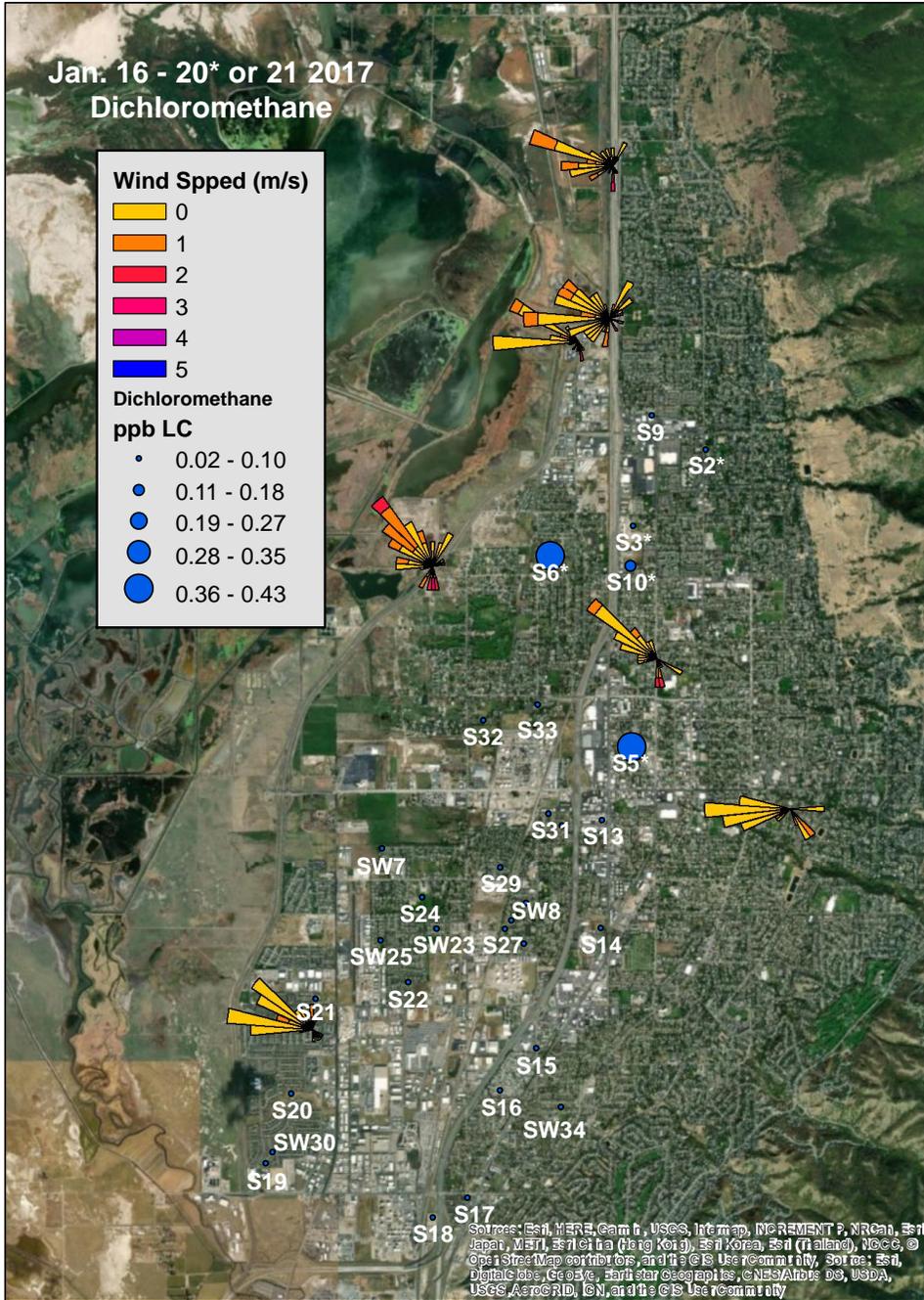


Figure 6. Wind roses and spatial variation in dichloromethane concentration (ppb LC) during weekdays of January 16-20 or 21 2017. * represents sites where samples were collected during daytime (7:30 am – 5:30 pm) only.

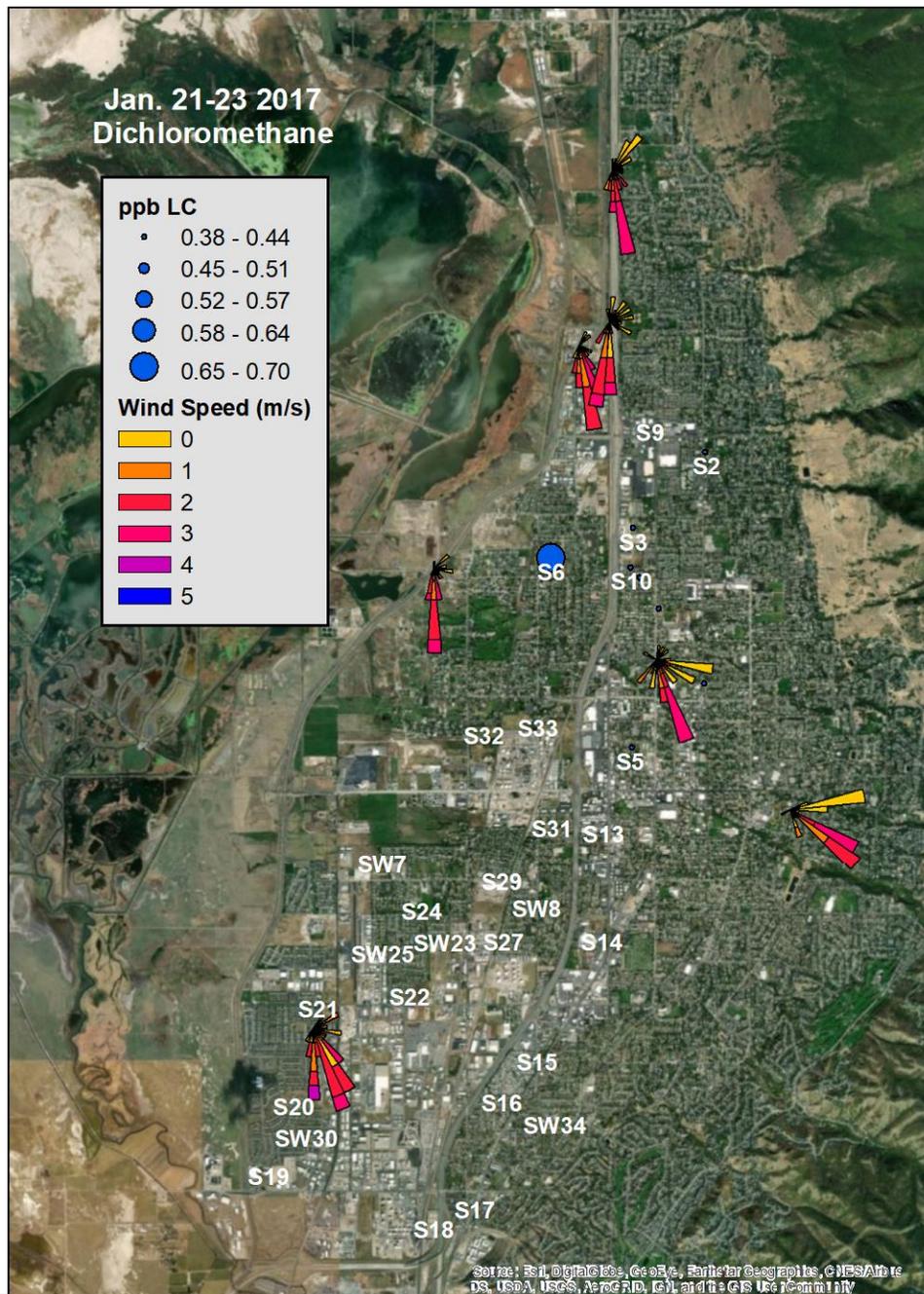


Figure 7. Wind roses and spatial variation in dichloromethane concentration (ppb LC) during weekend of January 21-23 2017 at sites S2-S6 and S10-S11. Weekend samples were not collected at other sites.

several instruments, including a differential ultraviolet absorption spectrometer (DUVAS) for benzene, toluene, ethylbenzene, and xylenes as well as formaldehyde measurements, a global positioning system (GPS), a compact weather station that provides motion-corrected wind speed and direction and a mechanism for collecting air canister samples. The GMAP was operated over three weekdays (February 5-7 2018) and a total of 23 air canister samples were taken at background locations and downwind of many potential emission sites (Figure 9). Because of logistical reasons, canister samples were taken at different times of the day rather than concurrently. No formaldehyde readings above the detection limit were recorded by the GMAP DUVAS instrument during that time period. Dichloromethane concentrations, taken via the air sample canisters, were also below the quantitation limit (< 1 ppbv). Only formaldehyde concentrations measured via the air sample canisters were above detection limit, with high formaldehyde concentrations being observed at several locations. Formaldehyde concentrations were overall higher on February 7 (Table 4) with peak concentrations (27.5 ppbv) recorded at UDAQ's BV-NATTS site (canister # 3068; station #3) and 0.66 miles northwest of the station (28.2 ppbv, canister # 4604; station #7). Measurements taken at these two locations were only 5 minutes apart. These two samples also had a fairly similar composition profile, dominated by ethanol and acetone with contributions from heptane, toluene and styrene, possibly suggesting a common source(s). Potential sources include industrial emissions/solvent usage (Sarkar et al. 2017). The sample collected at UDAQ's BV station also showed contributions from hexane, benzene and cyclohexane, suggesting an additional source at this site, possibly fuel emissions (Zheng et al. 2018). Contributions from these species in addition to heptane, toluene, ethylbenzene, m- and p-xylene were also observed at stations located in proximity to oil refineries. It is also noteworthy that almost all samples, including those collected at a background location (station #12), displayed contributions from acetone in addition to formaldehyde. The presence of these two compounds and the lack of spatial dependence is potentially consistent with secondary carbonyl production in the sampling area (De Gouw et al. 2009; Chen et al. 2014).



Figure 9. Sampling locations where grab canister samples were collected during February 5-7 2018.

Table 4. Analytical results for grab air canister samples. Data is sorted by air canister number and station. "TIC" represents tentatively identified compounds from a mass spectral search of library data for which no reference standard was available for quantitative analysis.

Station #	Canister #	Start Date and Time	End Date and Time	Concentration (ppbv)																				
				Formaldehyde	Propylene	Ethanol	Acetone	Methyl Ethyl Ketone	Hexane	Benzene	Cyclohexane	Heptane	Toluene	Ethylbenzene	m- and/or p-Xylene	Styrene	o-Xylene	Propane	Isobutane	Methyl-Alcohol	Butane	2-Methyl Butane	Pentane	1-Chloro-4-(trifluoromethyl)-benzene
1	4618	-	-	12.0			3.65																	
	3118	2/5/18	2/5/18	15.4			1.18																	
	4613	10:52:36	10:53:52	9.29			1.15																	
	3114	2/6/18 15:40:46	2/6/18 15:41:29	14.1		2.08	1.75																	
2	3069	2/5/18 14:33:43	2/5/18 14:34:24	17.5			2.74																	
	3116	2/6/18 15:18:27	2/6/18 15:19:02	17.2			16.8	6.29			2.57	8.07	37.3		8.27									
3	3119	2/5/18 15:21:59	2/5/18 15:22:38	20.0			1.63																	
	4612	2/6/18 11:37:27	2/6/18 11:38:06	10.4			2.57																	
	3068	2/7/18 10:03:13	2/7/18 10:03:53	27.5		5.81	7.54	1.31	4.01	1.18	1.43	1.99	2.47		1.25		TIC	TIC	TIC	TIC	TIC	TIC	TIC	TIC
4	3101	2/5/18 16:47:58	2/5/18 16:48:47	15.7		1.14	1.54																	
	853	2/5/18 16:50:56	2/5/18 16:51:35	25.9		1.23	2.02																	
	4616	2/6/18 13:07:07	2/6/18 13:07:53	9.55			3.51										TIC							
5	280	2/6/18 11:19:31	2/6/18 11:20:09	10.9		1.02	2.28																	
	4617	2/7/18 10:12:49	2/7/18 10:13:35	21.2		19.6	5.61					2.09					TIC	TIC	TIC	TIC			TIC	
6	523	2/6/18 14:49:06	2/6/18 14:49:50	9.70			1.38																	
7	4604	2/7/18 09:57:41	2/7/18 09:58:20	28.2		5.06	6.43	1.24				1.24	1.98		1.17		TIC	TIC	TIC	TIC			TIC	
8	3117	2/7/18 10:28:52	2/7/18 10:29:32	13.2	3.52	4.89			15.8	1.83	3.60	2.83	2.14				TIC	TIC	TIC	TIC	TIC	TIC	TIC	TIC
9	4606	2/7/18 10:48:06	2/7/18 10:48:49	13.1		1.45	23.9							1.97	5.52		1.61							TIC
10	3067	2/7/18 10:56:55	2/7/18 10:57:35	19.6		1.48	2.48																	
11	520	2/7/18 11:28:35	2/7/18 11:29:16	20.4	1.32	2.25	5.30								2.85									
12	3015	2/7/18 15:47:44	2/7/18 15:48:42	17.9			1.27																	
	4614	2/7/18	2/7/18	8.97			1.16																	
	4600	15:52:02	15:53:06	10.0			1.06																	

7. Findings and Conclusions

A saturation air monitoring study was conducted to determine potential sources of formaldehyde and dichloromethane in Davis County, Utah. Formaldehyde and acetaldehyde are hazardous air pollutants often found in concentrations exceeding the one-in-a-million cancer risk threshold in the Bountiful area. Passive samples were collected at 34 air monitoring sampling sites located throughout the area and at varying distances from potential emission sources. Samples were collected during winter and summer 2017 then analyzed for a suite of carbonyls and VOCs. Mobile and grab canister sample measurements were also conducted by EPA at the request of UDAQ during February 2018.

Findings indicated that formaldehyde concentrations were generally higher at all sampling sites over the summer than winter, with acetaldehyde being strongly correlated to formaldehyde, suggesting their common sources. Formaldehyde levels also displayed limited spatial variation, particularly during winter, likely suggesting a mix of source emissions. This was also indicated by the grab canister samples that showed that samples collected at most stations were dominated by ethanol and acetone, with potential sources including industrial emissions/solvent usage and secondary carbonyl production. Samples collected at UDAQ's BV station and close to oil refineries also showed contributions from aromatics, hexane, cyclohexane and heptane, suggesting an additional source at these sites, possibly fuel emissions.

Dichloromethane levels, on the other hand, were only higher during winter than summer in the northern part of the sampling area. Dichloromethane concentrations also varied across sampling weeks and sampling sites, with daytime wintertime concentrations overall exceeding overnight concentrations. The relatively large spatial variation in dichloromethane concentrations suggests the influence of emission hotspots.

While this study provides additional insight on the sources and spatial distribution of dichloromethane and formaldehyde, further work is needed for more accurate source identification. Findings from this study were limited by the relatively low dichloromethane concentrations compared to historical measurements collected at the BV-NATTS site. Measurements were also limited by the long sampling durations. Follow-up studies are currently underway.

8. Other Ongoing Work

Through state legislative funding, UDAQ funded a source apportionment study to further investigate the sources of formaldehyde and dichloromethane. Continuous measurements were conducted during winter 2019 using a GC-FID and a Broadband Cavity Enhanced Absorption Spectrometer (BBCEAS). Parallel measurements of gaseous (O₃, NO_x, CO) and particulate (BC, PM_{2.5}) co-pollutants as well as meteorological parameters were also conducted. To identify sources of formaldehyde and dichloromethane, source apportionment was conducted using

Positive Matrix Factorization. Temporal trends were also investigated and back wind trajectory analysis was also conducted for further source identification. A detailed description of the study is available at <https://deq.utah.gov/air-quality/bountiful-city-dichloromethane-and-formaldehyde-source-apportionment-study>.

Another study evaluating low-cost monitors for formaldehyde monitoring is currently being undertaken. The study is funded through a US EPA grant and consists of collecting continuous and 8-hr formaldehyde measurements at three different locations in the Bountiful-North Salt Lake area.

9. Acknowledgements

Special thanks to the Davis County Health Department, who was instrumental in helping UDAQ reach out to community members and secure sampling sites. Thanks to city officials, Davis school district, local fire departments as well as community members for allowing us to place sampling monitors on their properties. Also, thanks to the Air Monitoring Section staff at the Utah Division of Air Quality as well as students at the University of Utah for their assistance in collecting the samples. Also thanks in particular to Cristina Jaramillo at the University of Utah for helping coordinate the sample collection effort.

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