Final Report, May 31, 2013 rev 1
Partially Satisfying Task 6.1

WORK ORDER UNDER THE CONTRACT BETWEEN TCEQ AND CONTRACTOR:
The University of Texas at Austin

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Ozone Precursors and Toxic Chemical Compound Monitoring Continuation

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1. Background

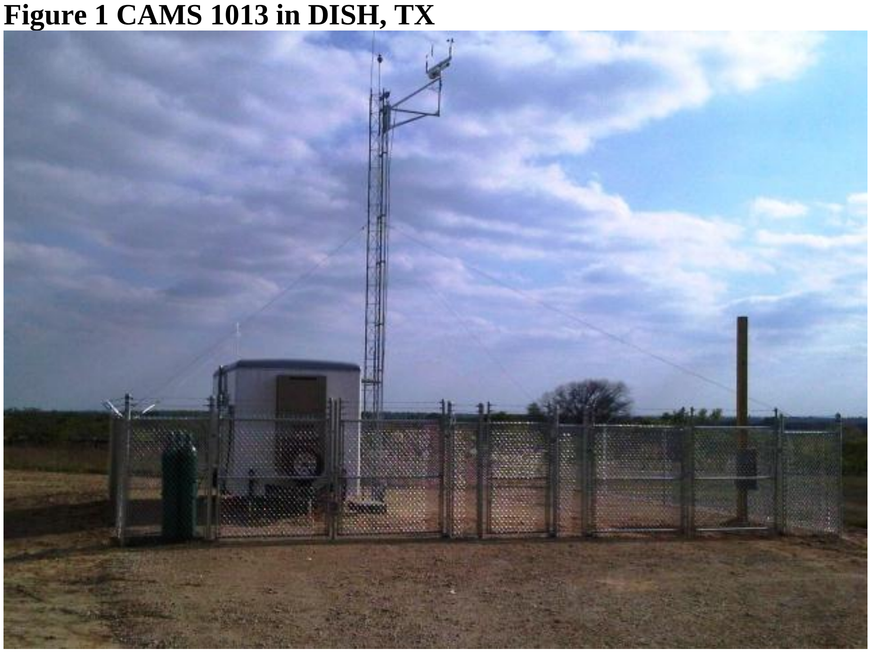
This is the final report on augmented monitoring in the Barnett Shale area near Fort Worth, TX conducted by The University of Texas at Austin. The Texas Commission on Environmental Quality (TCEQ) determined that the growth of oil and natural gas activities in the Dallas / Fort Worth (DFW) area is a cause for concern both for air toxics exposure and ozone precursors. The specific area of interest has been the Barnett Shale region, generally in the western half of the DFW area. The purpose of this project has been for The University of Texas at Austin Center for Energy and Environmental Resources (UT CEER) to monitor ambient air in the Barnett Shale region to assess the effects of oil & natural gas emissions sources, analyze the data, and summarize the results.

UT Austin performed the following activities for the TCEQ at four continuous ambient monitoring station (CAMS) sites in DFW area:

- Keller, CAMS 17 – Monitored oxides of nitrogen (NOx)
- Eagle Mountain Lake (EML), CAMS 75, Auto-GC Site 42 – Monitored hydrocarbons with an automated gas-chromatograph instrument (auto-GC) and NOx. Originally used refurbished auto-GC; replaced with a new auto-GC August 2011.
- Parker County, CAMS 76 – monitored NOx
- DISH, CAMS 1013, Auto-GC Site 43 – Operated new CAMS installed in DISH, TX in Denton County with auto-GC and meteorological instruments.

Auto-GC monitoring at Eagle Mountain Lake ended on the morning of February 27, 2013. Auto-GC monitoring at DISH ended on May 7, 2013. NOx monitoring at Parker County CAMS 76 will end on or before April 30, 2013. NOx instruments at Eagle Mountain Lake and Keller will be transferred to TCEQ ownership and will continue to operate in place without UT's involvement. A photo of the CAMS 1013 DISH site appears in Figure 1.

Figure 1 CAMS 1013 in DISH, TX



2. Summary of Activities April 2010 – May 2013 (38 months)

The monthly data completeness for the two auto-GCs is shown in Table 1 for validated data only. Data collection began April 19, 2010, so the first data row in Table 1 is May 2010 so as to only show compete months. Since May 2010, data recovery averages at or above 97 percent of scheduled hours at each of the two sites. The annual data completeness for NO_2, one of three species measured by NOx analyzers, is shown in Table 2.

Table 1 Percent Auto-GC Data Recovery/Validated May 2010 – Apr 2013, as of 5/31/2013

Month	**EML**	**DISH**	**Month**	**EML**	**DISH**	**Month**	**EML**	**DISH**
May 2010	97	97	May 2011	97*	100	May 2012	100	100
Jun 2010	99	94	Jun 2011	99*	98	June 2012	97	100
Jul 2010	99	92	Jul 2011	98*	99	Jul 2012	96	100
Aug 2010	96	99	Aug 2011	82	100	Aug 2012	97	100
Sep 2010	98	95	Sep 2011	98*	100	Sep 2012	94	99
Oct 2010	100	95	Oct 2011	97	96	Oct 2012	98	100
Nov 2010	99	98	Nov 2011	99	100	Nov 2012	100	93
Dec 2010	100	99	Dec 2011	98	99	Dec 2012	88	95
Jan 2011	97	99	Jan 2012	99	99	Jan 2013	100	100
Feb 2011	99	93	Feb 2012	99	90*	Feb 2013	92	100
Mar 2011	98	94	Mar 2012	91	100	Mar 2013	N/A	99
Apr 2011	98	96	Apr 2012	98	99	Apr 2013	N/A	100
						Average	**97**	**98**

* Although there is high hourly recovery, many individual compounds were invalid

Table 2 Percent NO_2 Data Recovery/Validated May 2010 – Apr 2013, as of 5/31/2013

NO_2 %	2010	2011	2012	2013
Parker	94.6	97.7	95.6	98.0
Keller	96.3	96.5	97.4	97.7
EML	95.1	96.6	96.6	92.6

Shut-down Operations

Auto-GC monitoring at EML ended on the morning of February 27, but the NOx monitor continued under TCEQ direction. The NOx monitoring at Keller CAMS 17 has also been continued under TCEQ direction. The NOx monitor at Parker County CAMS 75 was discontinued on March 19, 2013 and has been returned to UT CEER in Austin. The EML auto-GC was put into storage by Orsat, and the EML trailer was been returned to the TCEQ Central Office in Austin. The DISH auto-GC ended operation on May 7, 2013, and the trailer, auto-GC, and met-tower were moved to UT CEER in Austin.

Summary of Data Collected

Table 3 contains a statistical summary of the UT CEER NO, NO_2, and NOx data collected at the three sites by year. No values exceeded the level of the primary National Ambient Air Quality Standard for NO_2 (100 ppb for 1 hour). Note the lower number of observations in 2010 and 2013. The means for each of the three species are graphed by year in Figures 2, 3, and 4, all on the same scale. Mean concentrations decline from the urban Keller site to the suburban EML site to the rural Parker County site.

Table 4 shows the statistical summary through February 2013 for all auto-GC data collected at EML, and Table 5 shows the same through early May 2013 for DISH. No auto-GC measurements or averages of measurements have been equal or greater than TCEQ Air Monitoring Comparative Values (AMCV). Note that the summaries in Tables 4 and 5 include total non-methane hydrocarbon (TNMHC) and total target compound (TNMTC) as measured parameters. The ratio of TNMTC to TNMHC, representing the fraction of hydrocarbon mass in ***identified*** species is 0.94 at EML and 0.95 at DISH. Overall, total hydrocarbon mass ratio between DISH and EML was 1.65 (DISH 65 percent higher than EML). Note the scale difference in plotting the means concentrations for the two sites in Figures 5 and 6.

The values for maximum acetylene and 2-methylheptane in Table 5 are from 7 CST on May 26, 2010 and were likely to have been a quality assurance problem. They are highlighted in red font in the table. The Orsat contractor report on this sample states:

> We have looked at the May 26, 2010 data for DISH and it does look like a baseline excursion which affected both acetylene and 2-methylheptane (both RT of 24 min) related to a cylinder change by operator. Do not know why this was not caught initially or when AQS data report was returned except it was not flagged as new high on AQS report either.

The second highest one-hour maximum for acetylene – which would replace the current entry in Table 5 – was 15.98 ppbC. Similarly, the second highest 24-hour (one-day) average for acetylene was 2.33 ppbC (also on 5/26/2010), the second highest one-hour maximum for 2-methylheptane was 29.31 ppbC, and the second highest 24-hour average for 2-methylheptane was 4.93 ppbC (also on 5/26/2010). We propose to submit in the near future a memo to TCEQ Monitoring Division to flag the May 26, 2010, 7 CST data.

Another important quality assurance finding is the highly reactive volatile organic compound (HRVOC) trans-2-butene (t2butene) is of very unreliable species and should not be used to evaluate emissions inventories, to estimate air reactivity, or to assess modeling runs. Time series graphs of the hourly t2butene data at DISH and EML appear in Figures 7 and 8.

Table 3 Summary of NOx measurements at project sites

yr	Species	Statistics	2010	2011	2012	2013
C17	NO	count	6,066	8,456	8,551	3,257
		average	1.20	1.35	1.25	0.99
		95thp-tile	4.48	5.32	4.75	3.84
		max	110.45	115.17	83.16	75.75
C17	NO_2	count	6,074	8,456	8,552	3,257
		average	7.81	7.98	8.21	7.99
		95thp-tile	23.35	25.34	24.99	23.54
		max	47.89	55.14	58.05	52.19
C17	NOx	count	6,080	8,456	8,551	3,257
		average	8.99	9.25	9.37	8.93
		95thp-tile	27.43	29.73	28.82	27.08
		max	149.37	156.28	123.32	123.89
C75	NO	count	5,992	8,466	8,484	3,080
		average	0.63	0.90	1.10	0.74
		95thp-tile	3.28	4.26	4.19	3.37
		max	52.22	94.88	73.50	45.72
C75	NO_2	count	5,999	8,465	8,485	3,078
		average	6.59	6.80	6.34	6.15
		95thp-tile	21.16	22.07	20.89	20.09
		max	48.09	48.22	50.98	40.76
C75	NOx	count	5,999	8,466	8,480	3,080
		average	6.88	7.47	7.26	6.74
		95thp-tile	24.25	25.85	24.49	23.18
		max	79.70	126.70	116.94	77.71
C76	NO	count	6,018	8,558	8,383	1,835
		average	0.33	0.58	0.58	0.71
		95thp-tile	1.57	1.78	1.74	2.26
		max	59.56	96.49	104.51	41.03
C76	NO_2	count	6,025	8,559	8,398	1,835
		average	3.07	3.17	2.68	3.38
		95thp-tile	8.29	8.61	7.52	9.44
		max	41.06	44.59	42.31	26.88
C76	NOx	count	6,032	8,559	8,395	1,835
		average	2.93	3.60	3.11	3.99
		95thp-tile	8.71	9.90	8.68	10.82
		max	84.80	138.64	140.79	62.89

Figure 2 Keller CAMS 17 mean NO, NO_2, NOx by year (partial 2010 and 2013)

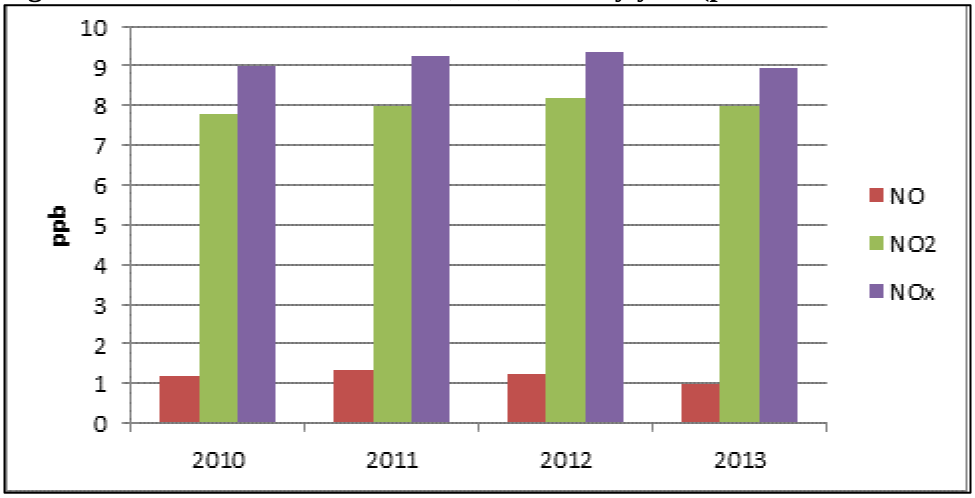


Figure 3 EML CAMS 75 mean NO, NO_2, NOx by year (partial 2010 and 2013)

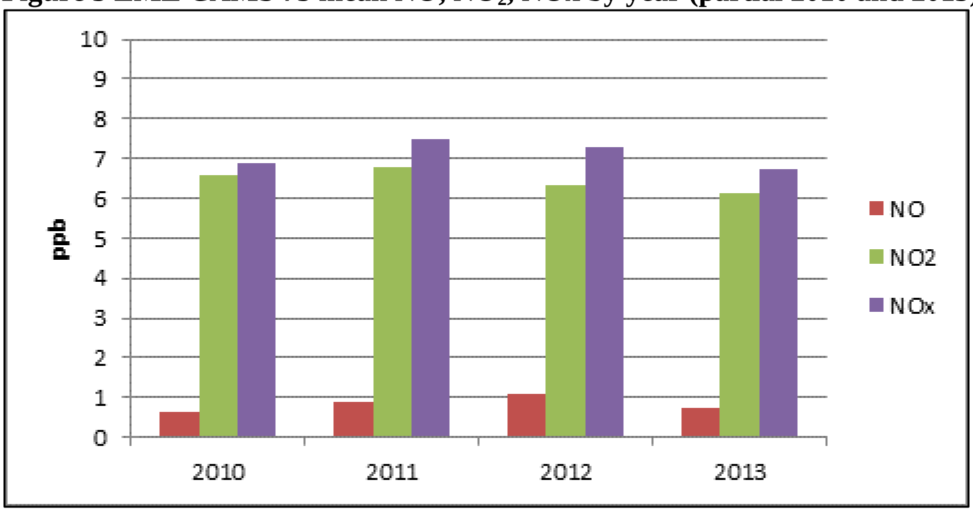


Figure 4 Parker Co CAMS 76 mean NO, NO_2, NOx by year (partial 2010 and 2013)

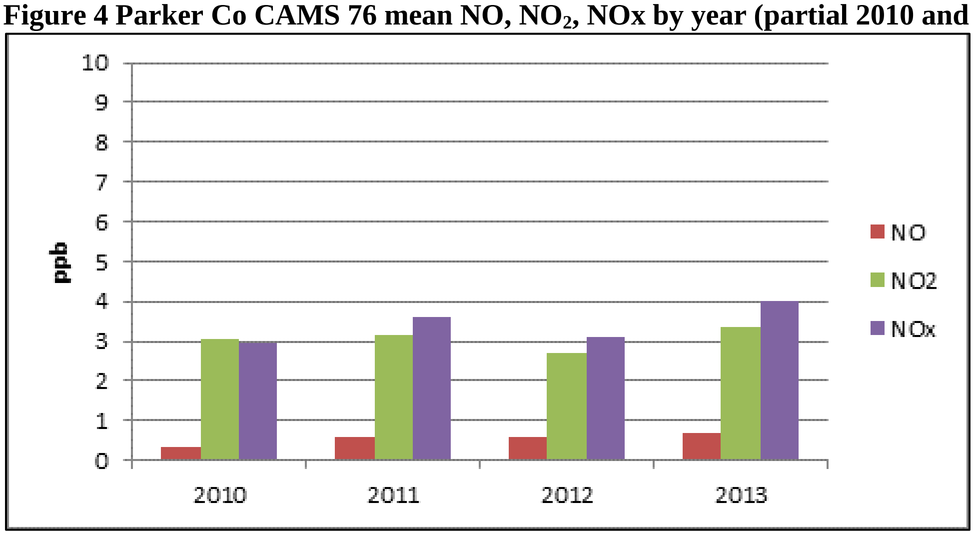


Table 4 EML auto-GC data summary April 2010 through February 2013

Species / ppbC units	Num obs	Max 1-Hour	Max 24-Hour	Mean
TNMTC	20,679	3,648.41	574.09	92.52
TNMHC	20,679	4,468.49	614.58	98.35
Ethane	21,872	1,693.60	188.90	34.85
Ethylene	21,211	22.19	3.03	0.69
Propane	21,871	568.70	139.89	21.82
Propylene	19,937	28.19	2.81	0.62
Isobutane	21,874	138.25	35.67	5.07
n-Butane	21,875	462.47	80.49	10.76
Acetylene	11,588	8.30	1.43	0.51
t-2-Butene	21,871	1.30	0.58	0.20
1-Butene	21,872	2.84	0.38	0.08
c-2-Butene	21,549	5.85	2.92	0.10
Cyclopentane	21,866	21.38	1.41	0.24
Isopentane	21,874	421.50	31.83	4.65
n-Pentane	21,875	586.85	33.94	4.44
1,3-Butadiene	21,873	0.99	0.23	0.04
t-2-Pentene	21,867	3.25	0.22	0.02
1-Pentene	21,869	1.86	0.17	0.02
c-2-Pentene	21,867	1.79	0.19	0.01
2,2-Dimethylbutane	21,866	14.03	0.90	0.11
Isoprene	21,869	14.78	3.62	0.32
n-Hexane	21,864	446.96	21.84	1.87
Methylcyclopentane	19,417	96.84	5.68	0.69
2,4-Dimethylpentane	19,417	17.87	2.04	0.05
Benzene	21,864	24.53	2.45	0.64
Cyclohexane	21,864	101.62	5.01	0.52
2-Methylhexane	15,058	110.89	5.60	0.49
2,3-Dimethylpentane	16,968	30.01	1.60	0.10
3-Methylhexane	21,863	112.23	5.72	0.50
2,2,4-Trimethylpentane	21,864	39.59	3.00	0.51
n-Heptane	21,863	223.50	11.06	0.84
Methylcyclohexane	21,864	164.59	8.20	0.80
2,3,4-Trimethylpentane	21,864	3.04	0.52	0.08
Toluene	21,864	62.36	5.53	1.04
2-Methylheptane	21,864	45.41	2.29	0.23
3-Methylheptane	21,864	35.47	1.87	0.19
n-Octane	21,864	86.02	4.45	0.30
Ethyl Benzene	21,864	7.58	0.46	0.08
p-Xylene + m-Xylene	21,864	21.81	2.11	0.36
Styrene	21,864	11.31	0.62	0.01
o-Xylene	21,864	4.21	0.53	0.10
n-Nonane	21,864	8.03	1.11	0.14
Isopropyl Benzene - Cumene	21,864	0.45	0.06	0.00
n-Propylbenzene	21,864	1.83	0.20	0.02
1,3,5-Trimethylbenzene	17,374	2.79	0.40	0.04
1,2,4-Trimethylbenzene	17,369	2.68	0.79	0.09
n-Decane	17,374	4.88	0.62	0.10
1,2,3-Trimethylbenzene	17,240	9.85	6.90	0.20

Table 5 DISH auto-GC data summary April 2010 through May 2013

Species / ppbC units	Num obs	Max 1-Hour	Max 24-Hour	Mean
TNMTC	19,938	3,691.36	1,260.90	153.42
TNMHC	19,938	3,852.92	1,316.90	161.64
Ethane	22,000	1,947.40	689.01	75.36
Ethylene	22,014	102.51	21.57	1.13
Propane	22,011	1,219.38	293.37	32.25
Propylene	22,014	10.60	3.92	0.46
Isobutane	22,014	386.39	76.92	6.91
n-Butane	22,014	467.37	104.50	12.83
Acetylene	22,014	326.55	18.70	0.64
t-2-Butene	22,014	3.29	0.26	0.07
1-Butene	22,013	11.85	0.85	0.10
c-2-Butene	22,013	3.70	0.47	0.03
Cyclopentane	22,014	6.15	1.31	0.27
Isopentane	22,014	164.89	44.86	5.67
n-Pentane	22,014	142.31	44.14	4.94
1,3-Butadiene	19,401	1.02	0.22	0.05
t-2-Pentene	22,013	1.31	0.13	0.01
1-Pentene	22,012	0.76	0.11	0.01
c-2-Pentene	22,012	0.71	0.07	0.00
2,2-Dimethylbutane	22,010	10.83	1.55	0.11
Isoprene	19,165	8.40	1.78	0.26
n-Hexane	22,003	263.46	57.39	3.07
Methylcyclopentane	22,011	24.57	4.92	0.77
2,4-Dimethylpentane	22,012	14.53	2.55	0.20
Benzene	22,012	15.12	3.22	0.90
Cyclohexane	21,910	27.41	5.51	0.67
2-Methylhexane	21,910	35.24	6.30	0.63
2,3-Dimethylpentane	21,910	15.93	2.92	0.26
3-Methylhexane	21,910	34.30	6.23	0.71
2,2,4-Trimethylpentane	21,909	76.45	13.62	1.12
n-Heptane	21,909	68.19	11.22	1.11
Methylcyclohexane	21,910	55.80	9.20	1.03
2,3,4-Trimethylpentane	21,910	30.02	5.41	0.32
Toluene	21,908	183.33	17.17	1.71
2-Methylheptane	21,909	109.03	7.18	0.34
3-Methylheptane	21,910	31.10	3.80	0.26
n-Octane	21,910	40.49	6.26	0.41
Ethyl Benzene	21,910	10.21	1.19	0.13
p-Xylene + m-Xylene	21,908	37.00	4.44	0.54
Styrene	21,909	2.76	0.34	0.02
o-Xylene	21,909	12.63	1.34	0.15
n-Nonane	21,909	19.80	3.03	0.20
Isopropyl Benzene - Cumene	21,909	9.16	0.44	0.01
n-Propylbenzene	21,908	1.99	0.31	0.03
1,3,5-Trimethylbenzene	21,670	6.90	1.11	0.08
1,2,4-Trimethylbenzene	21,669	8.21	1.71	0.18
n-Decane	21,669	11.08	1.23	0.17
1,2,3-Trimethylbenzene	21,001	21.01	2.87	0.25

Figure 5 EML auto-GC mean overall concentrations, ppbC, April 2010 through February 2013

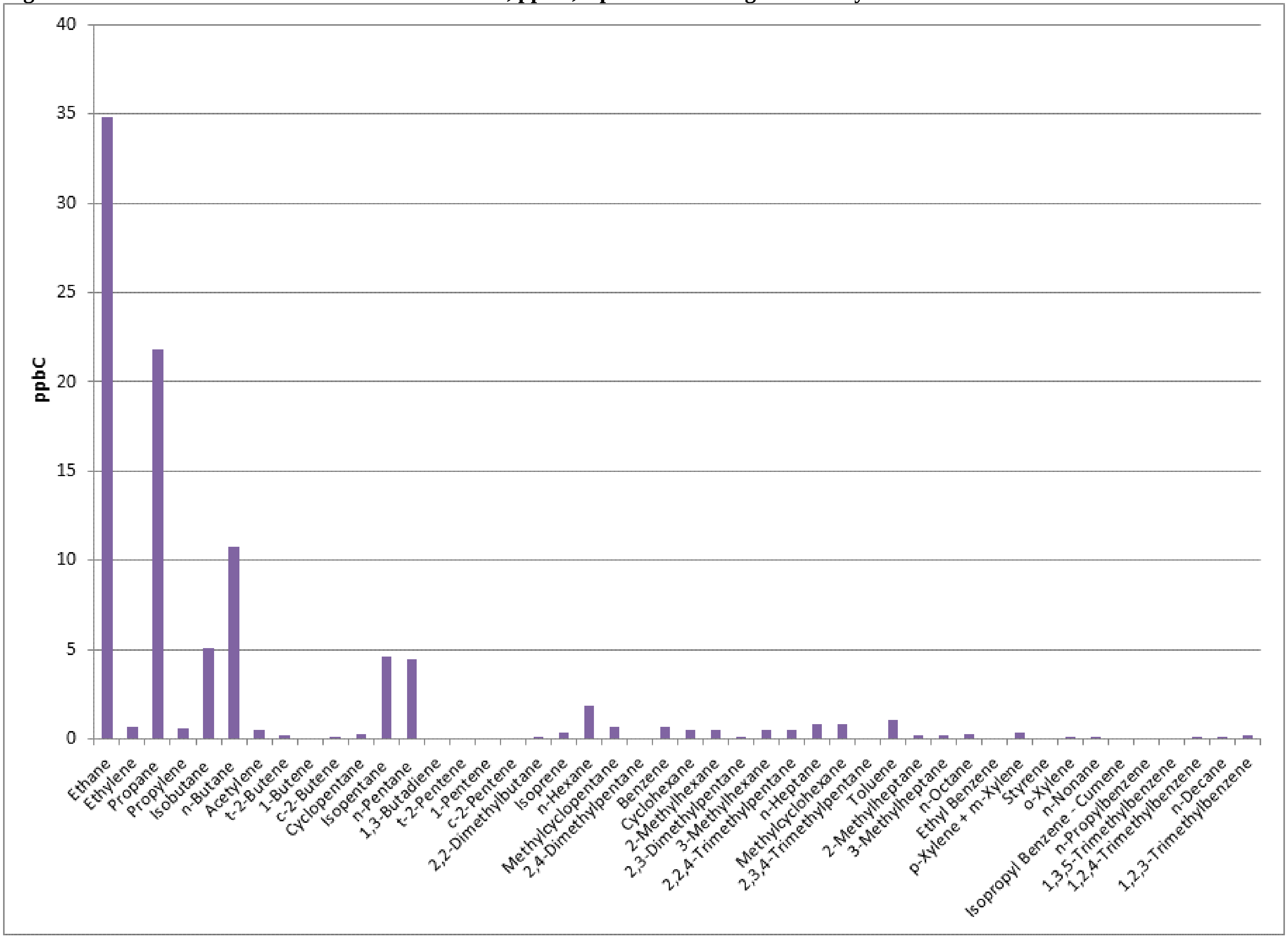


Figure 6 DISH auto-GC mean overall concentrations, ppbC, April 2010 through May 2013

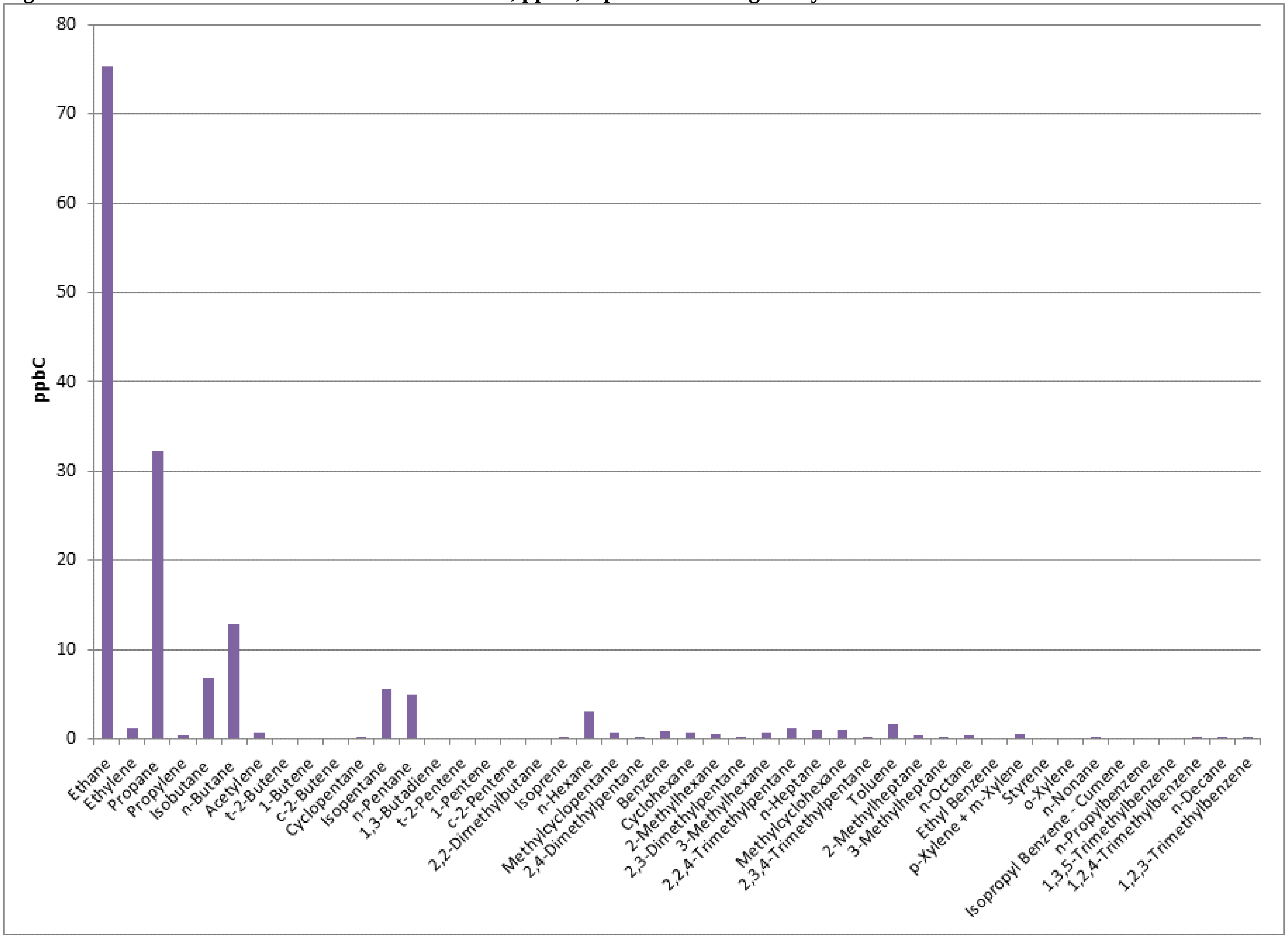


Figure 7 DISH t-2-butene 24-hour averaged time series

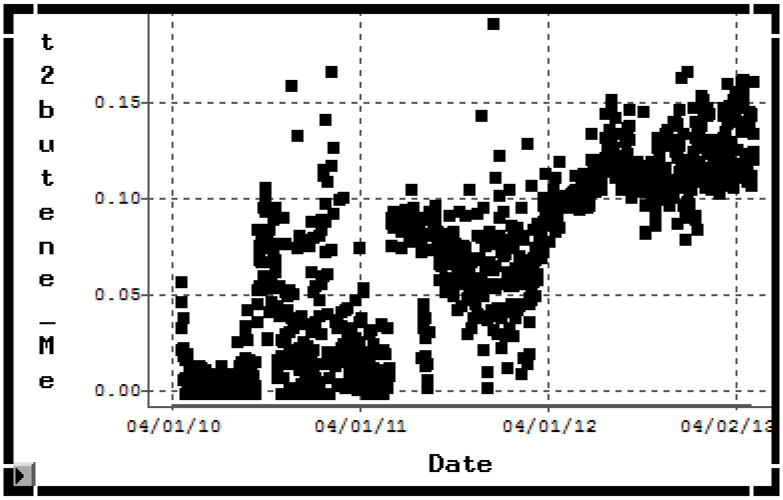
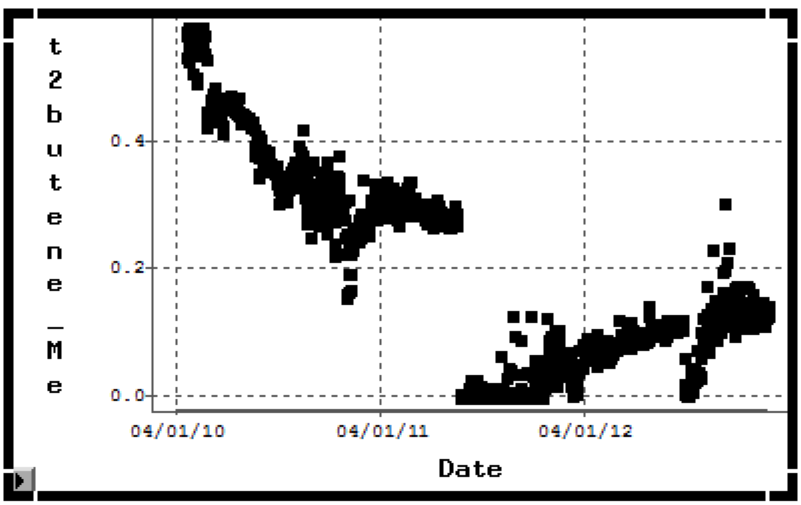


Figure 8 EML t-2-butene 24-hour averaged time series



Auto-GC Locations

Figure 9 shows a plotting of emissions source locations from the TCEQ inventory records from the Barnett Shale "Phase Two" emissions inventory. Both oxides of nitrogen (NOx) and volatile organic compounds (VOC) emission source locations are shown in Figure 9, displaying the extent of emission sources outside the DFW urban area to the northwest. The four auto-GCs on the northern side of Fort Worth (Decatur Thompson, Flower Mound Shiloh, and the two project sites) are also shown in the figure. TCEQ also collects data at the Everman Johnson site and at a new site in Kennedale on the southern side of Fort Worth, neither of which is shown in Figure 9.

Figure 10 shows an aerial photo of the DISH CAMS 1013 site, with the gas compressor stations and associated equipment plus on well site to the southeast. Figure 11 shows an aerial photo of the EML CAMS 75 site, with several production well pads to the north. Figure 12 is an image from a new Website operated by OGInfo.com for the area around EML. A note from a weekly email on oil & gas operations in Texas provide by the Powell Shale Digest in May 2013 appears below describing as to the source of the map in Figure 12.

> "Please take the time to review our new interactive, multi-layered *PSD/OGI Texas Shale Flex Map* (http://secure.oginfo.com/fastmaps/powellmap/mapviewer.php) application based on our well research data summary of production for each producer in the Barnett Shale of north Texas; Eagle Ford Shale of south Texas; and Haynesville Shale of east Texas to January 1, 2013. In order to see the complete map tutorial and all the 'bells & whistles' created to save you time, go to: http://secure.oginfo.com/fastmaps/powellmap/helphtml/map_tutorial.html. Much more information will be forthcoming in the near future. Let us know what you think of our new Texas shale interactive map."

Figure 9 VOC and NOx sources in the Barnett Shale, TCEQ Barnett Shale Phase Two emissions inventory, five local auto-GCs

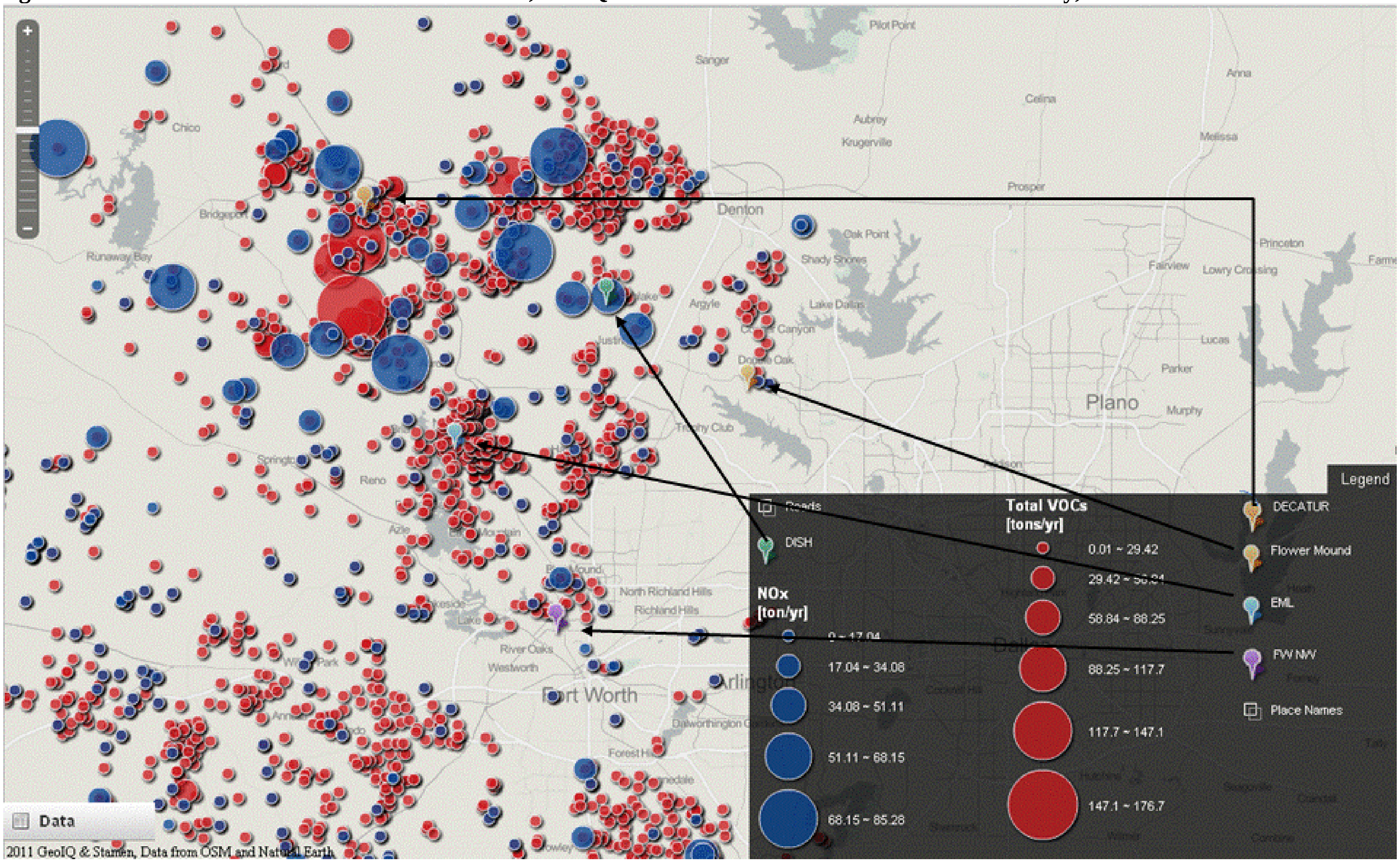
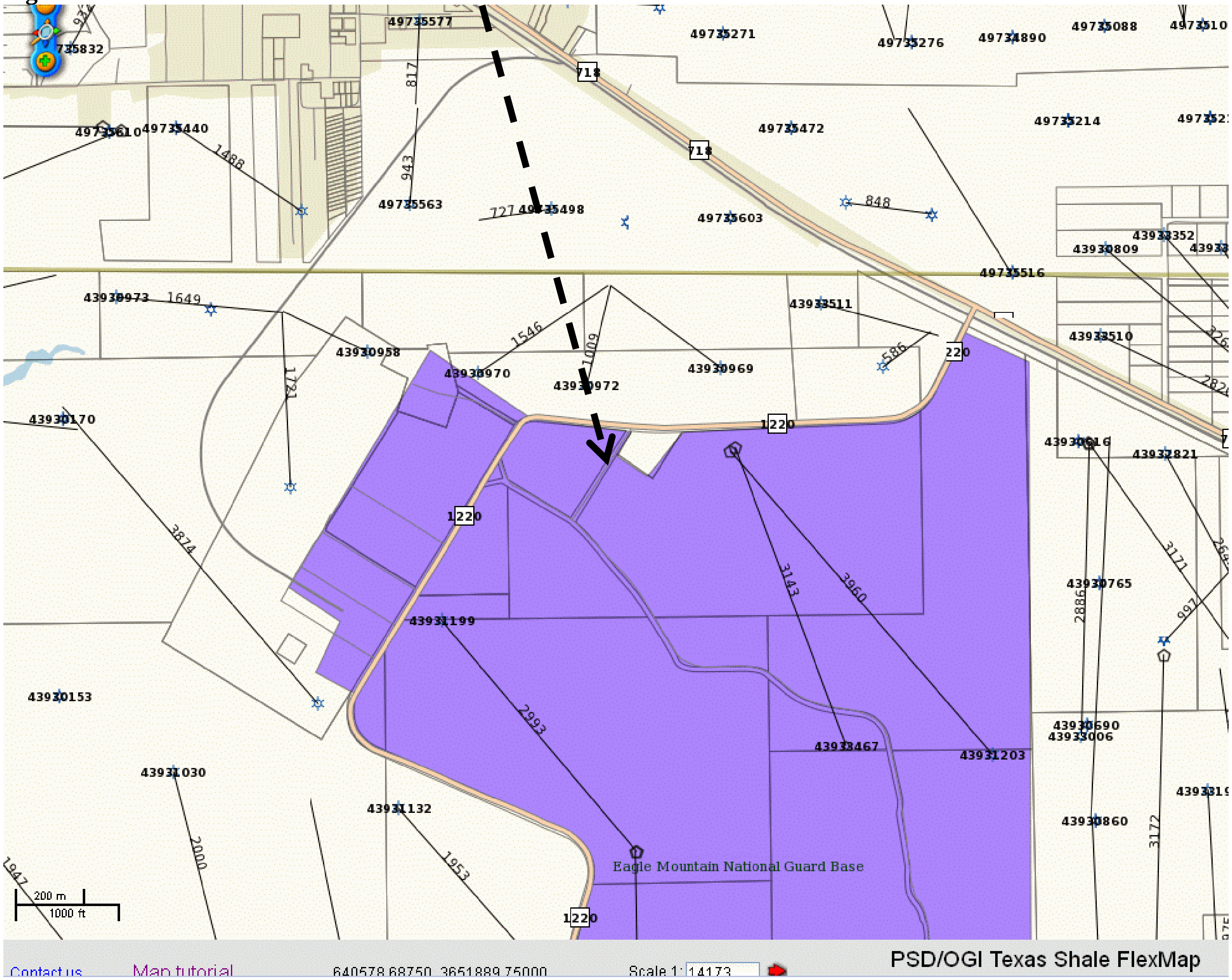


Figure 10 CAMS 1013 DISH site with 0.3 mile radius circle around it

Figure 11 CAMS 75 EML site with 0.3 mile radius circle around it

Figure 12 Well site information around CAMS 75 EML



3. Data Analyses

Benzene trends

Table 6 and Table 7 show the monthly statistics for benzene concentrations in parts per billion-volume (ppbV) units. The switch in units from ppbC to ppbV is made to facilitate comparisons to TCEQ Air Monitoring Comparison Values. The monthly mean values are graphed in Figure 13. As was pointed out in recent monthly reports, one should note that the difference in mean concentrations between the two sites has closed since about September 2011. It is important to note that the old refurbished auto-GC was replaced with a new system in August 2011, and this may contribute to a change in baseline concentrations or analyte recovery.

The close of February 2013 marked the end of 34 complete months at both auto-GCs, and the close of April 2013 marked the end of 36 complete months the DISH auto-GC, providing the ability to compare data behavior over up to three years (May 2010 – May 2013). In Tables 6 and 7 the highest values in each column are highlighted in red font. The mean monthly average at EML in its second to last full month of operation in January 2013 was the maximum one month average over the site's operation period.

Several meteorological factors affect the concentrations. In winter months, winds tend to be slower and the air does not mix as much as in the summer, giving air pollutants more opportunities to accumulate. So all else being equal, one can expect higher concentrations for many pollutants in colder weather months. Wind direction also plays an important role, and will be discussed later in this report.

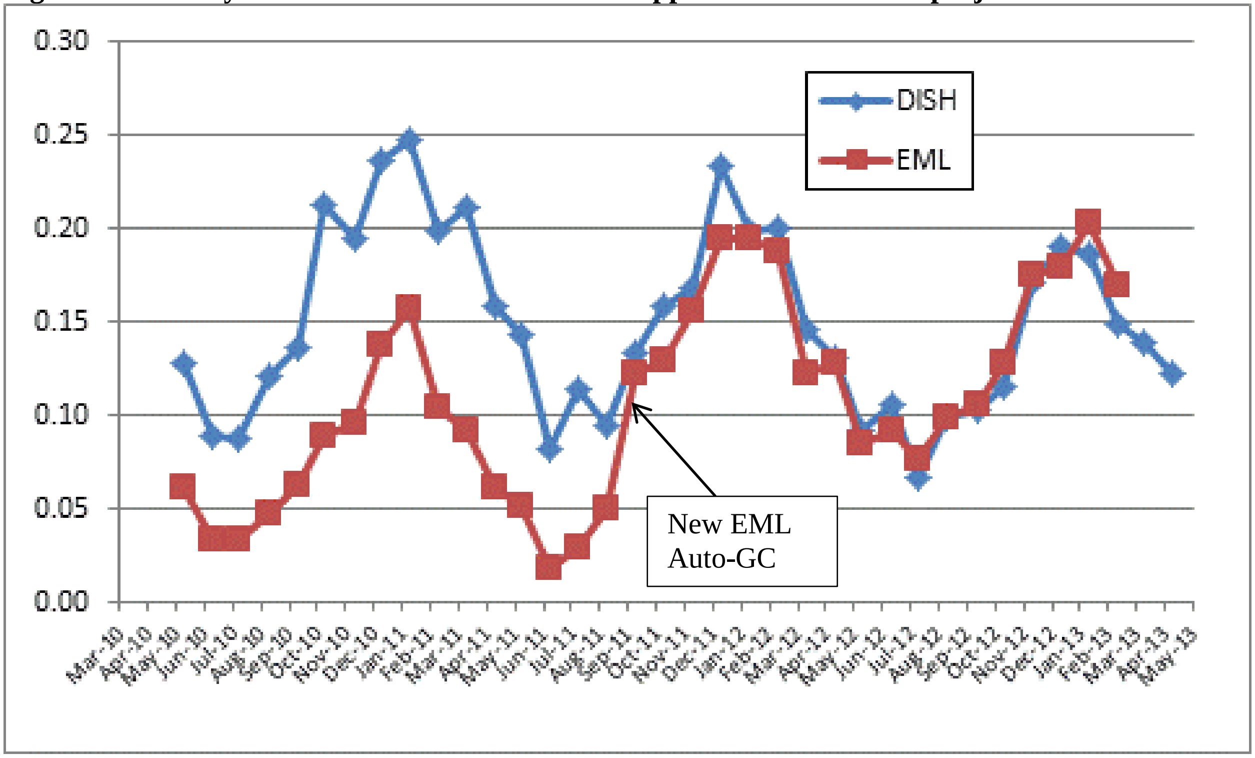
Table 6 Monthly statistics for benzene at DISH CAMS 1013 through May 7, 2013, ppbV units

Month	Max 1hr	Max 24hr	Mean
May-10	0.860	0.232	0.127
Jun-10	0.733	0.192	0.089
Jul-10	0.832	0.149	0.087
Aug-10	1.494	0.329	0.120
Sep-10	1.100	0.265	0.136
Oct-10	1.304	0.414	0.213
Nov-10	1.162	0.439	0.194
Dec-10	1.228	0.433	0.237
Jan-11	0.975	0.426	0.247
Feb-11	1.623	0.414	0.199
Mar-11	1.973	0.536	0.211
Apr-11	0.998	0.303	0.158
May-11	1.244	0.261	0.143
Jun-11	0.617	0.226	0.082
Jul-11	0.941	0.207	0.113
Aug-11	0.865	0.240	0.094
Sep-11	2.520	0.327	0.133
Oct-11	0.813	0.313	0.158
Nov-11	0.667	0.440	0.168
Dec-11	1.391	0.475	0.234
Jan-12	0.808	0.326	0.199
Feb-12	0.749	0.326	0.200
Mar-12	0.734	0.279	0.146
Apr-12	0.445	0.203	0.130
May-12	0.491	0.171	0.092
Jun-12	0.650	0.176	0.105
Jul-12	0.507	0.116	0.066
Aug-12	0.449	0.202	0.099
Sep-12	0.404	0.183	0.102
Oct-12	0.726	0.235	0.115
Nov-12	0.657	0.328	0.171
Dec-12	1.189	0.504	0.190
Jan-13	0.755	0.322	0.186
Feb-13	0.559	0.260	0.148
Mar-13	0.665	0.235	0.139
Apr-13	1.589	0.286	0.122

Table 7 Monthly statistics for benzene at EML CAMS 75 through Feb. 27, 2013, ppbV units

Month	Max 1hr	Max 24hr	Mean
May-10	0.322	0.103	0.061
Jun-10	0.215	0.094	0.033
Jul-10	0.198	0.072	0.033
Aug-10	0.281	0.150	0.047
Sep-10	0.357	0.143	0.062
Oct-10	0.415	0.157	0.089
Nov-10	0.376	0.179	0.096
Dec-10	0.429	0.211	0.137
Jan-11	0.493	0.285	0.157
Feb-11	0.408	0.201	0.104
Mar-11	0.373	0.183	0.092
Apr-11	0.713	0.148	0.061
May-11	0.302	0.128	0.051
Jun-11	0.338	0.076	0.017
Jul-11	0.310	0.057	0.029
Aug-11	0.373	0.167	0.050
Sep-11	4.089	0.347	0.122
Oct-11	0.455	0.233	0.129
Nov-11	0.758	0.354	0.155
Dec-11	0.733	0.301	0.194
Jan-12	0.818	0.407	0.195
Feb-12	0.791	0.344	0.188
Mar-12	0.431	0.254	0.122
Apr-12	0.595	0.233	0.128
May-12	0.421	0.137	0.084
Jun-12	0.456	0.177	0.092
Jul-12	0.370	0.143	0.076
Aug-12	0.613	0.160	0.099
Sep-12	0.547	0.184	0.106
Oct-12	0.528	0.238	0.128
Nov-12	0.684	0.290	0.175
Dec-12	0.515	0.294	0.179
Jan-13	0.732	0.353	0.203
Feb-13	0.727	0.305	0.170

Figure 13 Monthly mean concentrations of benzene ppbV units at the two project sites



Auto-GC data comparisons and temporal behavior

As was cited in Section 2 of this report, the overall total hydrocarbon concentrations for DISH were generally greater than at EML. DISH collected data two months beyond EML, those months (March, April) having mean concentrations close to the overall annual averages for most species, so little bias is created by directly comparing all the DISH data with all the EML data. Figure 14 shows a scatter plot of the mean concentrations at EML vs. the mean concentrations at DISH from Tables 4 and 5, with a simple linear regression fit. Units are in ppbC. The switch back to ppbC from ppbV is made to facilitate comparisons between species on a mass basis. Concentrations for alkane species – ethane, propane, n-butane, isobutane, n-pentane, and isopentane – strongly influence the relationship. When just ethane and propane are removed from the graph, the relationship becomes much closer to 1-to-1, as shown in Figure 15, but after removing all alkanes up through and including n-hexane, the relationship is approximately EML = 0.65×DISH, shown in Figure 16.

Figures 17, 18, and 19 show the mean concentrations from DISH with 46 auto-GC species by month of the year, with 44 auto-GC species – excepting ethane and propane – by month of the year, and with 39 auto-GC species – excepting ethane, propane, isobutane, n-butane, isopentane, n-pentane, and n-hexane – by month of the year. The biogenic species isoprene peaks in the summer, while other species peak in the winter. Figures 20, 21, and 22 show a similar series of graphs for EML. The EML isoprene summertime maximum is significantly higher than at DISH. Additional graphs will be provided upon request.

Figures 23 and 24 show the mean concentration for the sum of all species (TNMTC) by hour of the day (Central Standard Time = CST) split by day type, where Monday through Friday are classified as "WD" for weekday, and Saturday and Sunday are combined and classified as "WE" for weekend. At both sites, there are slightly higher concentrations for a set of early morning weekday hours, which may or may not be a motor vehicle or work-week effect. Behavior of individual species has not been examined.

Figure 14 Mean concentrations at EML vs DISH April 2010 – May 2012, all 46 auto-GC species

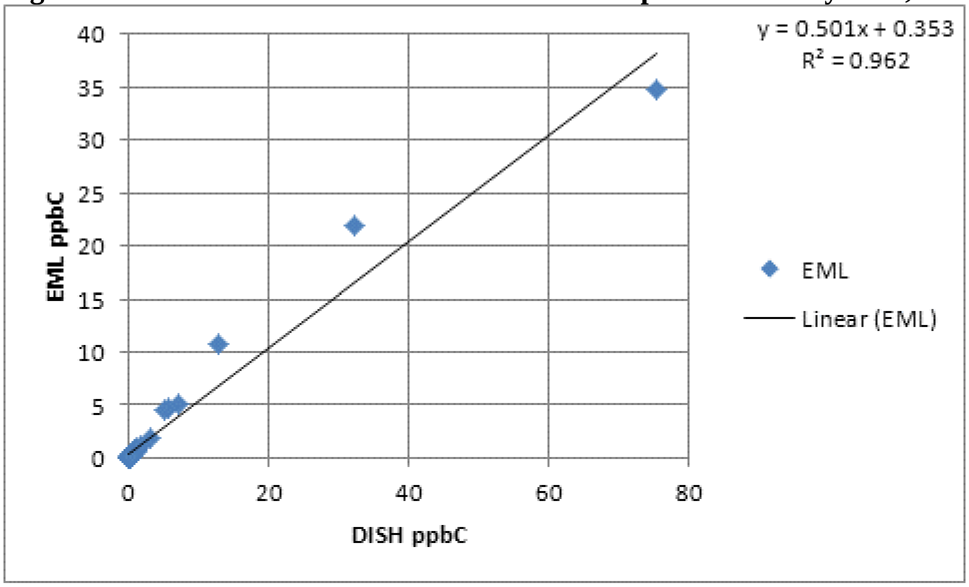


Figure 15 Mean concentrations at EML vs DISH April 2010 – May 2012, 44 auto-GC species (no ethane, propane)

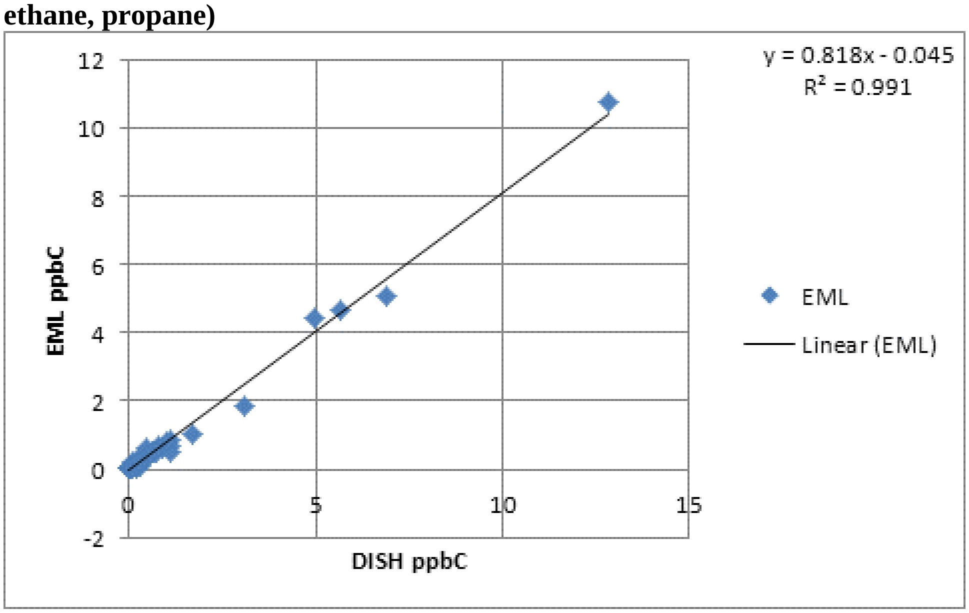


Figure 16 Mean concentrations at EML vs DISH April 2010 – May 2012, 39 auto-GC species (no C2-C4 alkanes, no n-pentane, isopentane, n-hexane)

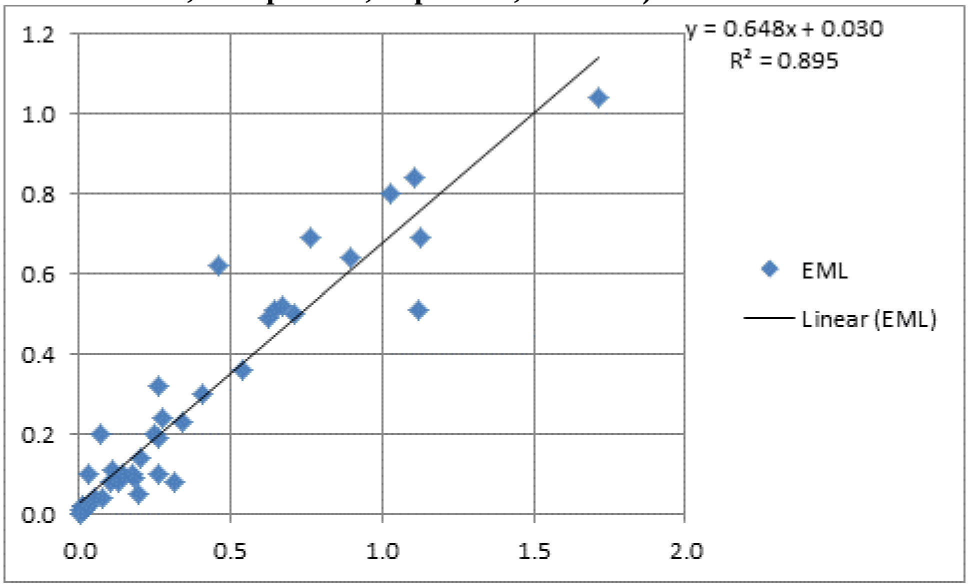


Figure 17 DISH mean concentrations 46 auto-GC species April 2010 – May 2013

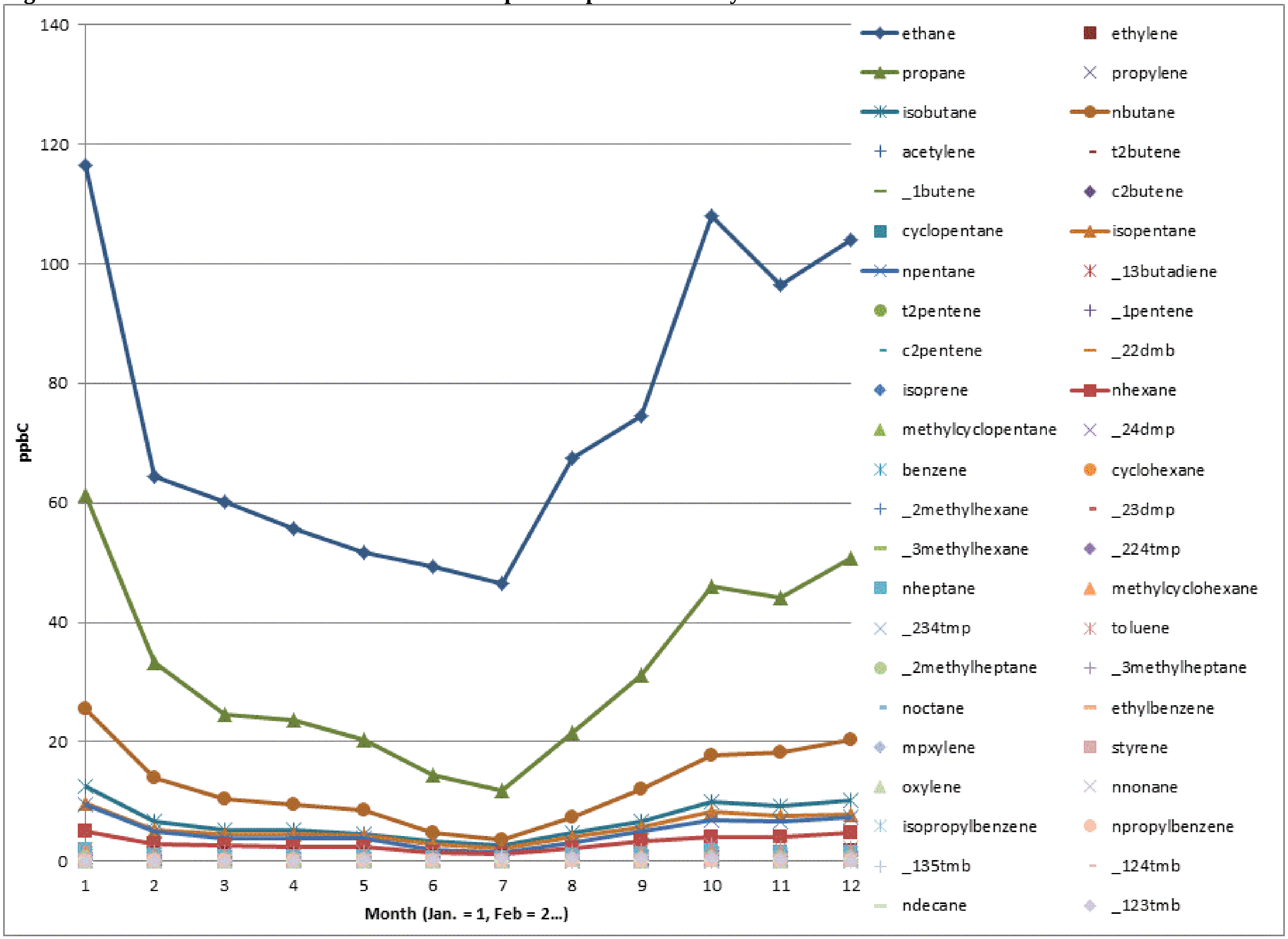


Figure 18 DISH mean concentrations 44 auto-GC species April 2010 – May 2013 (excepting ethane, propane)

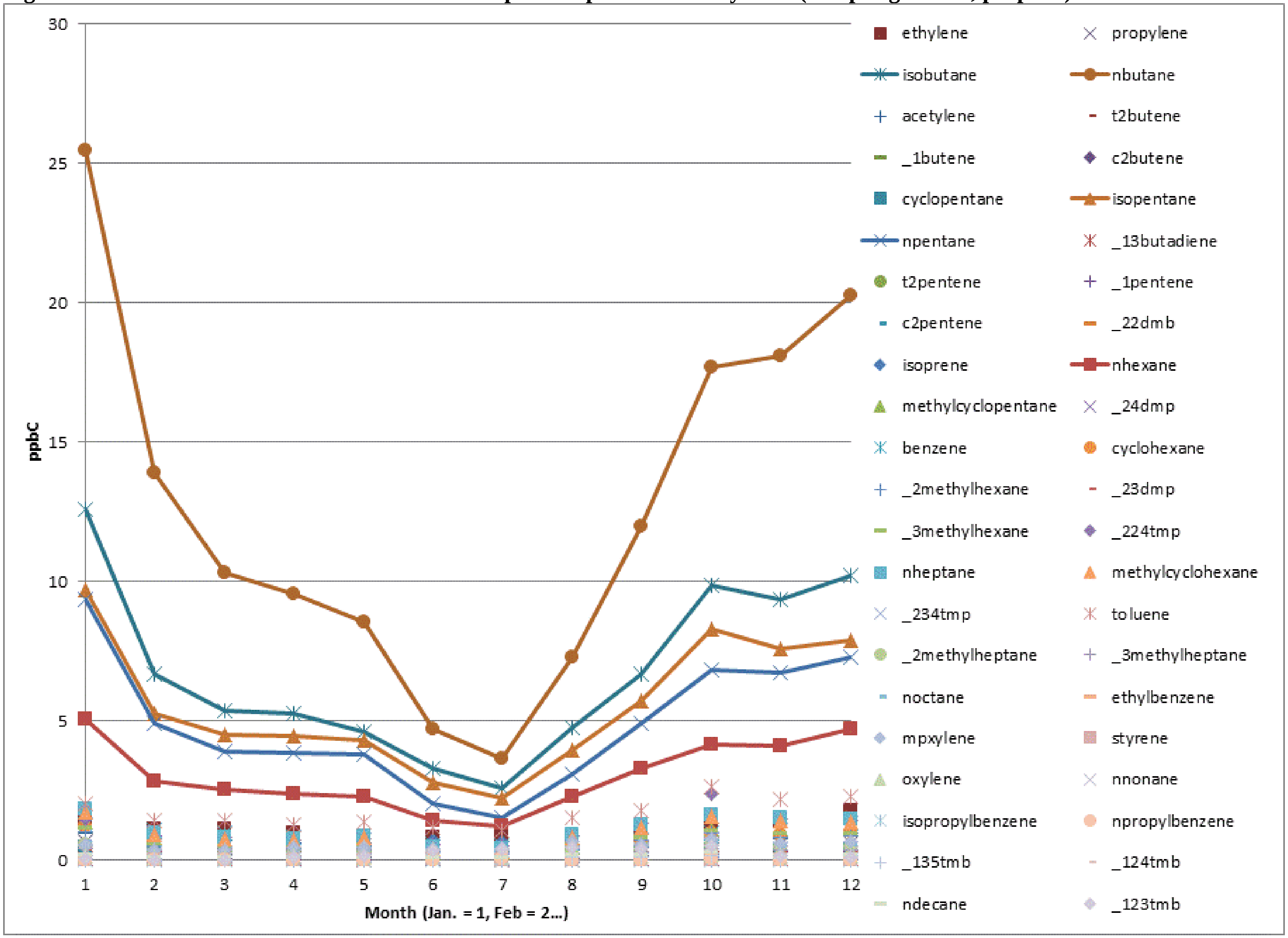


Figure 19 DISH mean concentrations 39 auto-GC species (excepting C2-C4 alkanes, n-pentane, isopentane, n-hexane

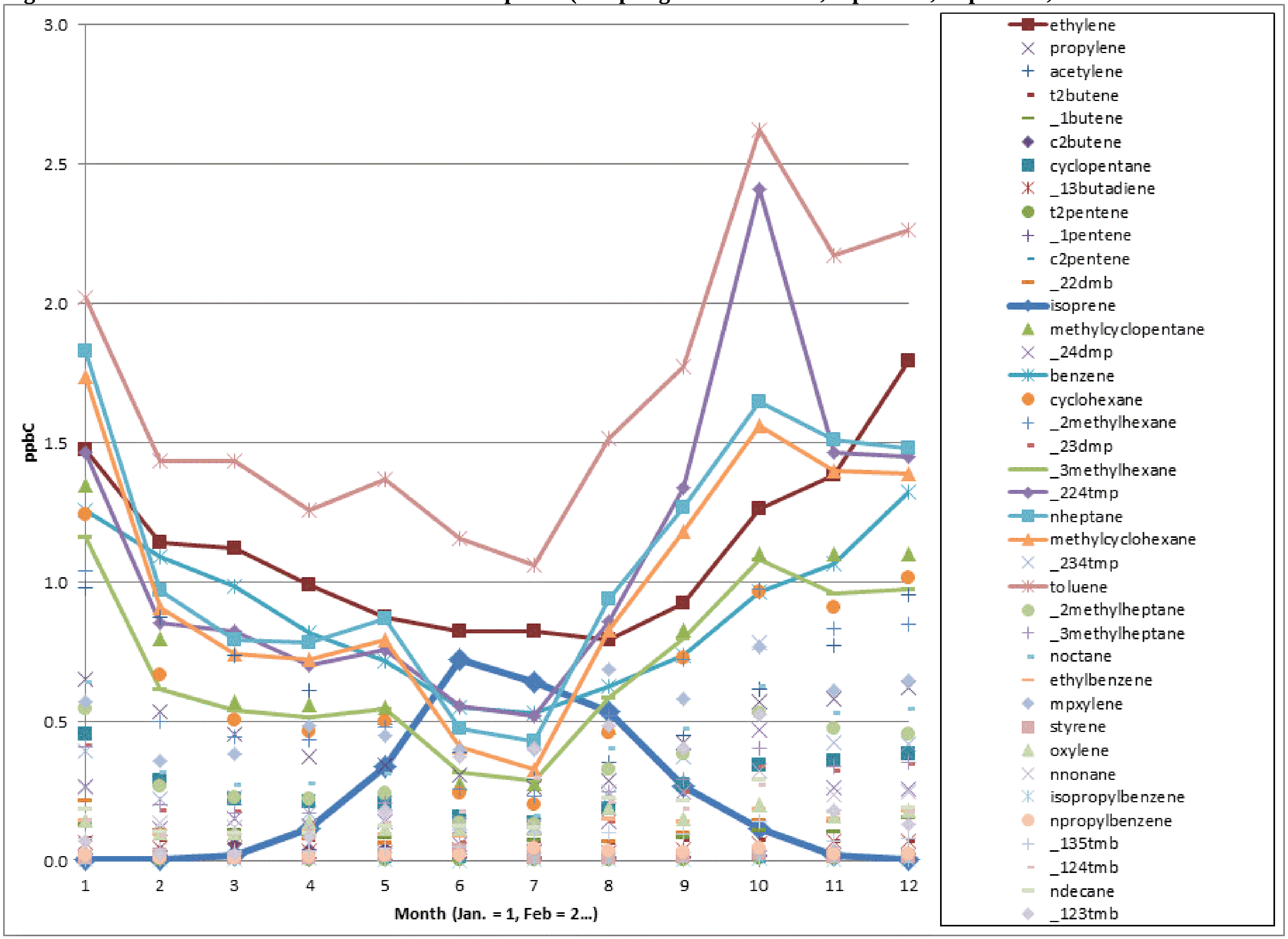


Figure 20 EML mean concentrations 46 auto-GC species April 2010 – February 2013

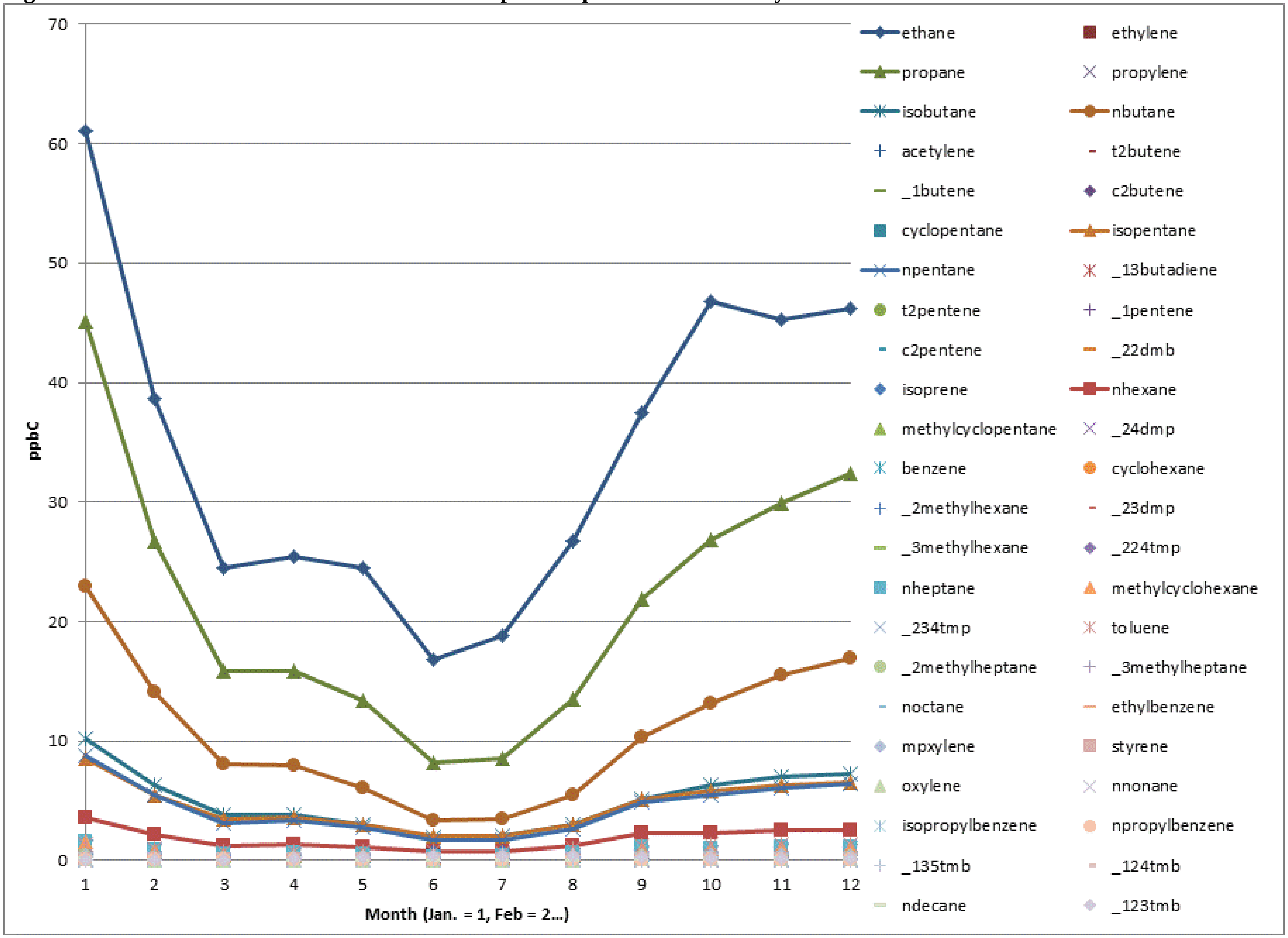


Figure 21 EML mean concentrations 44 auto-GC species April 2010 – February 2013 (excepting ethane, propane)

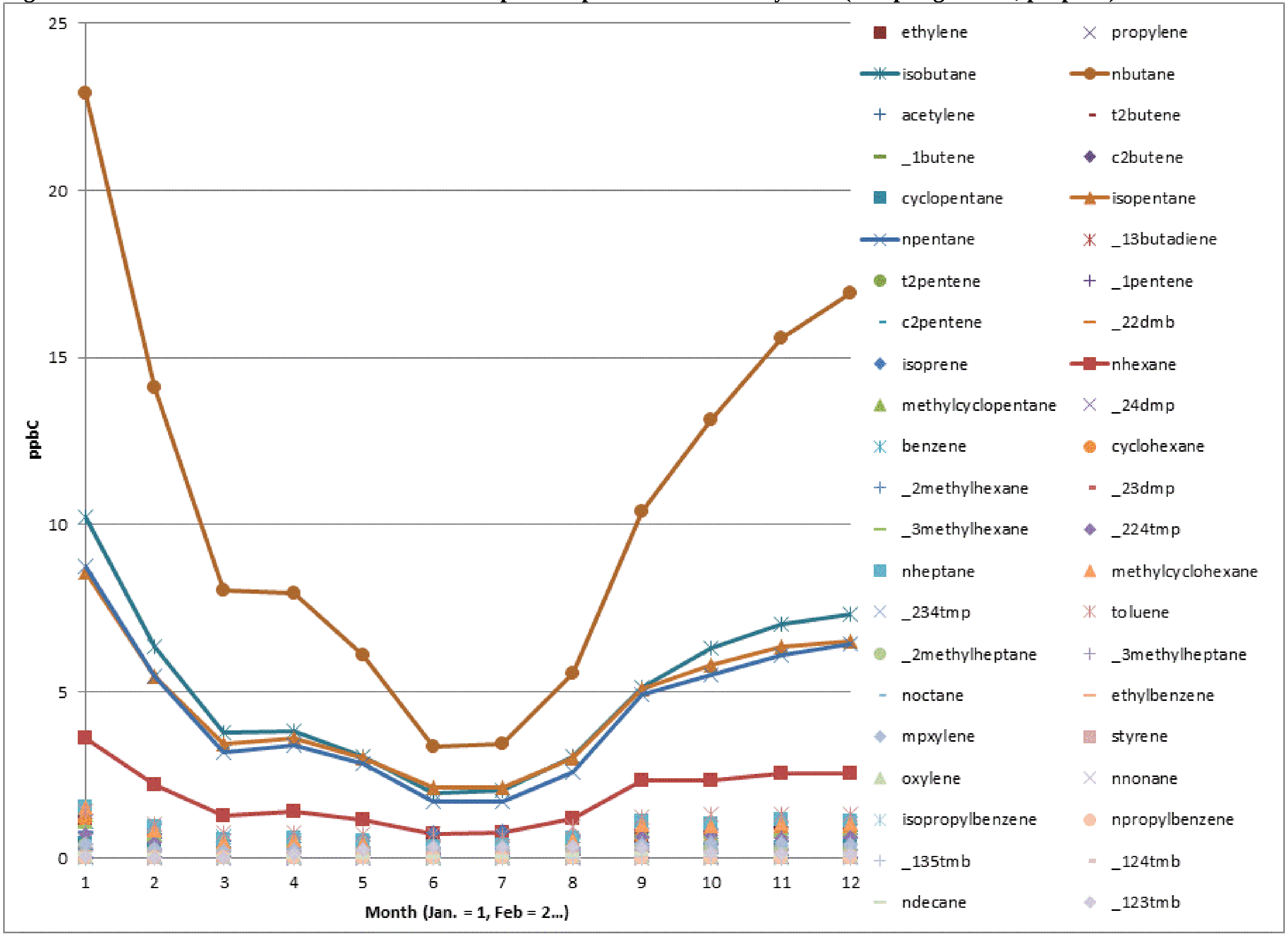


Figure 22 EML mean concentrations 39 auto-GC species (excepting C2-C4 alkanes, n-pentane, isopentane, n-hexane

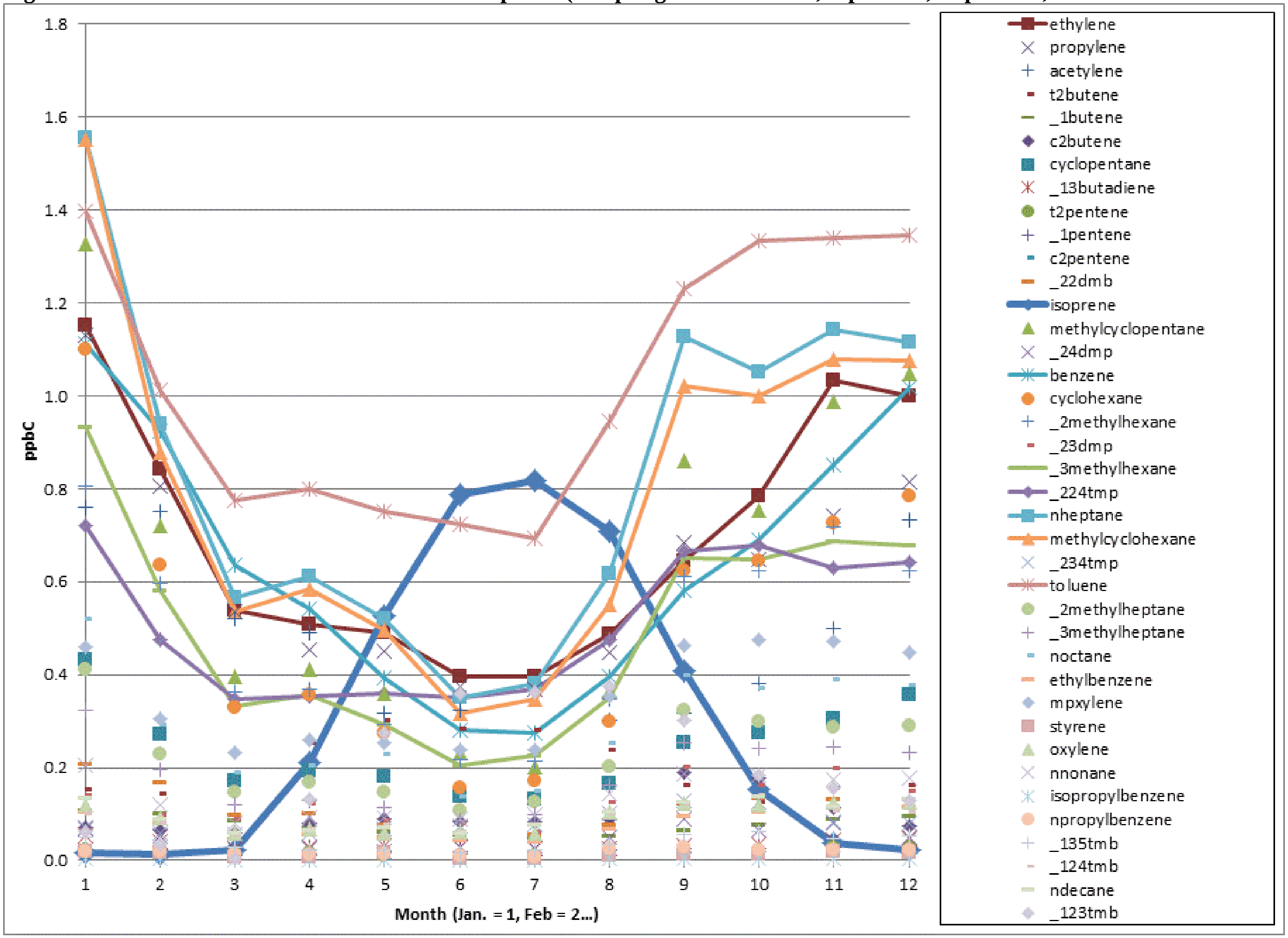


Figure 23 DISH mean concentrations Sum of HCs (TNMTC) by day type (we=weekend, wd=weekday)

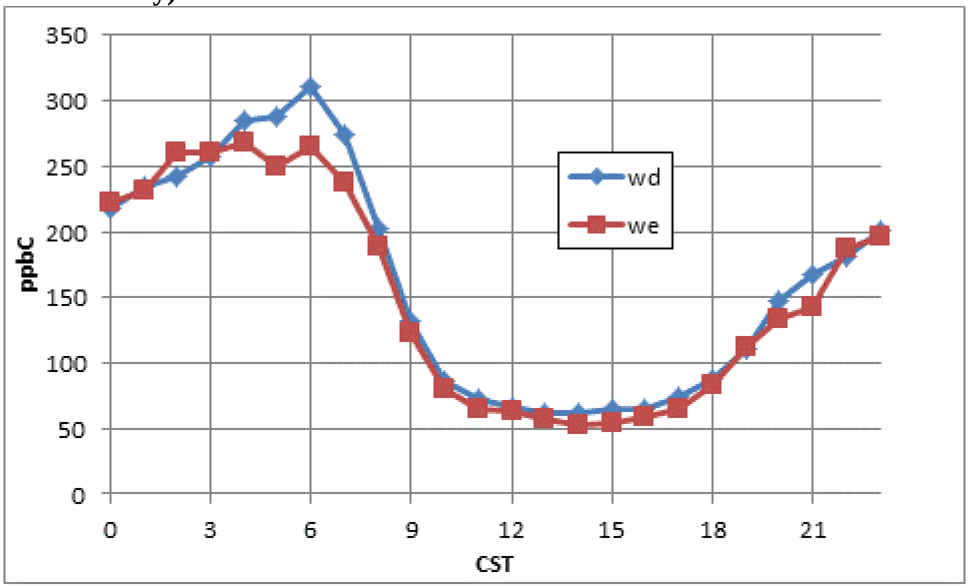
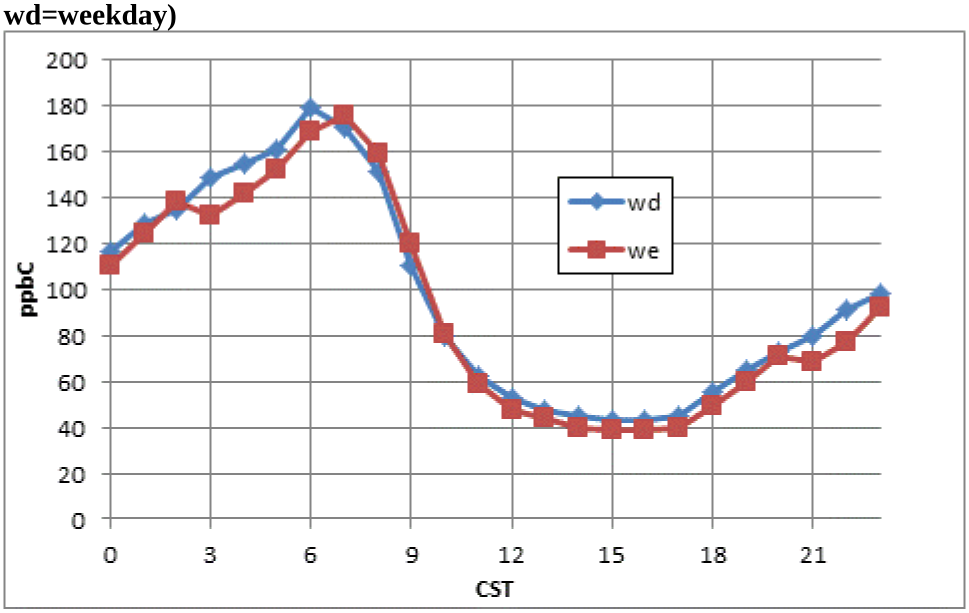


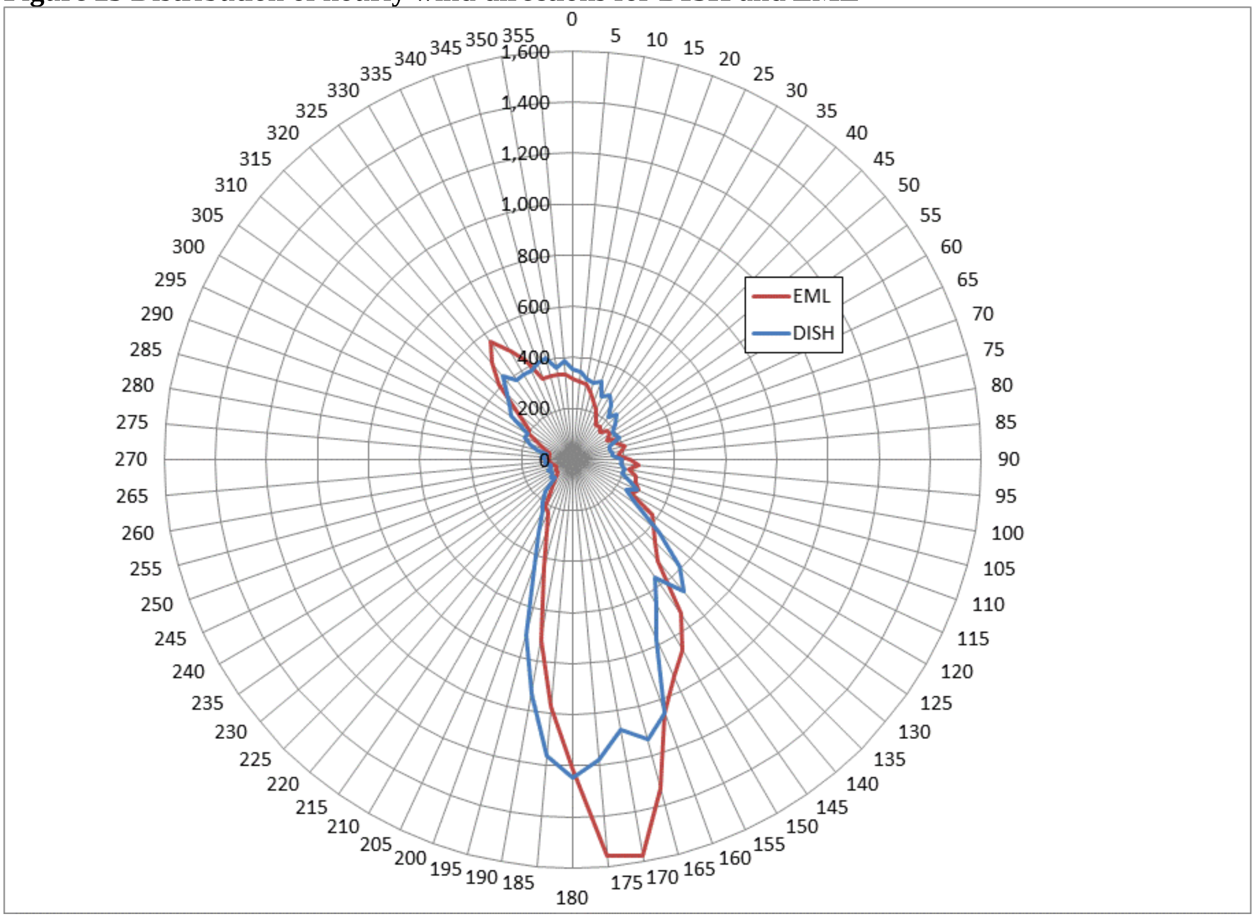
Figure 24 EML mean concentrations Sum of HCs (TNMTC) by day type (we=weekend, wd=weekday)



Auto-GC data directionality analysis

Figure 25 shows the distribution of hourly wind direction resultants at the two auto-GC sites over three years. Both have a strong prevailing wind to the south southeast, and a smaller secondary peak direction to the northwest. Westerly winds are relatively rare at both sites.

Figure 25 Distribution of hourly wind directions for DISH and EML



We use the term "directionality analysis" to refer to the use of wind data coupled with pollutant concentration data to assess a parameter or statistic as a function of wind direction. The simplest case may be a scatterplot of concentrations versus the wind direction for coincident data. For example, the data table in Table 8 could be presented graphically as in Figure 26. It appears clear from this figure that a source of benzene measured at DISH CAMS 1013 lies off in the southeast direction from the monitor.

Figure 26 All DISH CAMS 1013 hourly data, benzene ppbC vs. wind direction degrees

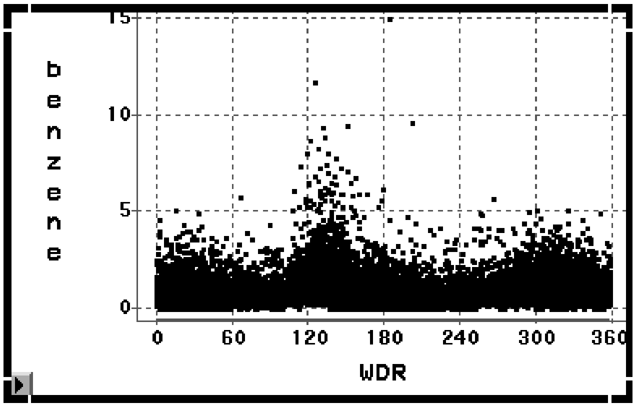
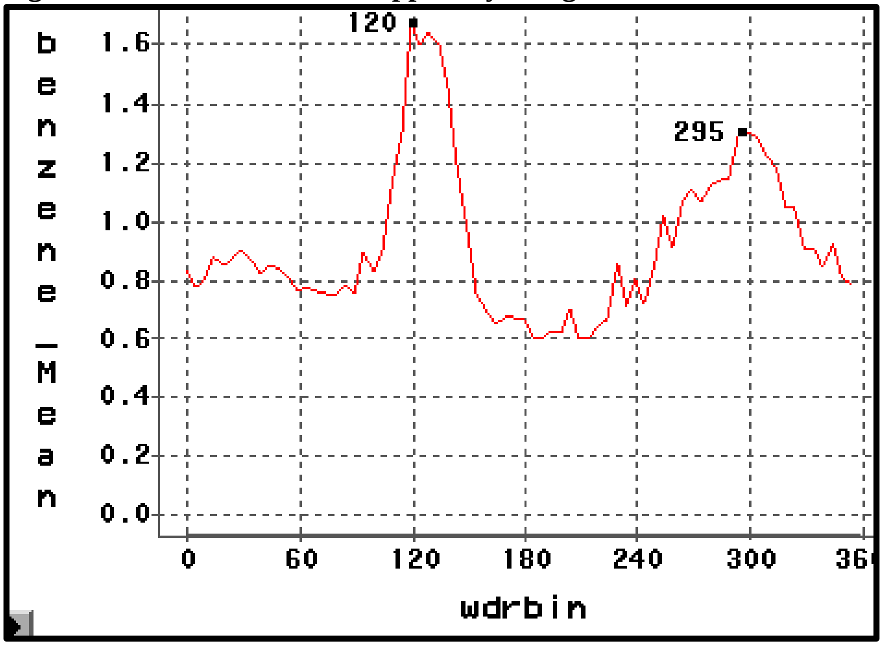


Table 8 Subset of DISH CAMS 1013 data coincident wind and benzene ppbC data

Date	Time	WSR	WDR	benzene
⋮	⋮	⋮	⋮	⋮
3/7/2011	0:00	7.6	112.3	2.12
3/7/2011	1:00	7.4	113.0	1.85
3/7/2011	2:00	10.1	**125.2**	**3.22**
3/7/2011	3:00	11.8	**126.6**	**11.84**
3/7/2011	4:00	13.4	**131.0**	**5.83**
3/7/2011	5:00	12.6	142.0	1.57
3/7/2011	6:00	10.4	137.4	1.85
3/7/2011	7:00	11.3	135.0	2.54
3/7/2011	8:00	16.7	142.6	1.93
3/7/2011	9:00	17.5	159.4	1.36
3/7/2011	10:00	14.6	157.3	1.29
3/7/2011	11:00	14.3	153.5	1.22
3/7/2011	12:00	15.9	158.7	1.15
3/7/2011	13:00	14.4	163.2	1.17
3/7/2011	14:00	16.4	165.4	1.00
3/7/2011	15:00	15.3	150.9	0.88
3/7/2011	16:00	14.3	142.1	2.50
3/7/2011	17:00	12.7	**119.8**	**5.31**
3/7/2011	18:00	13.0	**119.6**	**3.27**
3/7/2011	19:00	13.4	**122.1**	**5.65**
3/7/2011	20:00	15.7	**127.8**	**5.14**
⋮	⋮	⋮	⋮	⋮

A next step proposed in looking at directionality is to average the benzene concentrations by wind direction bin, where we group observations by rounding the coincident wind directions to the closest, say, five degree multiple. For due north winds we would map all wind directions greater than or equal to 357.5 degrees (-2.5 degrees) to 0 degrees and all wind directions less than 2.5 degrees to 0 degrees. The resulting graph for benzene at DISH appears in Figure 27. There appear to be two peaks in the graph in Figure 2, one near 120 – 130 degrees and one near 295 degrees.

Figure 27 DISH mean benzene ppbC by 5-degree wind direction bin



In Figures 28, 29, and 30, categories of species have been graphed as functions of 5-degree wind bin for DISH. Figure 28 features alkanes. Figure 29 features benzene, toluene, ethyl-benzene, and xylene species (BTEX). Figure 30 features HRVOCs. Figures 31, 32, and 33 contain similar graphs for EML. No smoothing or wind speed filtering has been applied to the graphs. Peaks in the graphs have been labeled as to the 5-degree wind bin associated with the highest mean concentrations. Mean concentrations associated with westerly winds have relatively high uncertainty owing to the low incidence of westerly winds and generally there are lower speed/more variable winds from the west.

The graphs in Figures 28 – 33 convey information about the effects of wind direction on concentrations, and help to reflect the similar behavior of species with regard to directionality. However, as we will discuss, the directionality assessment with regard to the strength of upwind sources should take wind speed into account. We address this issue below.

Figure 28 DISH alkanes by 5-degree wind direction bin (no wind speed filter or adjustment)

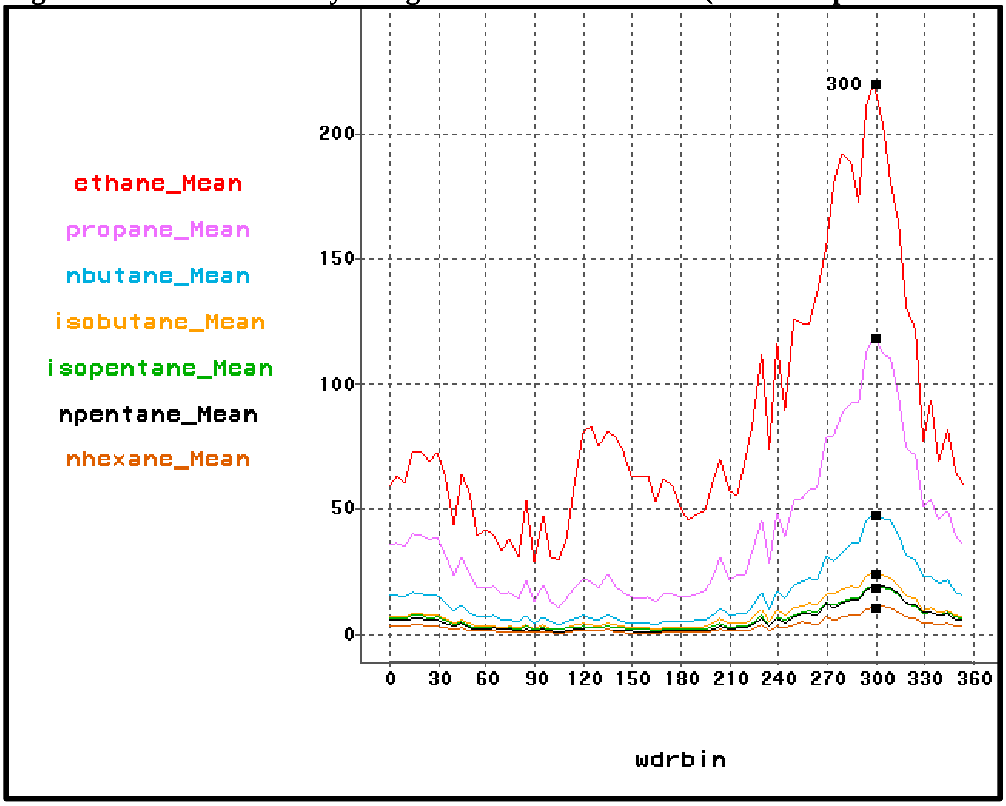


Figure 29DISH BTEX by 5-degree wind direction bin (no wind speed filter or adjustment)

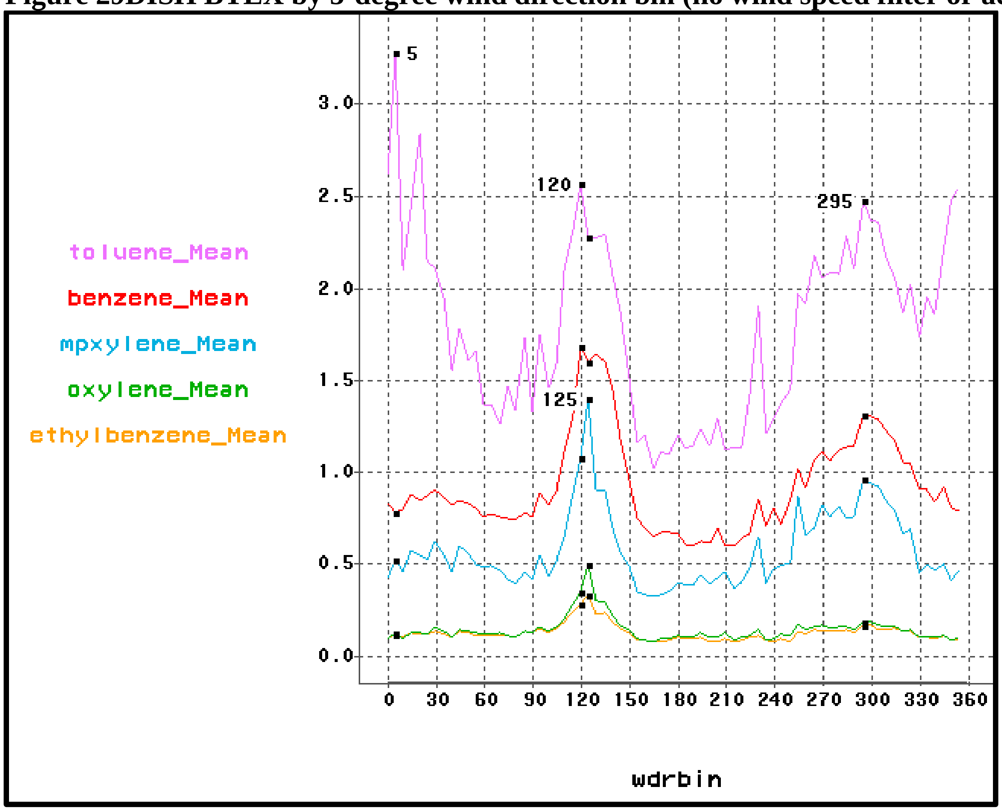


Figure 30 DISH HRVOCs by 5-degree wind direction bin (no wind speed filter or adjustment)

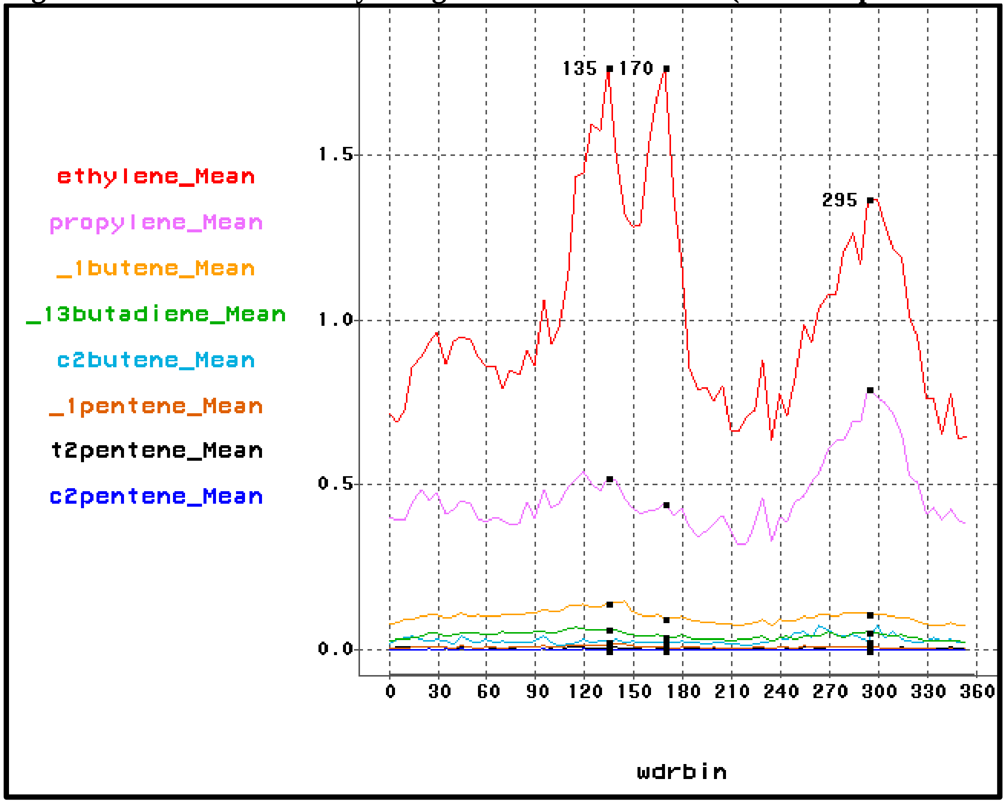


Figure 31 EML alkanes by 5-degree wind direction bin (no wind speed filter or adjustment)

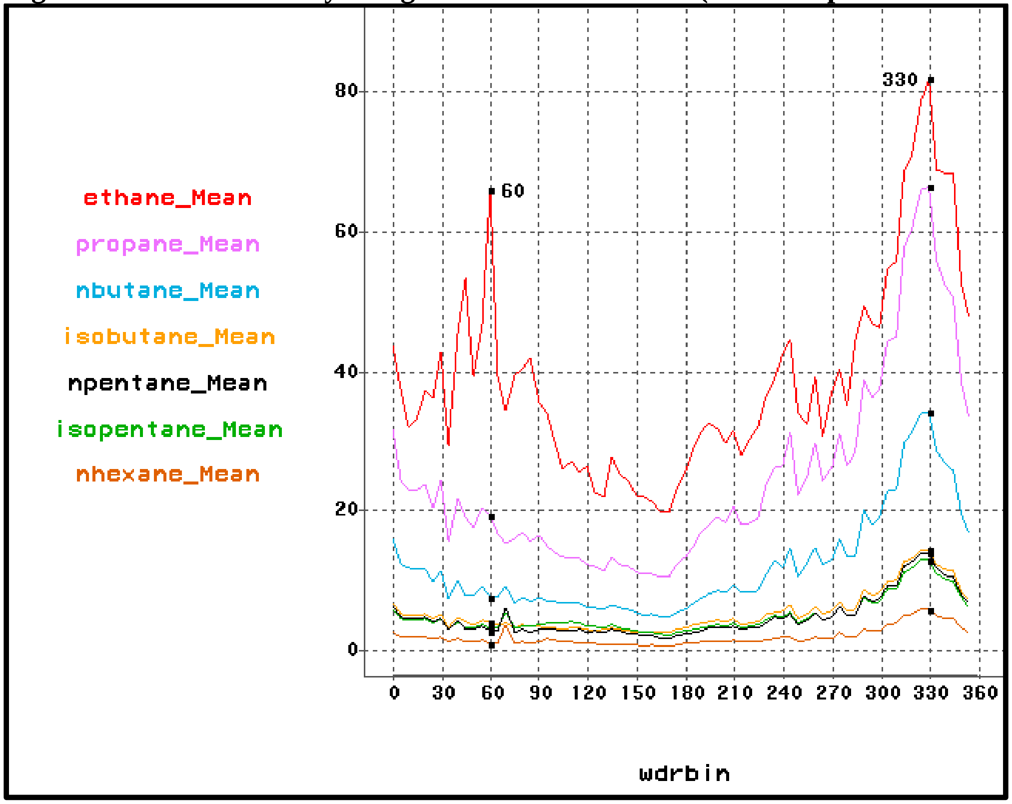


Figure 32 EML BTEX by 5-degree wind direction bin (no wind speed filter or adjustment)

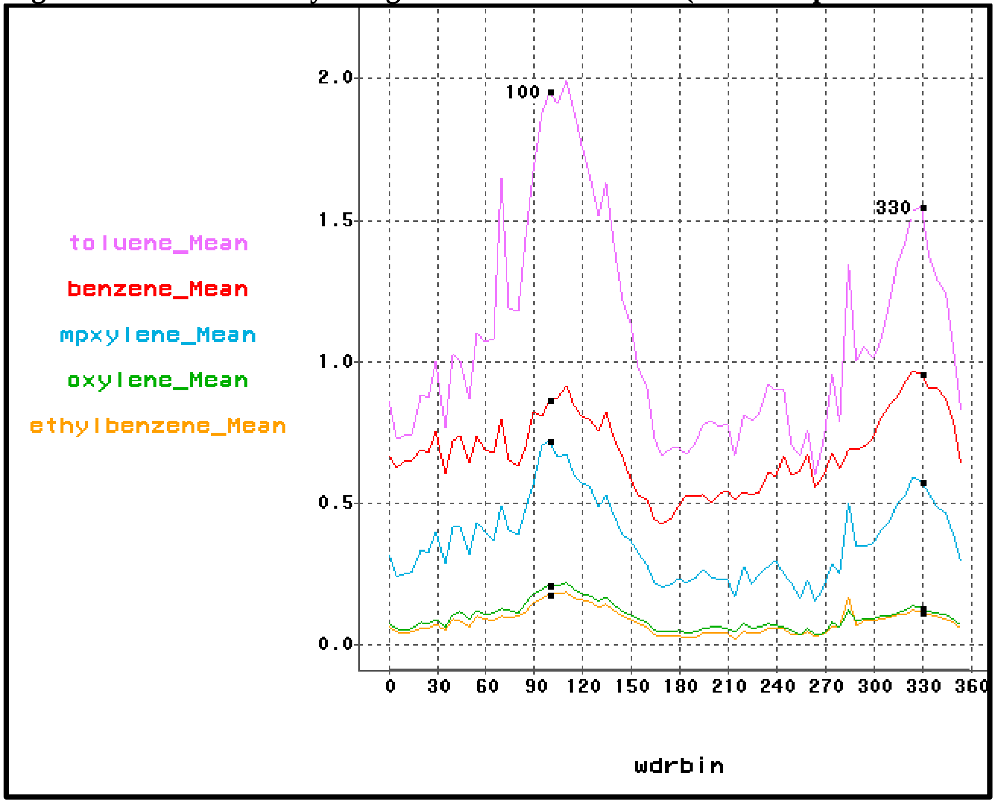
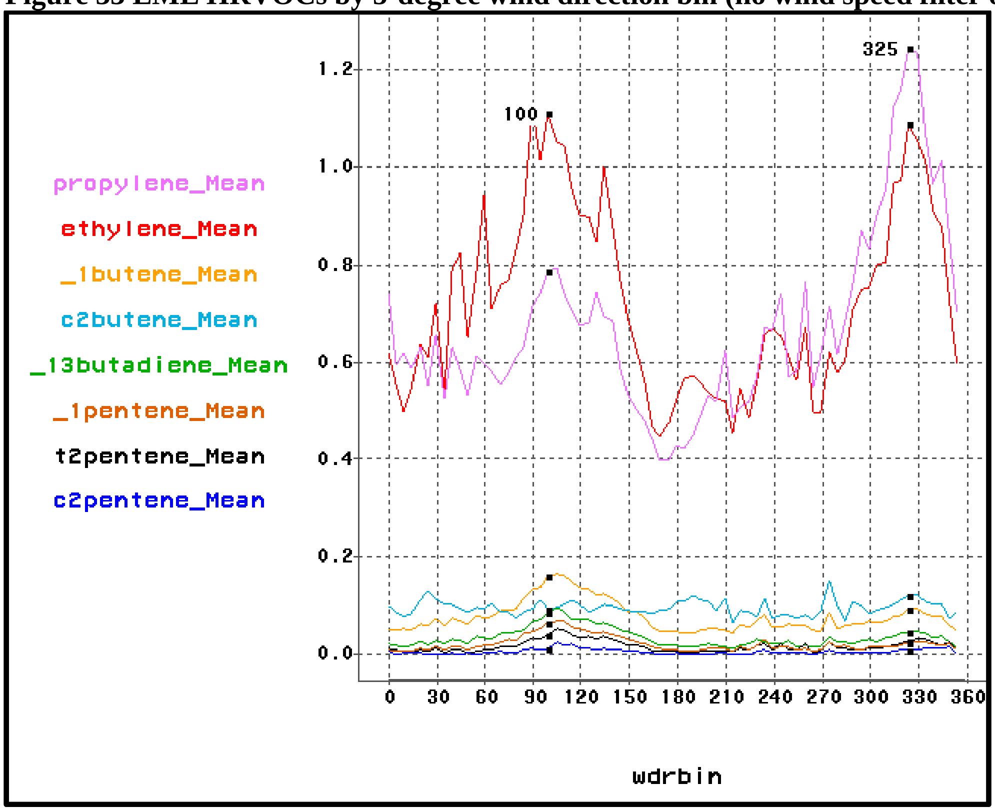
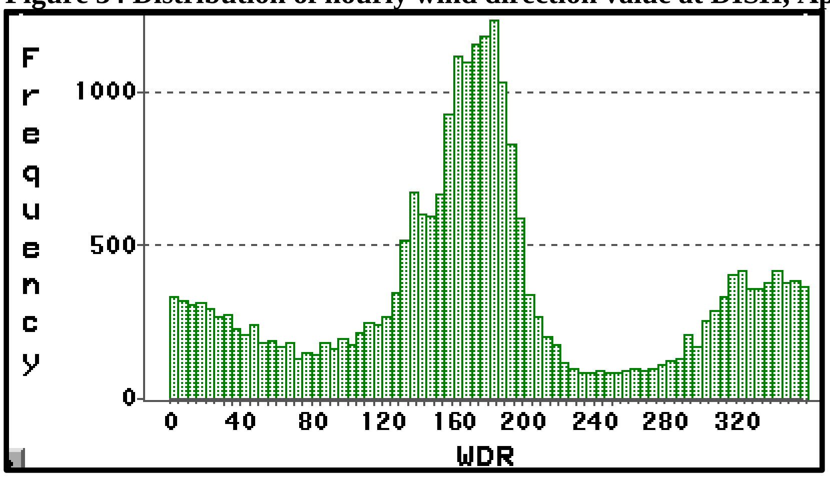


Figure 33 EML HRVOCs by 5-degree wind direction bin (no wind speed filter or adjustment)



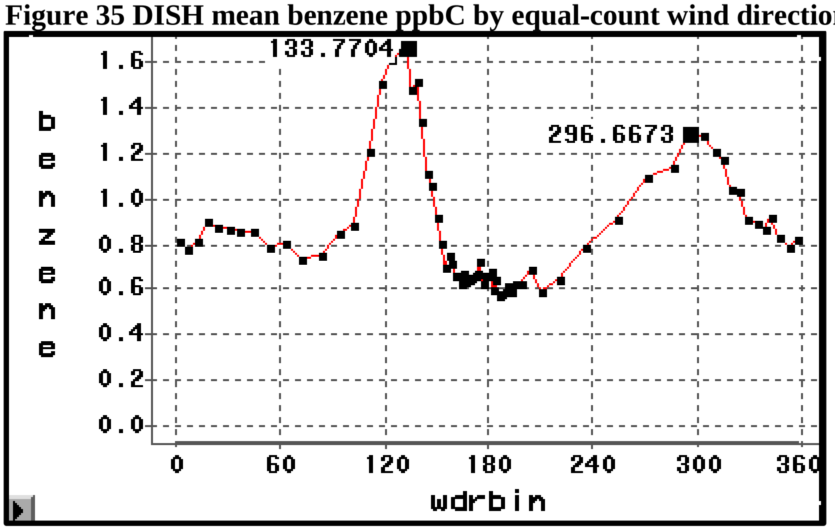
The graphs in Figures 28 – 33 could be smoothed to reduce some of the short-scale variability in the graphs using a variety of approaches. One possible modification is to use different sized wind direction bins, say, depending on the number of observations in each general direction. If bins have relatively few observations, the mean for that bin is more susceptible to the effects of outliers. Figure 34 shows a histogram for the number of measured wind direction values in 5-degree bins at DISH (compare this with the wind direction radar plot Figure 25). Given the 23,387 hourly observations with simultaneous measurements of wind direction and benzene concentration at DISH divided among 72 wind direction bins there is an average of 325 observations per bin, with a maximum of 1,247 observations in the bin centered at 180 degrees and a minimum of 89 observations in the bin centered on 255 degrees.

Figure 34 Distribution of hourly wind direction value at DISH, April 2010 – May 2013



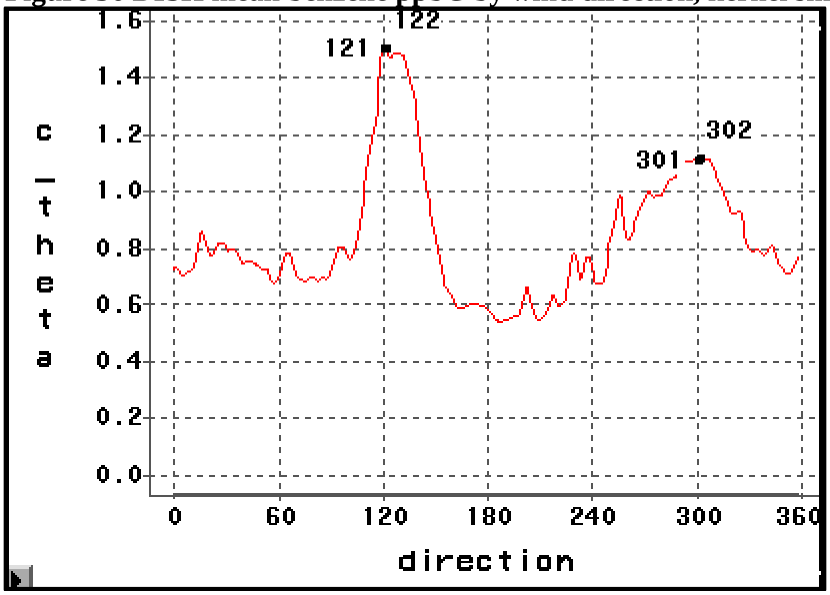
Westerly winds have the lowest frequency in East Texas, followed by easterly winds, then by northerly winds. By moving to bins with equal counts of observations (325 observations), and taking the average concentration of benzene by bin, the resulting graph for DISH benzene is shown in Figure 35. In Figure 35, all the plotted points are shown, to illustrate the relative density of points along the curve. In this graph, the peak direction has shifted a few degrees to the south, and now at 134 degrees. The graph appears smoother than the graph in Figure 27.

Figure 35 DISH mean benzene ppbC by equal-count wind direction bins (72 bins total)



The approaches in Figures 27 – 33 and 35 used averages calculated for discrete ranges of angles. A more complicated alternative is to use nonparametric regression / kernel-smoothing (e.g. R. C. Henry et al., Atmospheric Environment 36 (2002) 2237–2244). This approach can produce a finer resolution graph. Figure 36 shows the result of applying kernel-smoothing for DISH benzene with a *full width at half measure* (FWHM, see Henry et al. 2002) equal to 5. This application of this method allows an estimate of the mean concentration at individual degrees, and the maxima are at 121 and 122 degrees.

Figure 36 DISH mean benzene ppbC by wind direction, kernel smoothing FWHM=5



Wind speed effects on Auto-GC data directionality analysis

The concentration of a primary pollutant is usually related in part to wind speed. Light wind speeds allow pollutants to accumulate to higher concentrations, whereas higher wind speeds imply increased ventilation and increased mixing of polluted air with clean air leading to lower concentrations. (Exceptions include particulate matter, for which there can be higher concentration under higher speed winds that pick up dust from the ground, and for the headspace vapor in some storage tanks, which can be sucked into the air by the low pressure on the tank roof under high speed winds.) Figure 37 show the scatter plot for benzene versus wind speed at DISH CAMS 1013. The simple linear regression fit suggests the average concentration declines by 0.056 ppbC with an increase of 1 mile per hour (mph) in wind speed. Figure 38 shows the relationship between the average DISH benzene concentration as a function of wind speed where we use 1 mph wind speed bins. Figure 38 shows a 0.117 ppbC per mph drop in average concentration going from 0 mph to 10 mph, and a 0.016 ppbC per mph drop in average concentration going from 10 mph to 20 mph. Above 20 mph there are too few observations to produce a smooth change from bin to bin, but in pooling all observations from the 21 mph bin and greater, the mean concentration is 0.504 ppbC. Figure 39 shows a graph of the mean wind speed as a function of wind direction at DISH, using 5-degree wind direction bins. Southerly winds are the fastest on average, and northerly winds are the second highest on average. Wind speeds associated with the afore-noted 120 and 295 degree directions are among the slowest on average.

Because light winds are more variable and thus less reliable in assessing directionality, it is generally beneficial in directionality analysis to filter out winds below some threshold speed. In this application, so as to minimize the loss of data from the particular ranges of wind directions with lowest incidences, we selected a 3 mile per hour (mph) threshold. This eliminates 10 percent of the data overall. Figure 40 shows the same kernel-smoothing method of directionality for benzene at DISH as Figure 36, using only winds greater than 3 mph speed. The absolute maximum benzene concentration has shifted to 128 degrees. The FWHM is a measure of the kernel size used in smoothing, and the value of 5 in Figures 36 and 40 is roughly similar to the bin size of 5 degrees used earlier in Figure 27. To decrease the short-scale variability in Figures 36 and 40, a FWHM value of 10 is used for the graph in Figure 41.

Figure 37 DISH benzene ppbC vs. wind speed mph

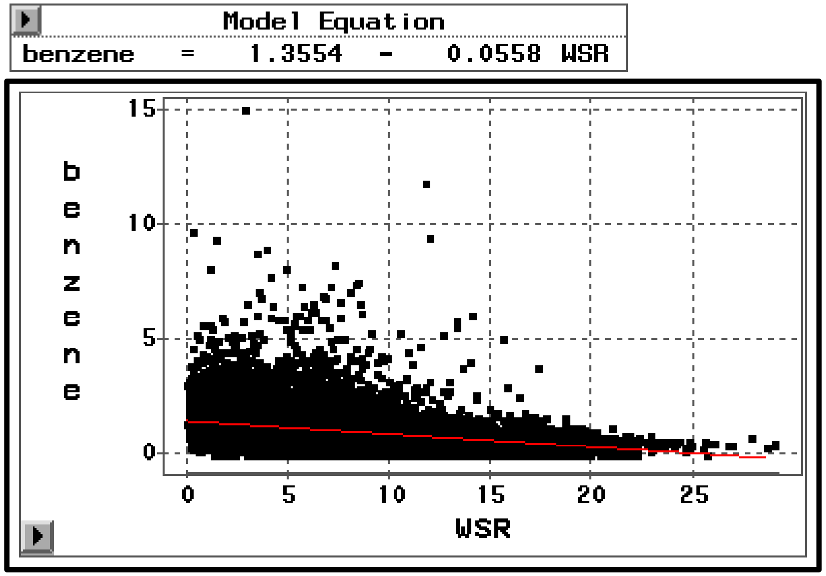


Figure 38 DISH mean benzene ppbC by 1-mph wind speed bin

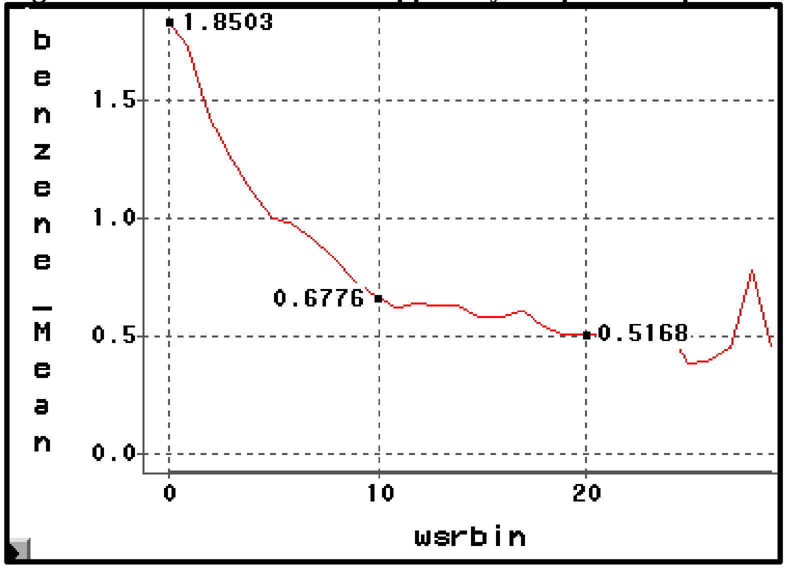


Figure 39 DISH mean wind speed mph by 5-deg. wind direction bin

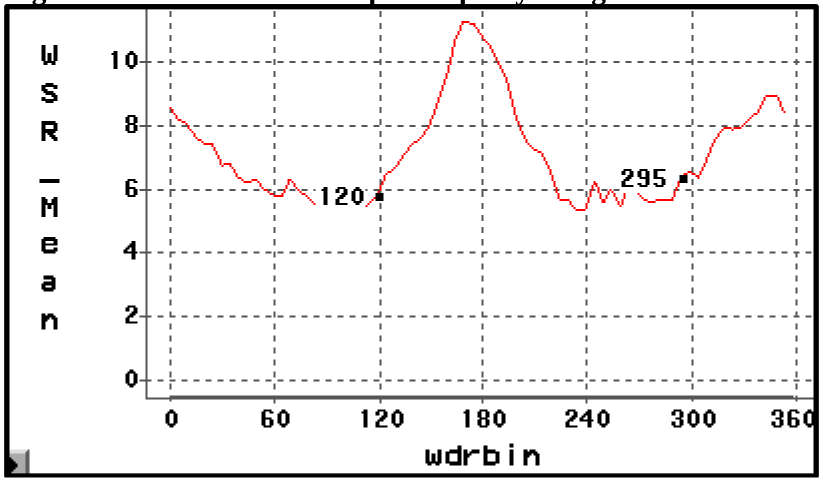


Figure 40 DISH mean benzene ppbC by wind direction, kernel smoothing FWHM=5, wsr > 3mph

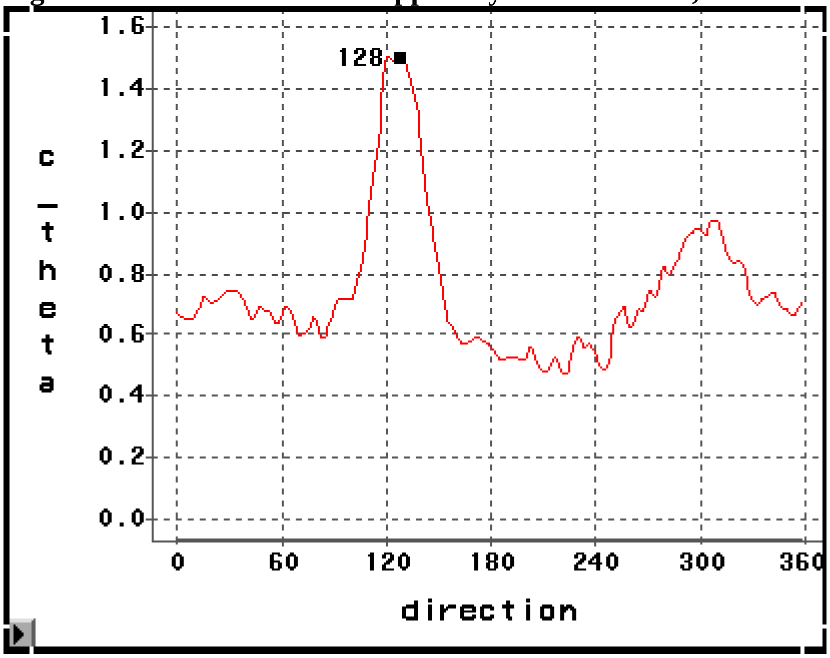
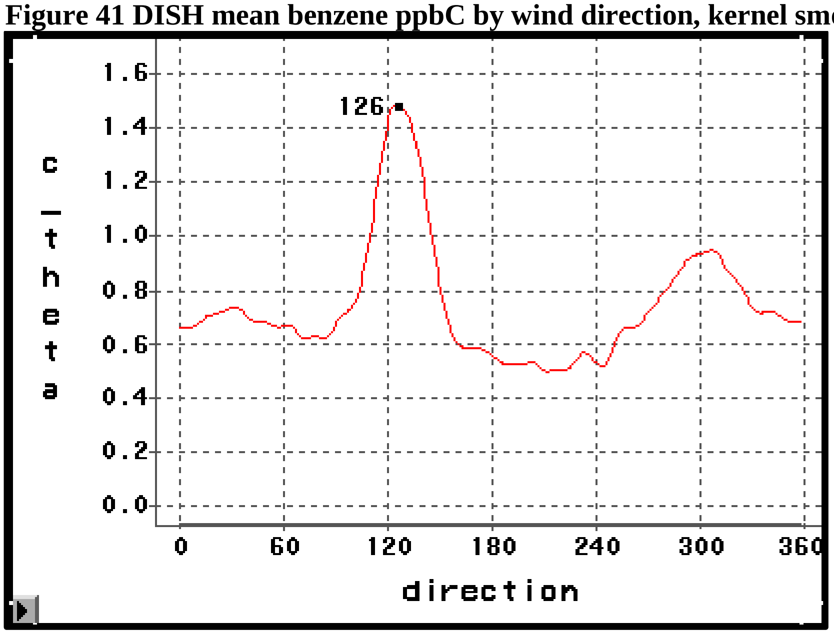
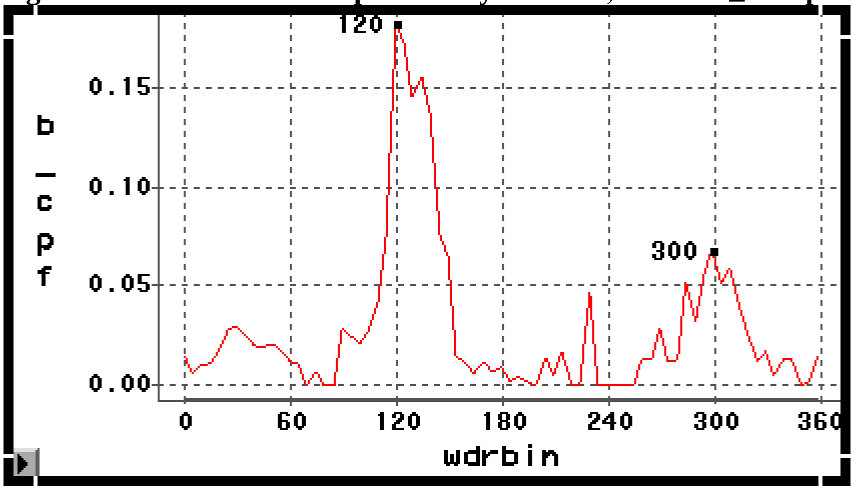


Figure 41 DISH mean benzene ppbC by wind direction, kernel smoothing FWHM=10, wsr > 3mph



Another more complicated directionality alternative is the so-called "conditional probability function" (CPF) in which one calculates the ratio of the number of observations above a threshold to the total number of observations in each wind direction bin (e.g., E. Kim and P.K Hopke, Atmospheric Environment 38 (2004) 4667–4673). This nonparametric approach avoids the leverage of a few large concentrations in calculating a mean presented by a highly skewed distribution of observations within a bin. Figure 42 is an application of this method. Given the distribution of DISH benzene observations with wind speed greater than 3 mph, the 95th percentile concentration was 1.969 ppbC. Figure 42 graphs the ratio between the number of observations greater than or equal to 1.969 ppbC to the number of measurements made in the wind direction bin. Thus, when the wind blows from southeast over 3 mph, more than 15 percent of the time the concentration is 2 ppbC (0.33 ppbV) or higher at the DISH site.

Figure 42 DISH conditional probability function, benzene ≥ 95th p-tile, 5-deg wind bins, wsr > 3mph



Most primary pollutant concentrations follow a diurnal pattern with higher overnight average concentration under lighter winds and the nighttime inversion/low mixing height, which traps primary emissions closer to the surface. (Isoprene is an exception, as shown earlier in Figures 19 and 22, and sulfur dioxide emitted from tall stacks, which is more likely to mix down to the ground during daytime hours). Figure 43 shows the mean concentration of benzene at DISH CAMS 1013 by hour of the day, and Figure 44 shows the average wind speed at DISH by hour of the day. The two graphs show a negative association.

Benzene concentrations also follow a seasonal pattern with higher average concentrations in the winter months as shown for DISH and EML earlier in Figures 17 – 22. Figure 45 shows the mean concentration of benzene at DISH CAMS 1013 by month of the year, and Figure 46 shows the average wind speed at DISH by month of the year. The association of mean wind speed and mean benzene concentration by month of year is not as clear as with the diurnal pattern comparisons. Peak average wind speeds occur in March and April, and minimum average wind speeds occur in July, August, and September, while peak average benzene is December – January and minimum average benzene is June – July.

The Gaussian dispersion model assumes that under a constant emission rate the resulting downwind pollutant concentrations will disperse in a plume following a bivariate Gaussian distribution centered on the plume centerline with spread characteristics based on downwind distance and the local meteorology, generally expressed in wind speed and the standard deviation of wind direction vertically and horizontally. Assuming a fixed downwind distance and constant standard deviation of wind direction, then all else held equal the concentration at a point would be proportional to wind speed. Thus, multiplying the concentration by the wind speed acts as a correction for the effects of the wind. In order to keep the resulting value on the same scale and in the same units as the measured concentration, the product can be divided by a measure of central tendency of the wind speed for the data set. The mean wind speed at DISH over the study period was 8.3 mph, and the median wind speed was 7.7 mph, so 8.0 mph is used as to normalize the product of concentration and wind speed at DISH. The mean wind speed at EML over the study period was 9.4 mph, and the median wind speed was 8.5 mph, so 9.0 mph is used as to normalize the product of concentration and wind speed at EML. The effect of this wind-speed-adjustment on the data can be observed by examining Figures 47 and 48, which compares the diurnal patterns for benzene for DISH and EML with and without the adjustment.

The effect of multiplying wind speed by concentration can be quantified by looking at the variability in the hour-by-hour mean concentrations in Figures 47 and 48. Table 9 compares the standard deviation of the 24 hourly mean values with and without wind speed adjustment for benzene at the two sites.

Table 9 The change in mean benzene hour-to-hour variablity with wind speed adjustment

	DISH	**EML**
Std. dev. no adjustment	0.2249	0.1808
Std. dev. with adjustment	0.0527	0.0745

Figure 49 shows the result of applying a wind speed adjustment to the hourly benzene data at DISH, merging the data with wind direction and binning the data in 5-degree bins. Also shown is the original line plot for the unadjusted means from Figure 27. The wind speed adjusted graph flattens out and spreads what had been a peak close to 295 – 300 degrees, so that the “peak” now is much less distinct. The graphed mean values for wind speed adjusted benzene are generally less than the corresponding unadjusted mean values, except for the directions from the south (155 to 195 degrees). Referring back to Figure 25 and 34, this range has a disproportionately large number of wind direction observations, which explains the apparent downward bias in the majority of the direction bin averages for the wind speed adjusted means in Figure 49.

Figure 43 DISH mean benzene ppbC by hour of the day CST

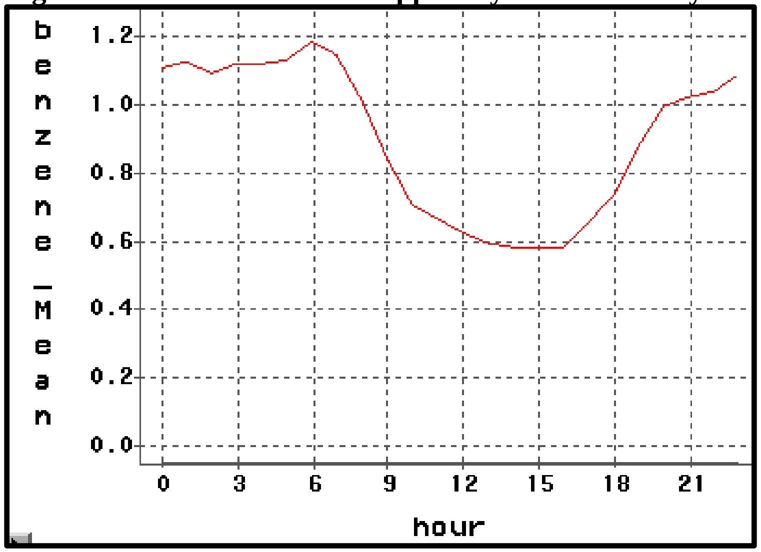


Figure 44 DISH mean wind speed mph hour of the day CST

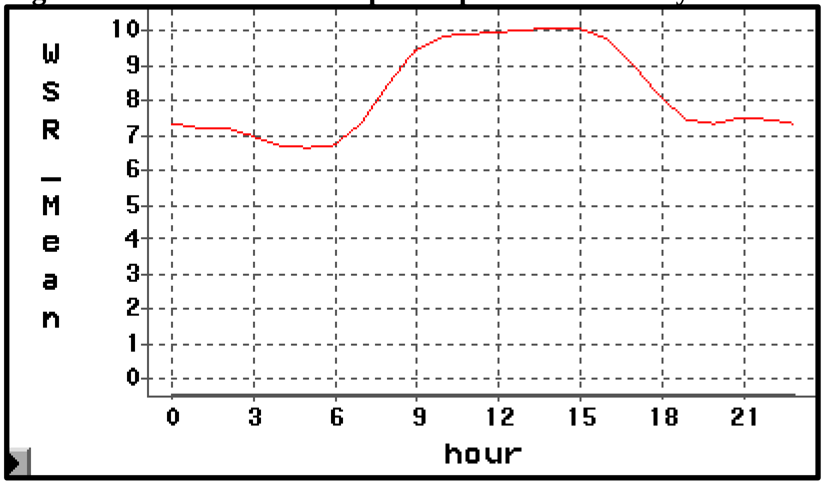


Figure 45 DISH mean benzene ppbC by month of the year (1=January, 2=February, etc.)

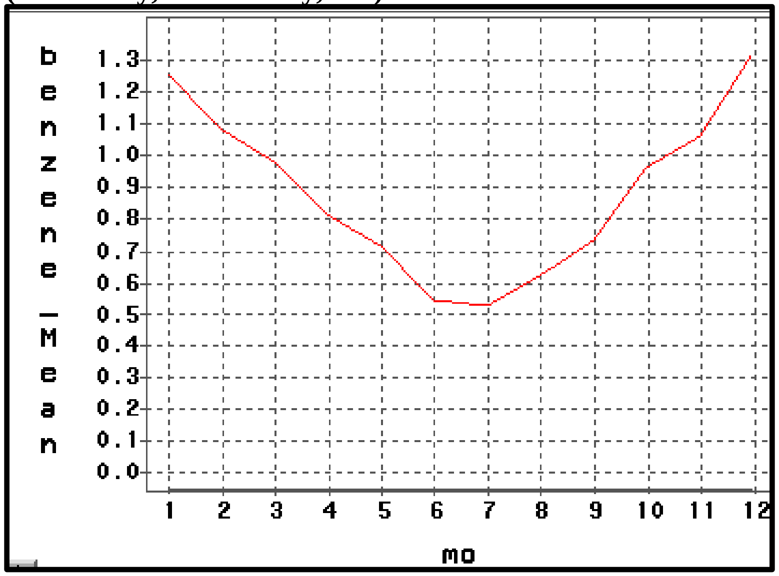


Figure 46 DISH mean wind speed mph by month of the year (1=January, 2=February, etc.)

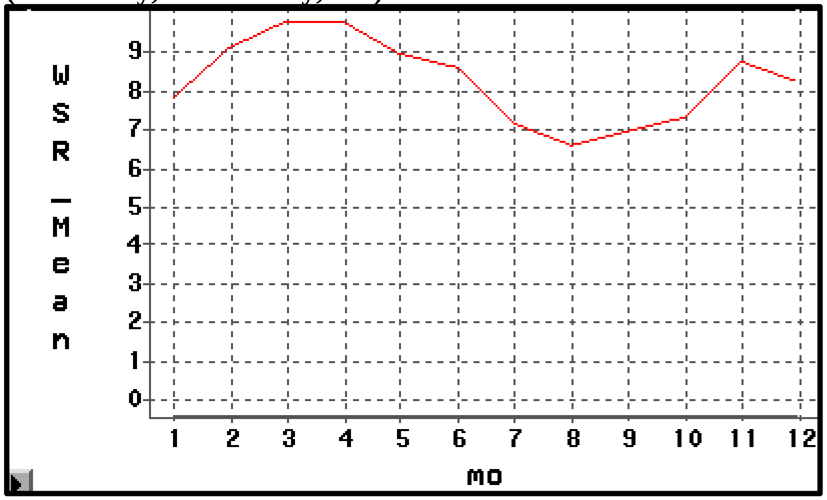


Figure 47 DISH diurnal pattern for benzene data ppbC and diurnal pattern for benzene times wind speed / mean wind speed, ppbC

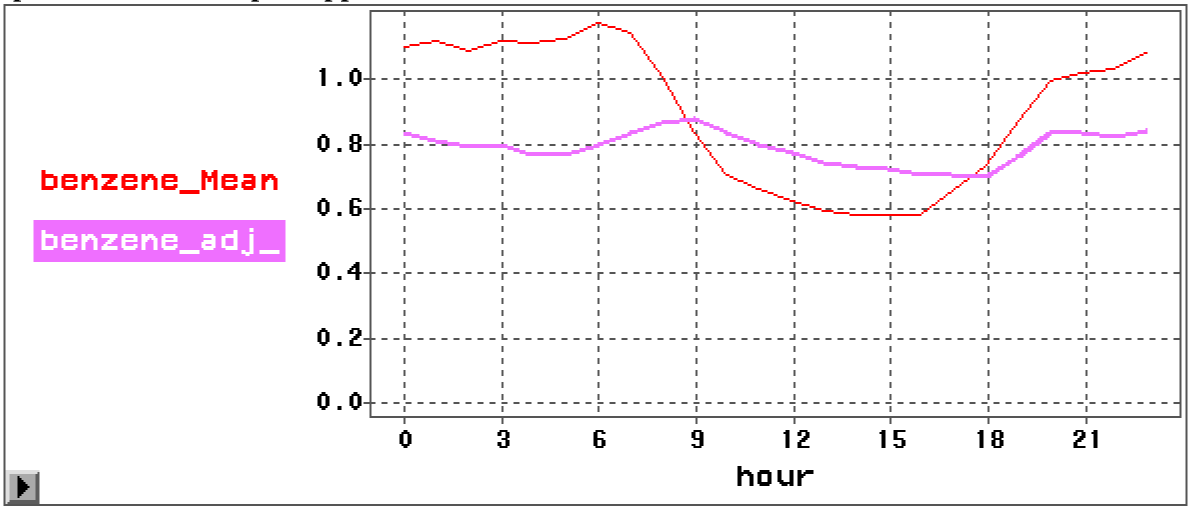


Figure 48 EML diurnal pattern for benzene data ppbC and diurnal pattern for benzene times wind speed / mean wind speed, ppbC

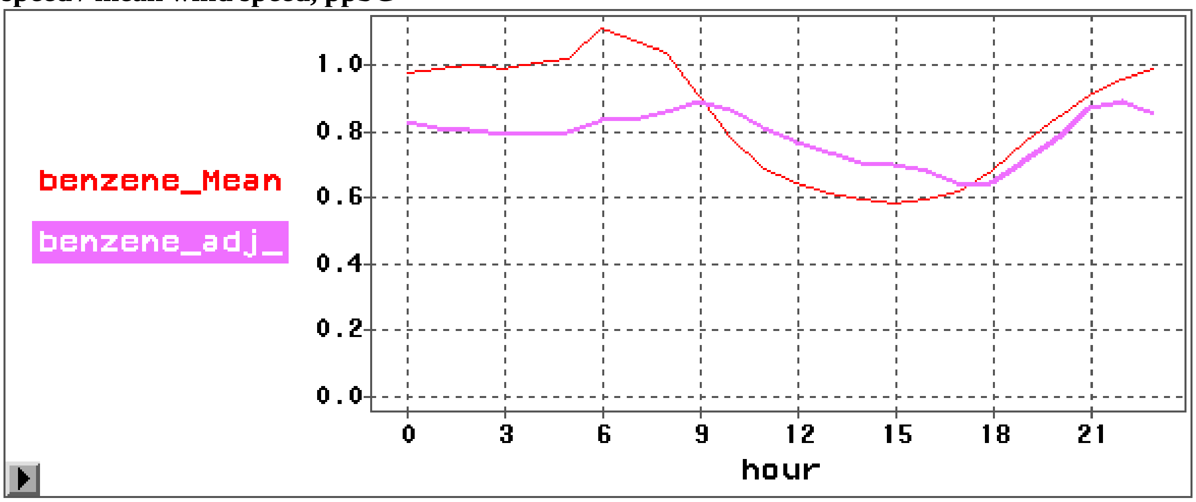
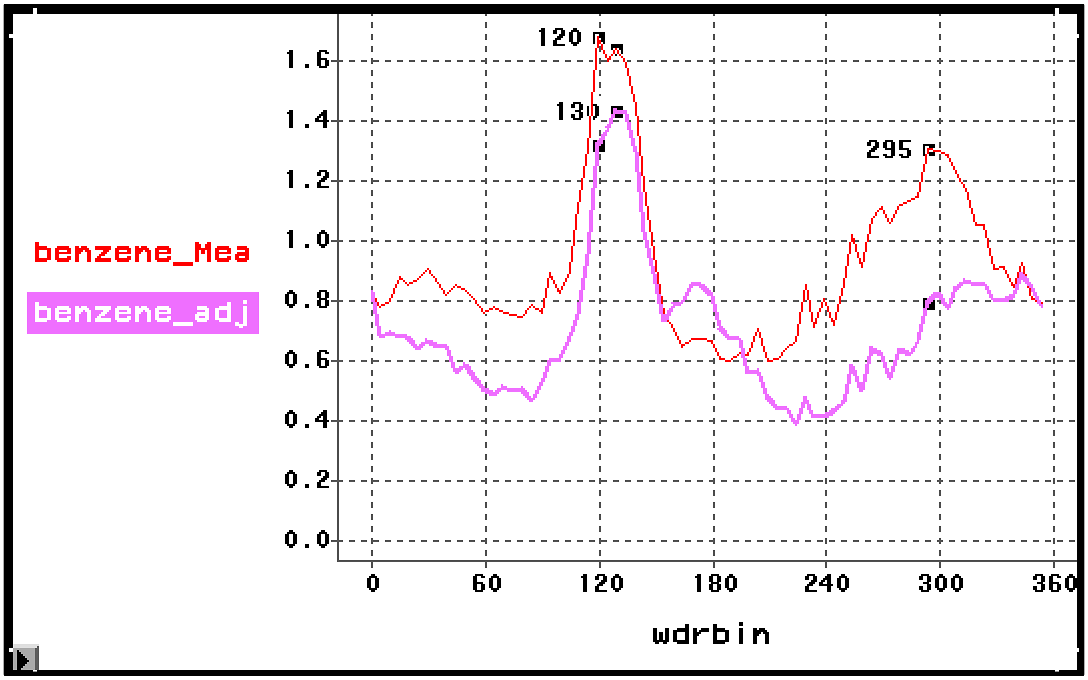


Figure 49 Comparison of DISH mean benzene without and with wind speed adjustment by 5-degree wind direction bin



The figures below have both the 3 mph and lower winds speed resultant (wsr) excluded, and have wind-speed (WS)-adjusted mean concentrations by 5-degree wind direction bins. In the graph for highly reactive VOCs (Figure 52), only ethylene and propylene are shown, as other HRVOC species are an order of magnitude lower. At DISH, Figure 50 shows that ethane has two peaks, at 170 and at 300 degrees, but other light alkanes have their peaks at 300 – 310 degrees. Figure 51 shows that toluene has two peaks, at 5 and at 125 degrees, but other BTEX species have their peaks at 125 degrees. Figure 52 shows that ethylene has one strong peak at 170 degrees, and propylene has a weak peak at 170 degrees.

At EML, Figure 53 shows that ethane has several peaks, the largest at 325 degrees. Other light alkanes also have their peaks at 325 degrees. Figure 54 shows that toluene has two peaks, at 110 and at 330 degrees, benzene has no strong peak, and other BTEX species have their peaks at 110 and 330 degrees as did toluene. Figure 55 shows that ethylene and propylene have relatively weak peaks at 135 degrees, has a weak peak at 325 degrees.

Figure 50 DISH seven alkane species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph

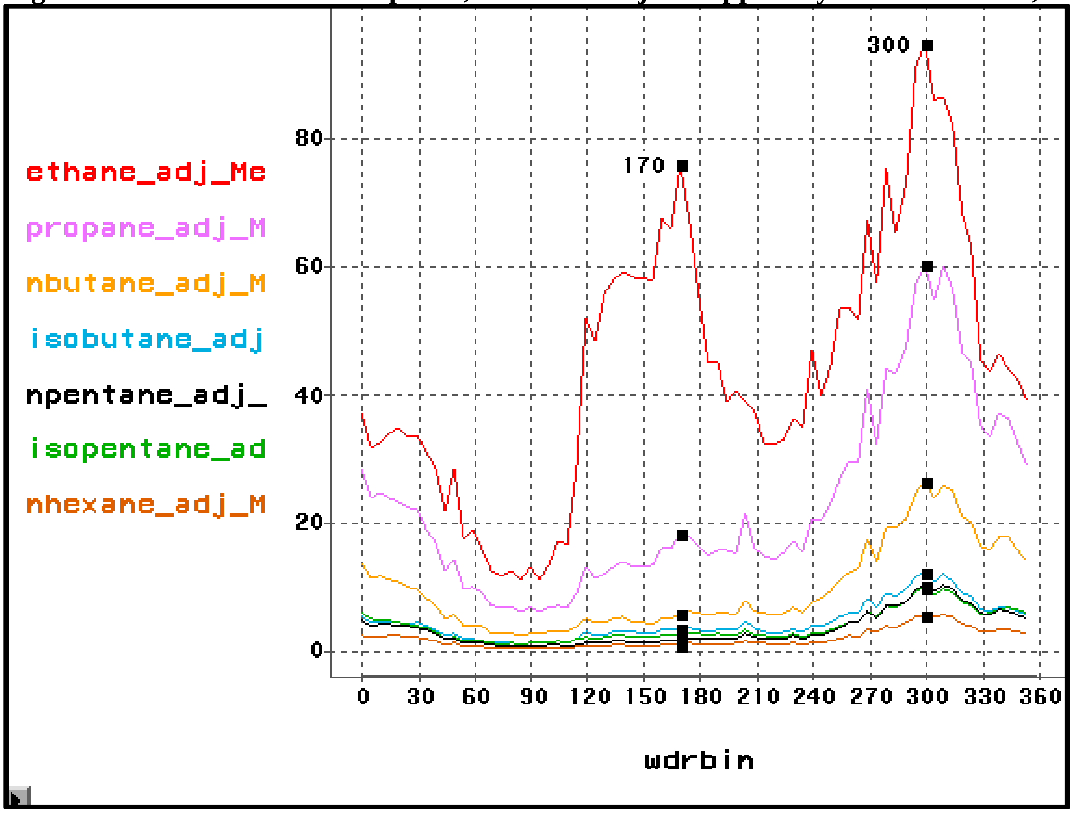


Figure 51 DISH BTEX species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph

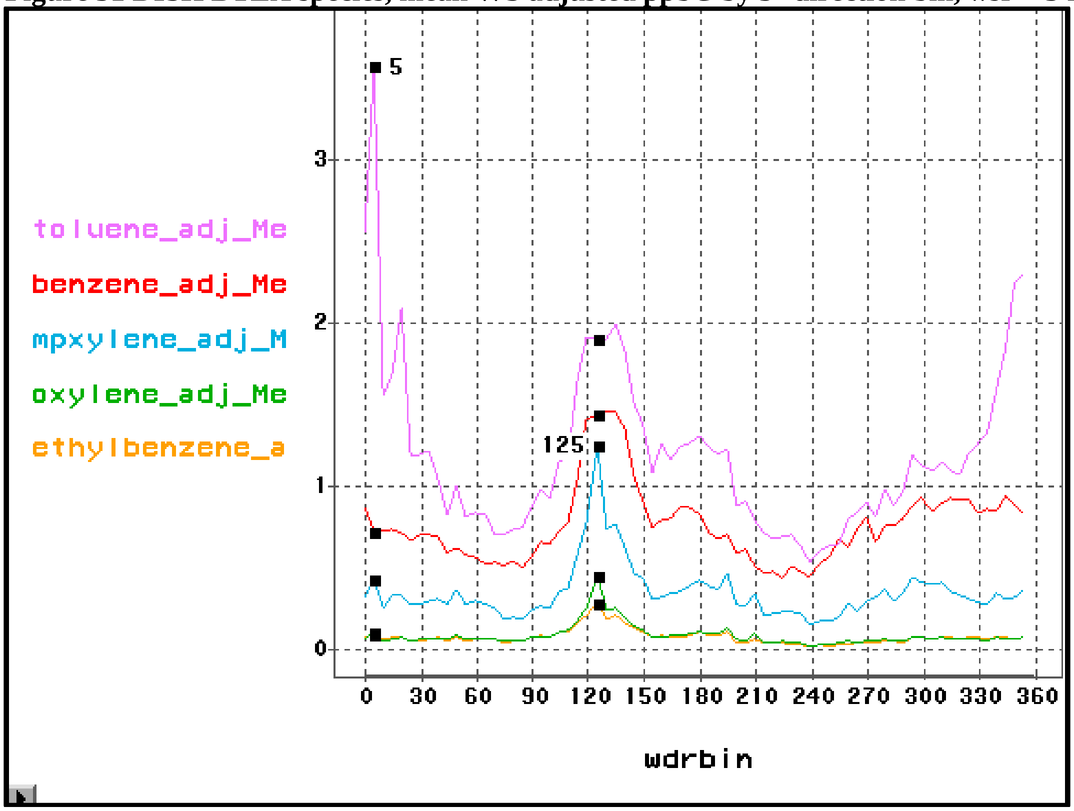


Figure 52 DISH two HRVOC species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph

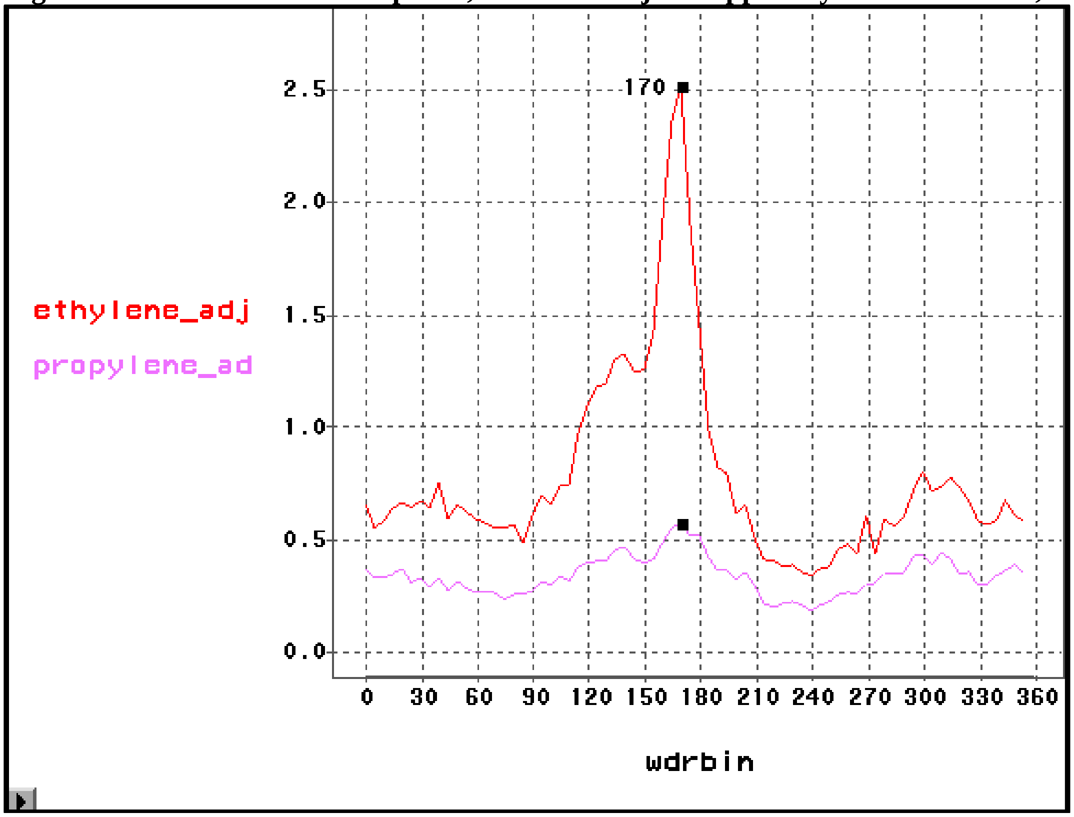


Figure 53 EML seven alkane species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph

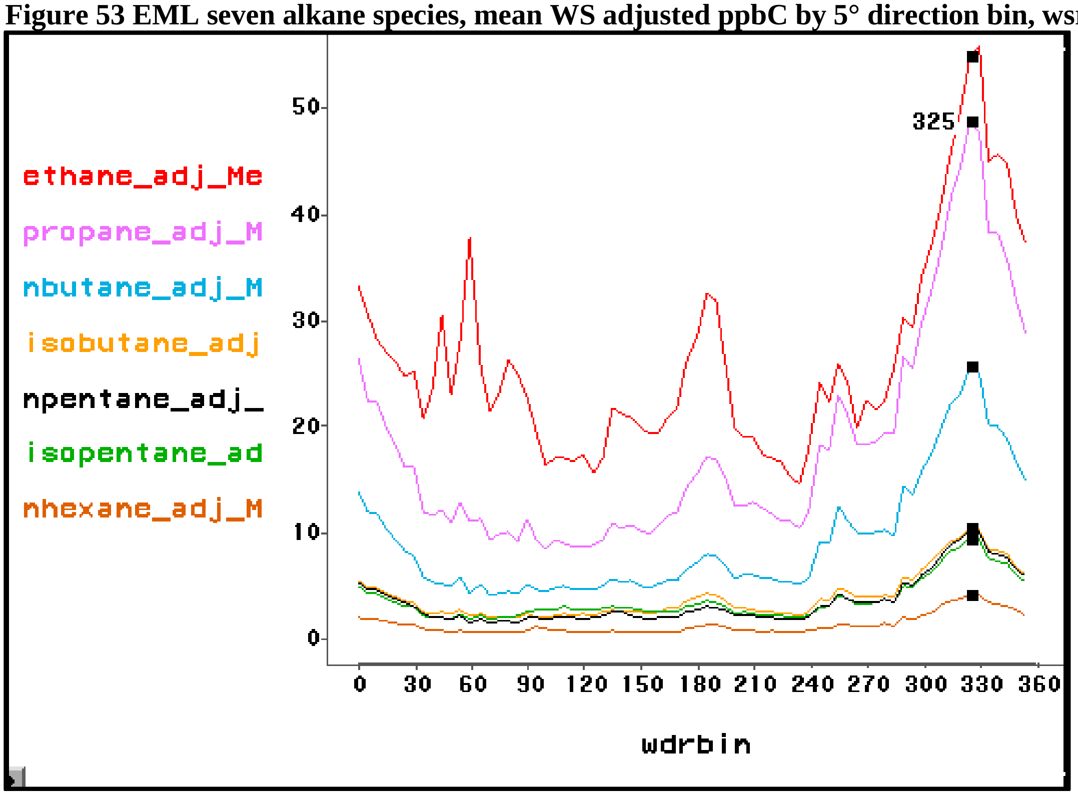


Figure 54 EML BTEX species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph

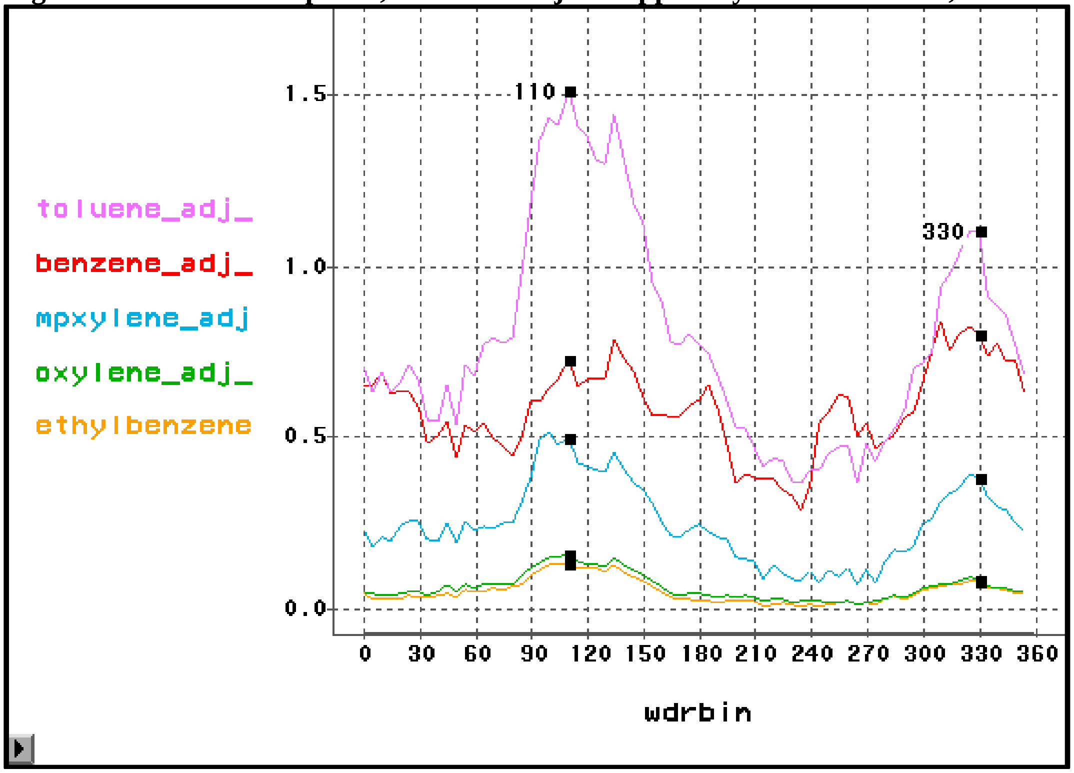
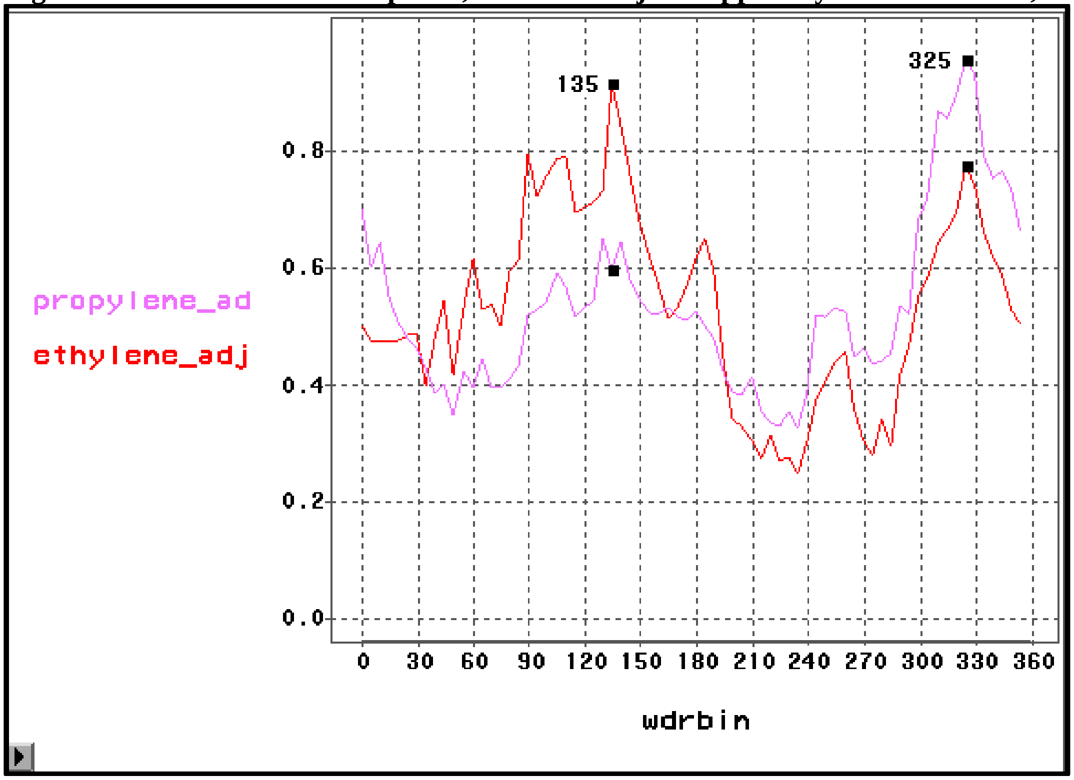


Figure 55 EML two HRVOC species, mean WS adjusted ppbC by 5° direction bin, wsr > 3 mph



Unexplained Nine-Carbon Event

In reviewing the auto-GC data from the DISH site, we came upon a two week period (July 14 – July 31, 2012) in which four branched aromatics (isopropylbenzene, n-propylbenzene, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene) had elevated concentrations under southerly winds. The key rounded 5-degree direction was 190 degrees. No other species behaved like this. One day of elevated 1,2,3-trimethylbenzene during this period may have been legitimate or a misidentification. These four 9-carbon species showed up in a very particular direction for a very specific time period. Figure 56 shows time series graphs for the five species just mentioned for the July 1 through August 15, 2012 period using their wind speed-adjusted values. Figure 57 shows the average wind speed-adjusted concentrations by 10 degree wind bin, with one graph for n-propylbenzene, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene on one scale and a second graph for isopropylbenzene on a different scale. The time series for the whole duration of operations April 2010 – May 2013 for the 10 degree wind sector 185 – 195 degrees appears in Figure 58. The two week period is a clear oddity in the data. There were some earlier and later higher concentrations of isopropylbenzene from that direction range. Table 10 summarizes the average ratios among the samples for three species to n-propylbenzene.

We reviewed the logs for this period and saw no operator notes which would indicate any significant changes made to the equipment. There were no hardware changes, calibrations or other changes which might have altered the instrument performance during this period. The only site visits were on July 19th and 26th. We looked at the monthly summary and pulled a chromatogram from July 30th that showed these targets high. This chart appears as Figure 59. Evidence suggests that these were valid air samples from an upwind source.

Table 10 Composition of the elevated C9 species relativeto n-propylbenzene in ppbC

Species	Ratio to n-propylbenzene
Isopropylbenzene	0.22 : 1.0
n-propyl benzene	1.0 : 1.0
1,2,4-trimethylbenzene	5.4 : 1.0
1,3,5-trimethylbenzene	1.8 : 1.0

Figure 56 DISH branched aromatics, ppbC, July 1, 2012 – August 15, 2012

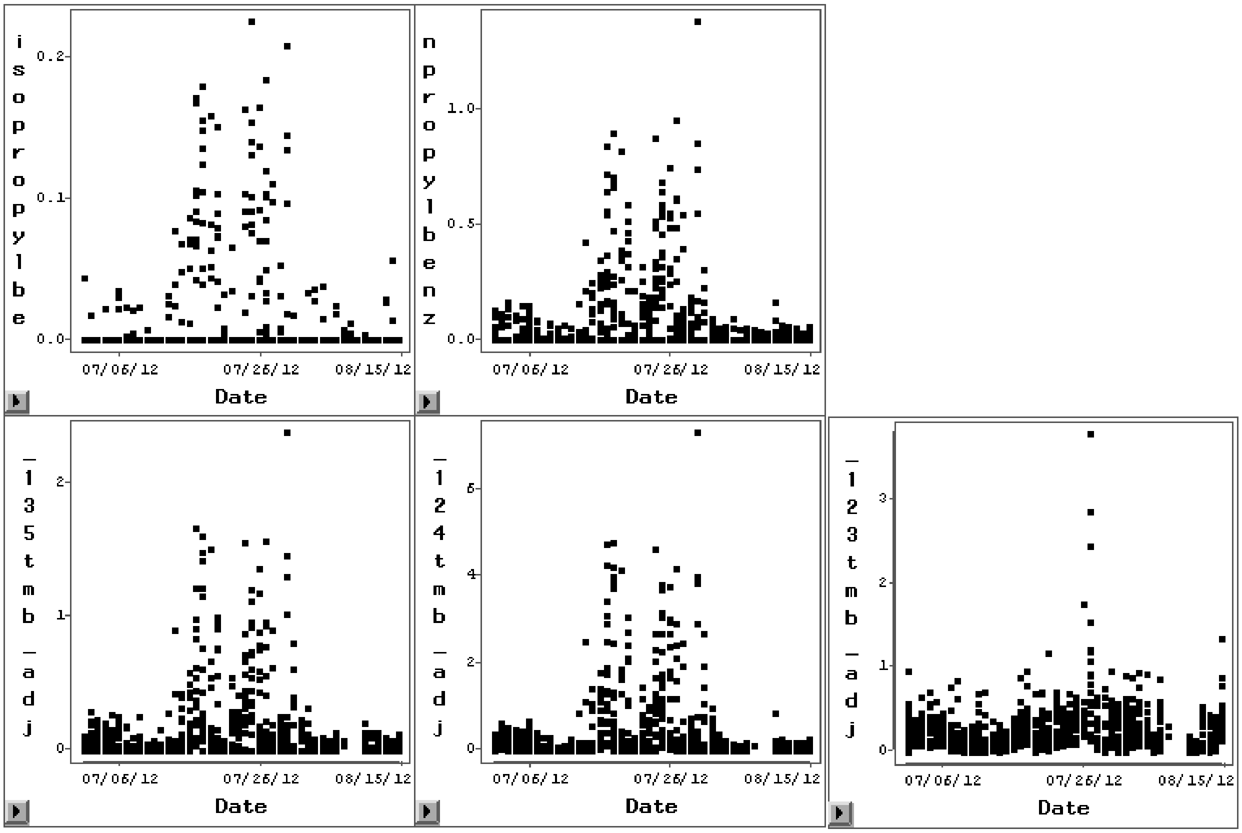


Figure 57 DISH branched aromatics July 1, 2012 – August 15, 2012 mean WS-adjusted concentration (ppbC) for four species, 10° wind bins, wsr > 3 mph

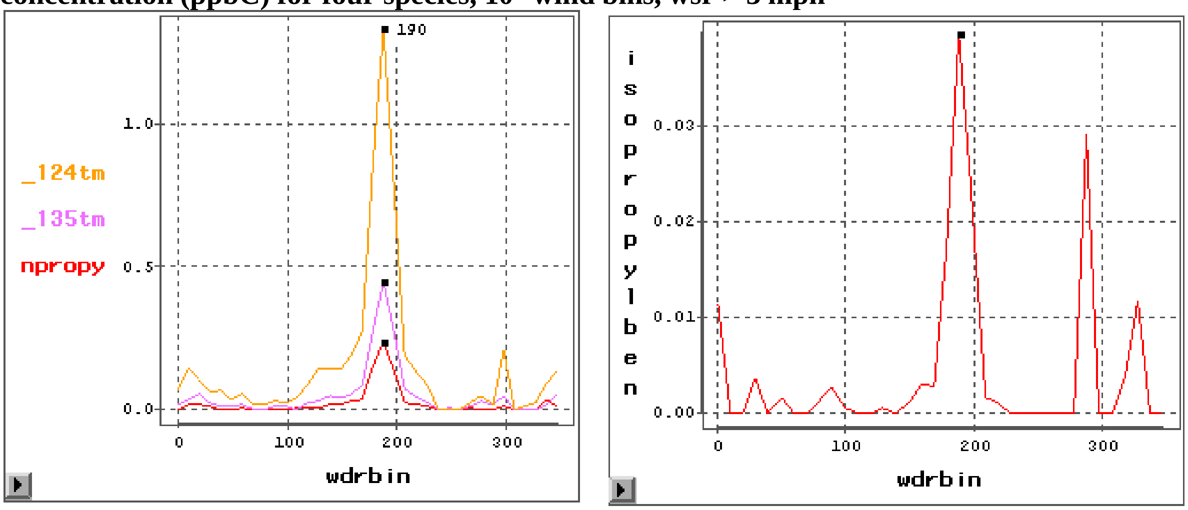


Figure 58 DISH branched aromatics April 2010 – April 2013, wind direction 185 to 195° only

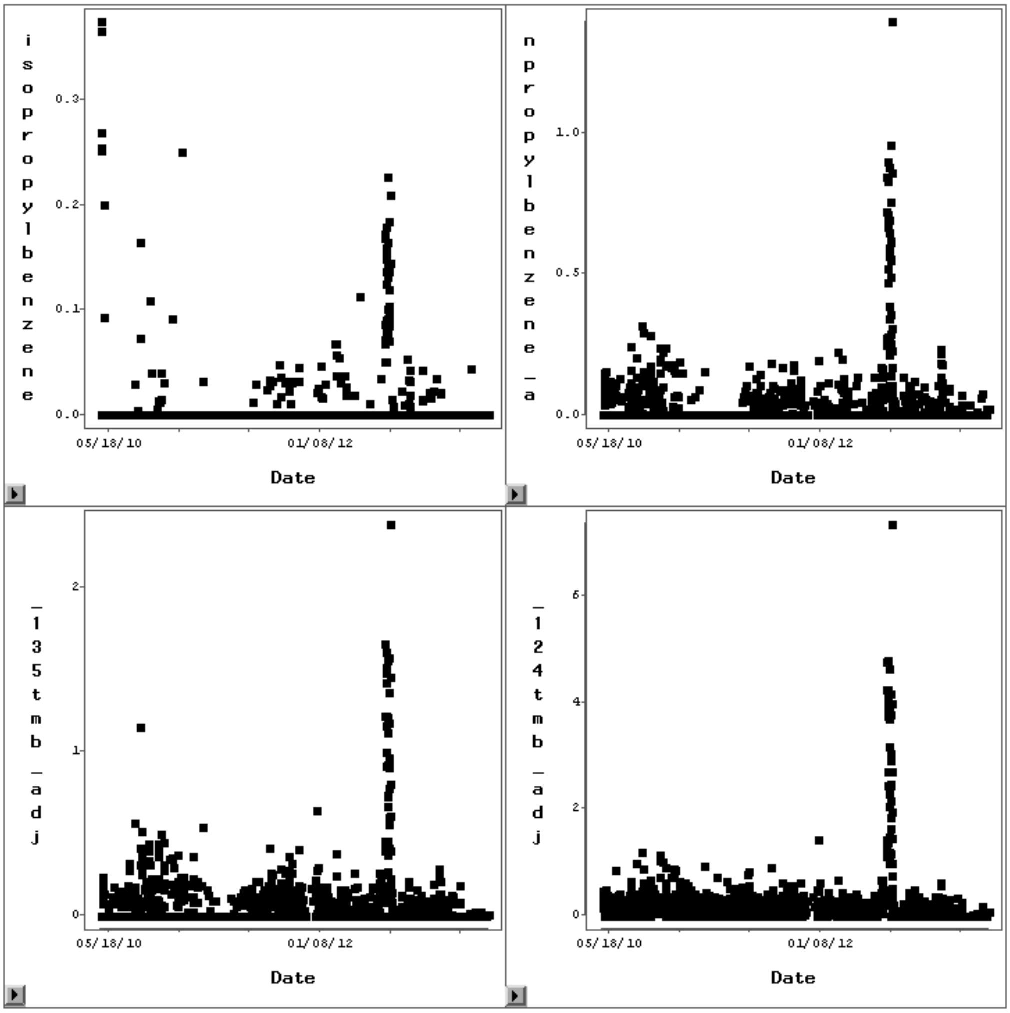
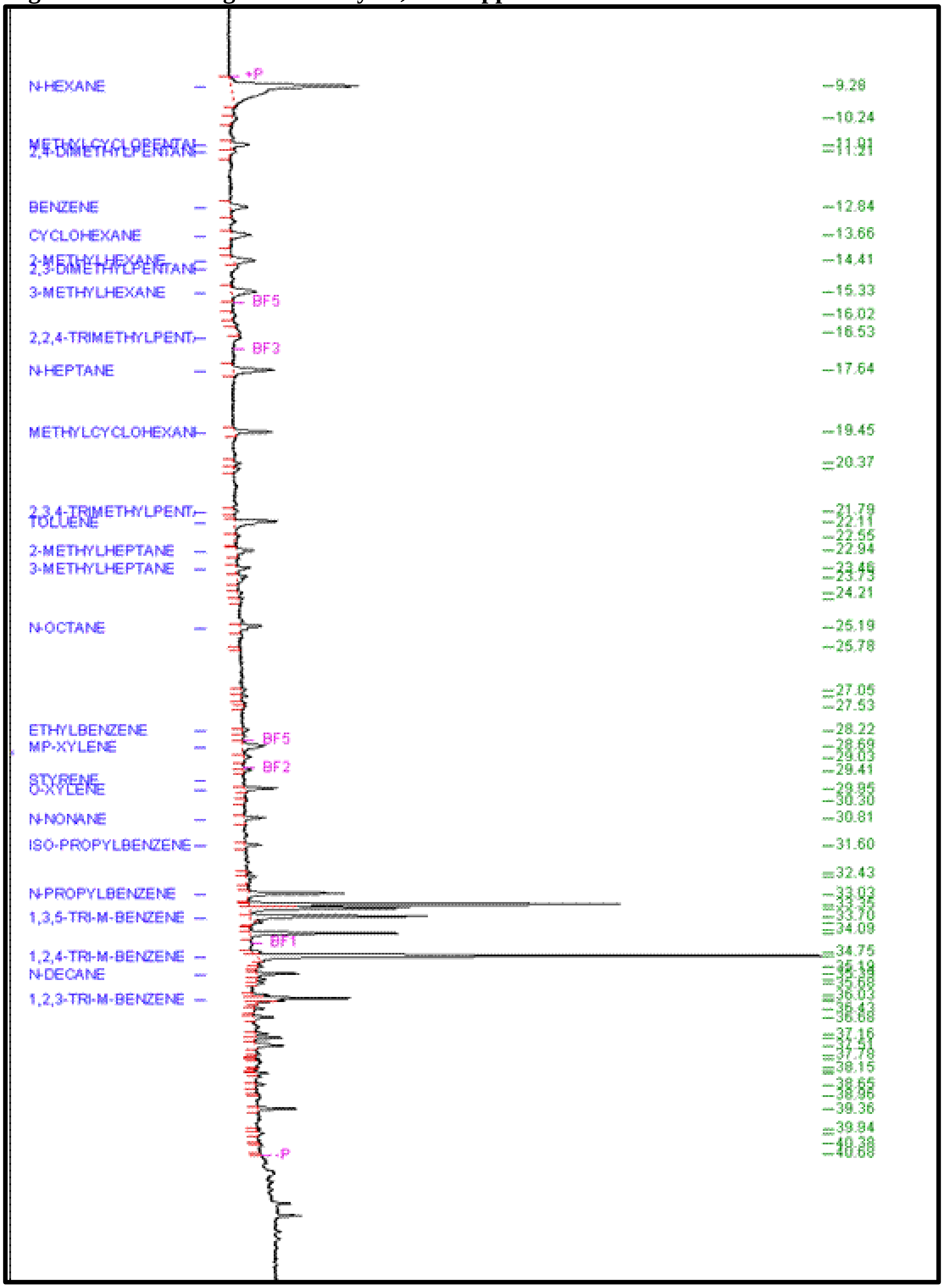


Figure 59 Chromatogram for July 30, 2012 appear correct



Oxides of nitrogen (NOx, NO, NO_2) data behavior

Figures 65, 66 and 67 show the time series of NOx, NO, and NO_2 hourly data, respectively, at the Eagle Mountain Lake CAMS 75 site. Tick marks in the graphs are the first day of each month. All 24 values for a given day are plotted at one point on the x-axis, and a line connects all the points on one day. All three graphs are on the same 0 to 160 ppb y-axis scale. Seasonality effects are such that concentrations appear to be higher in the winters compared to the summers. As was mentioned earlier regarding the benzene seasonality, assignable causes for the seasonality may include reduced wind speeds and reduced vertical mixing. Figures 68, 69, and 70 show the time series of NOx, NO, and NO_2 hourly data, respectively, at the Parker County CAMS 76 site, and Figures 71, 72, and 73 show the time series of NOx, NO, and NO_2 hourly data, respectively, at the Keller CAMS 17 site. The Keller site is the more urban of the three sites, and has the highest concentrations overall. The differences between the sites is made clearer in Figures 74, 75, and 76, which show the mean concentrations by month for 34 months (partial April 2010 and partial January 2013) of operation. We see in these last three graphs that NOx and NO_2 track each other. Although it is generally the case that primary NOx emissions are mostly NO, the NO is quickly oxidized to NO_2 in urban areas by ozone (O_3), so the NO_2 is closer to the total NOx than is NO.

Figure 60 Eagle Mountain Lake hourly NOx data April 2010 – June 2013

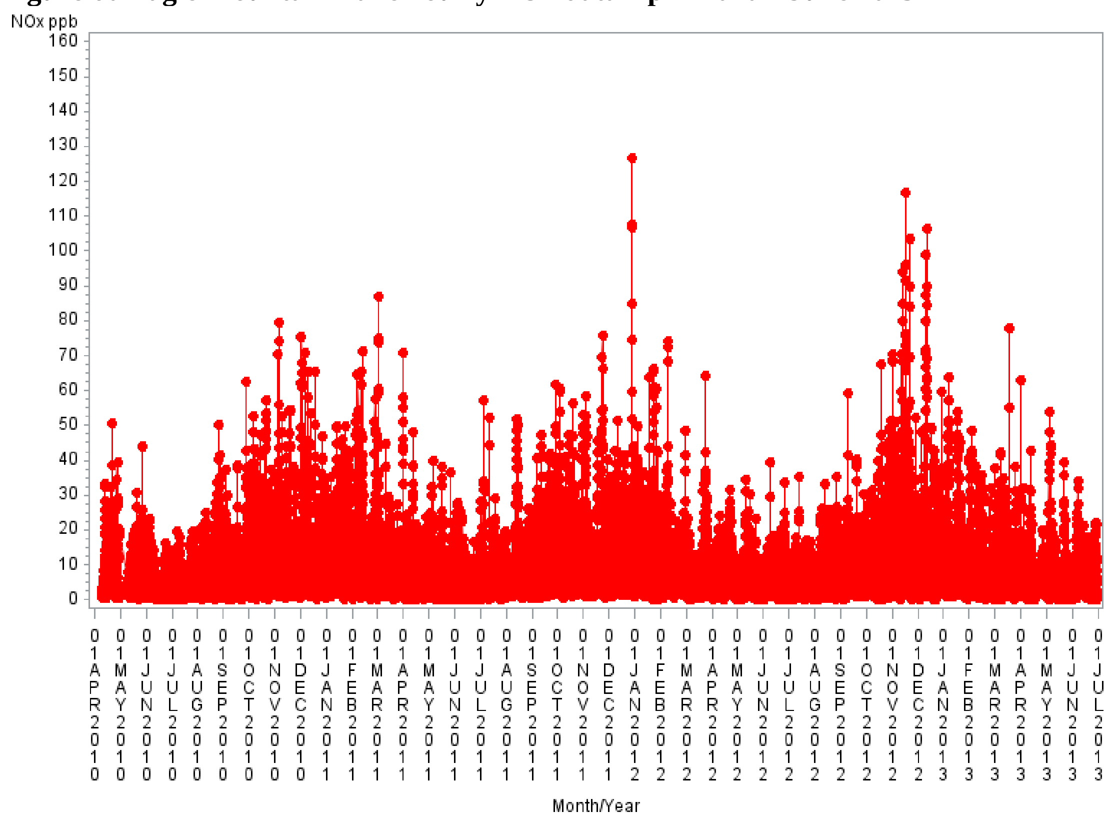


Figure 61 Eagle Mountain Lake hourly NO data April 2010 – June 2013

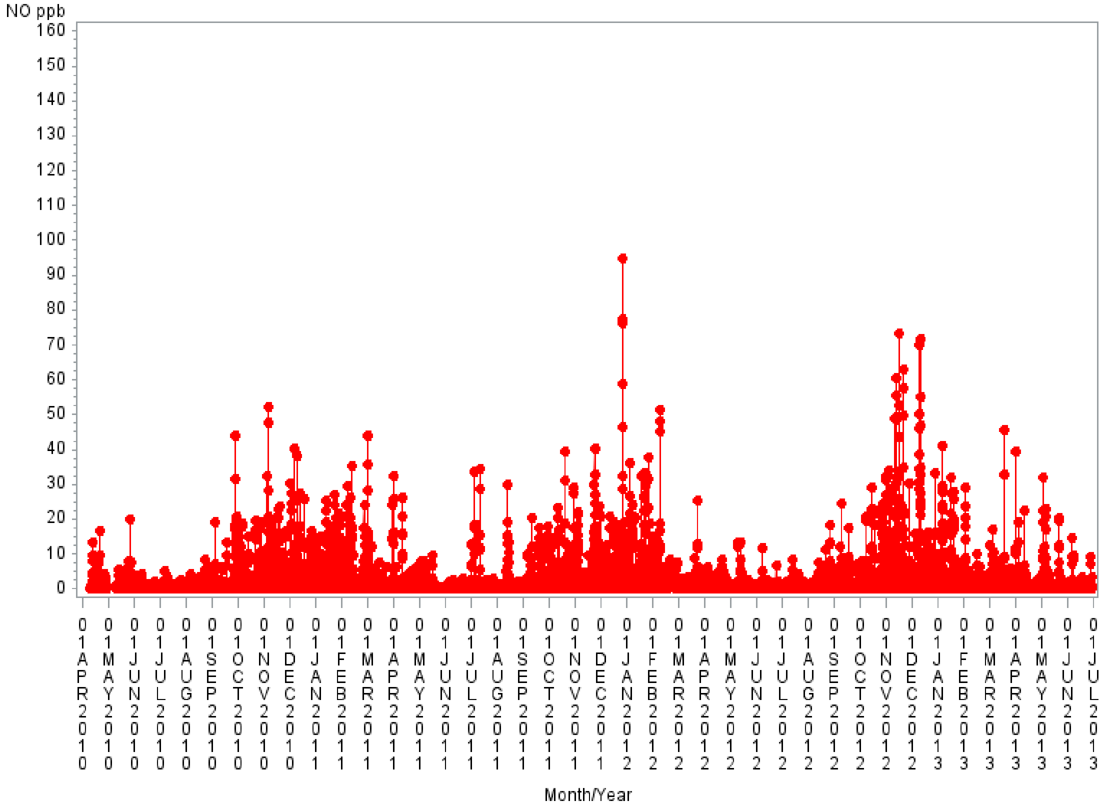


Figure 62 Eagle Mountain Lake hourly NO_2 data April 2010 – June 2013

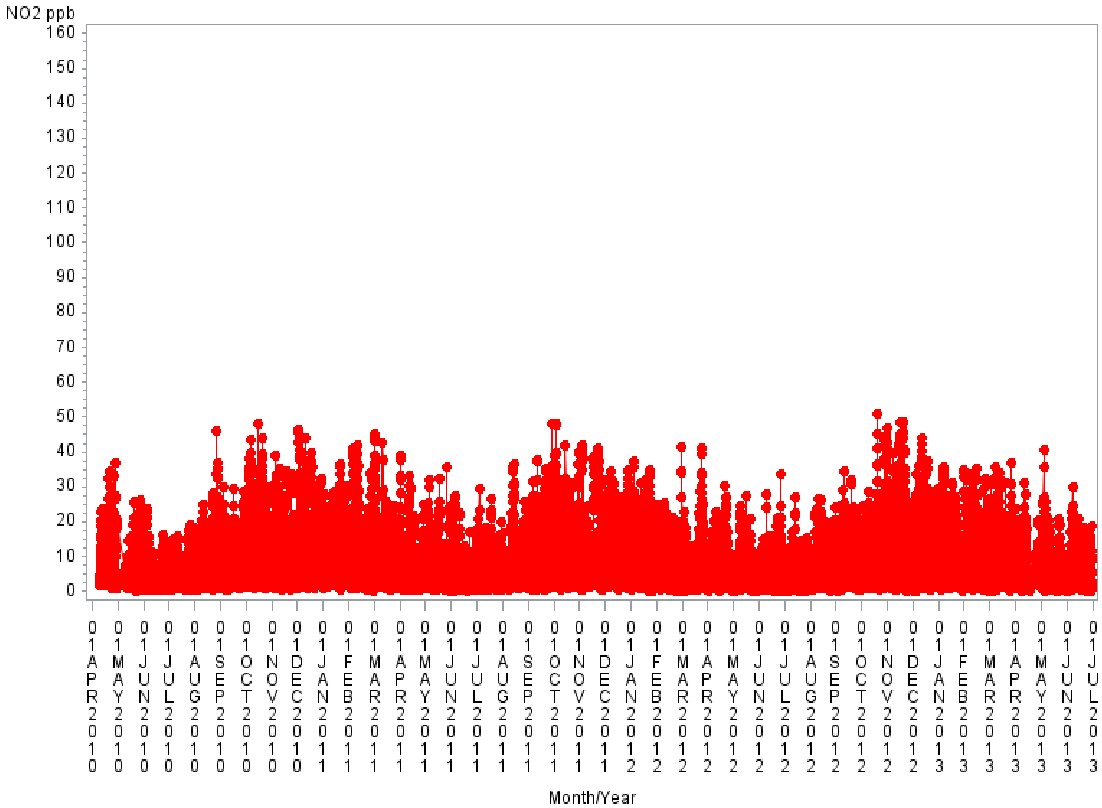


Figure 63 Parker County hourly NOx data April 2010 – March 2013

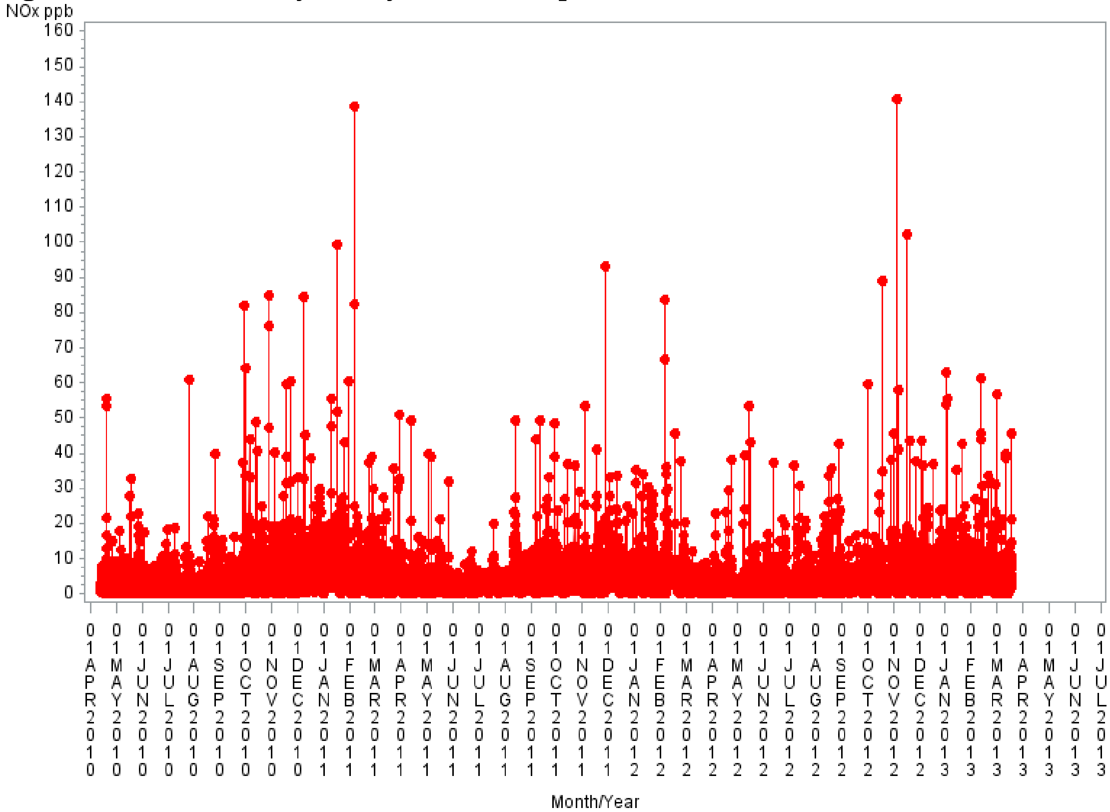


Figure 64 Parker County hourly NO data April 2010 – March 2013

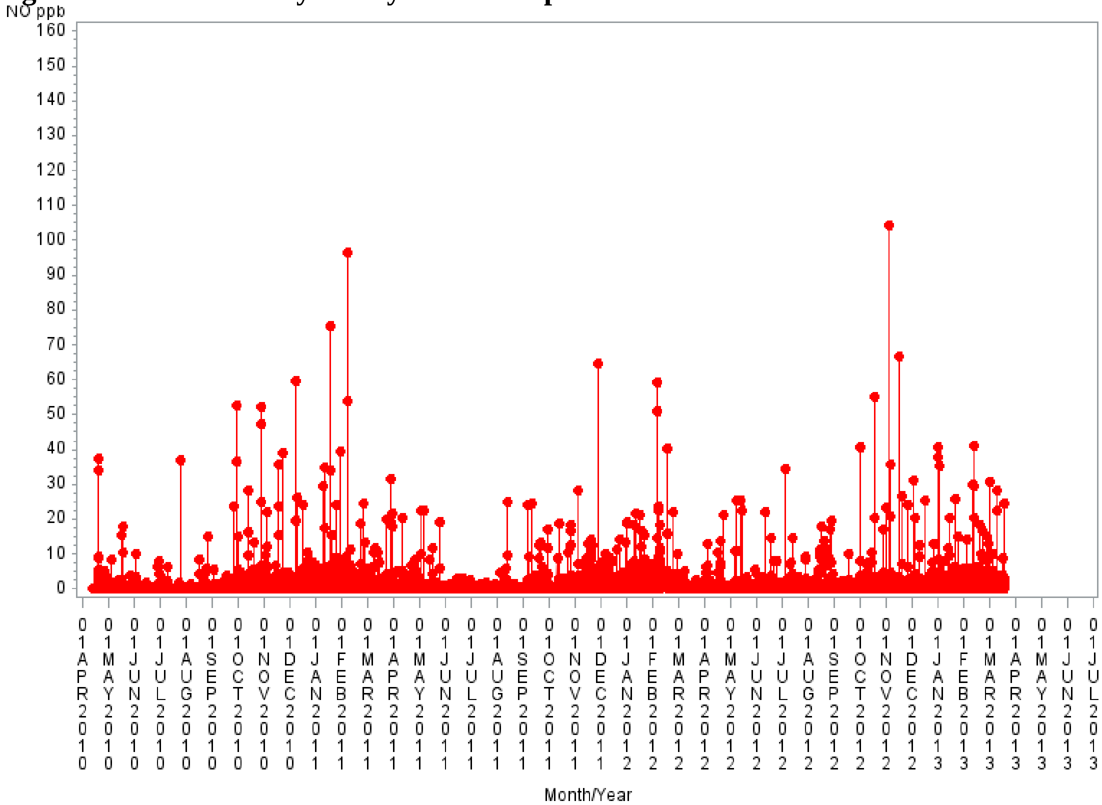


Figure 65 Parker County hourly NO_2 data April 2010 – March 2013

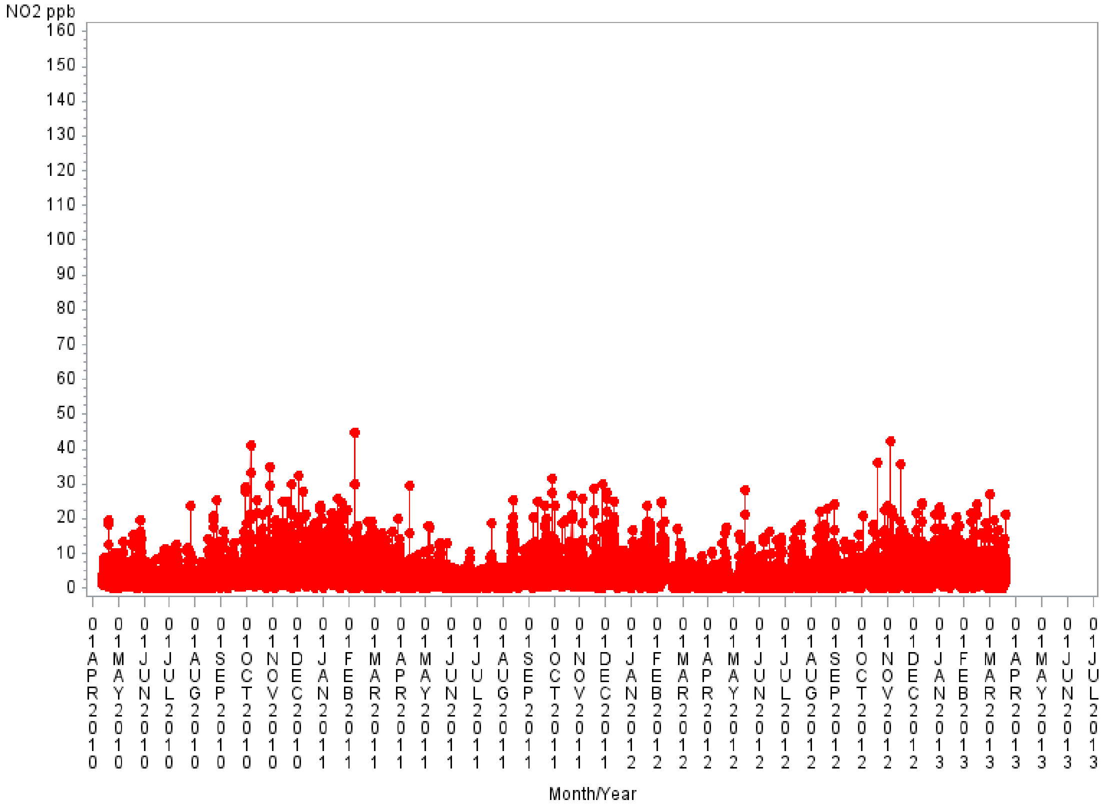


Figure 66 Keller hourly NOx data April 2010 – June 2013

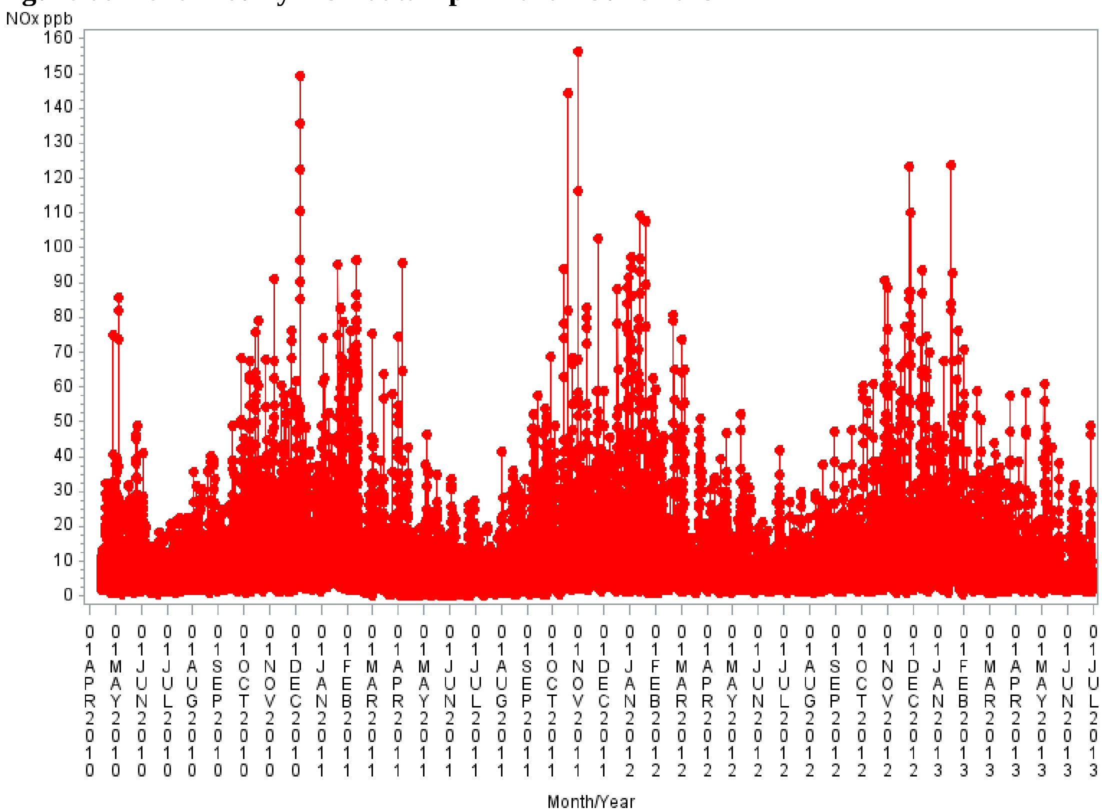


Figure 67 Keller hourly NO data April 2010 – June 2013

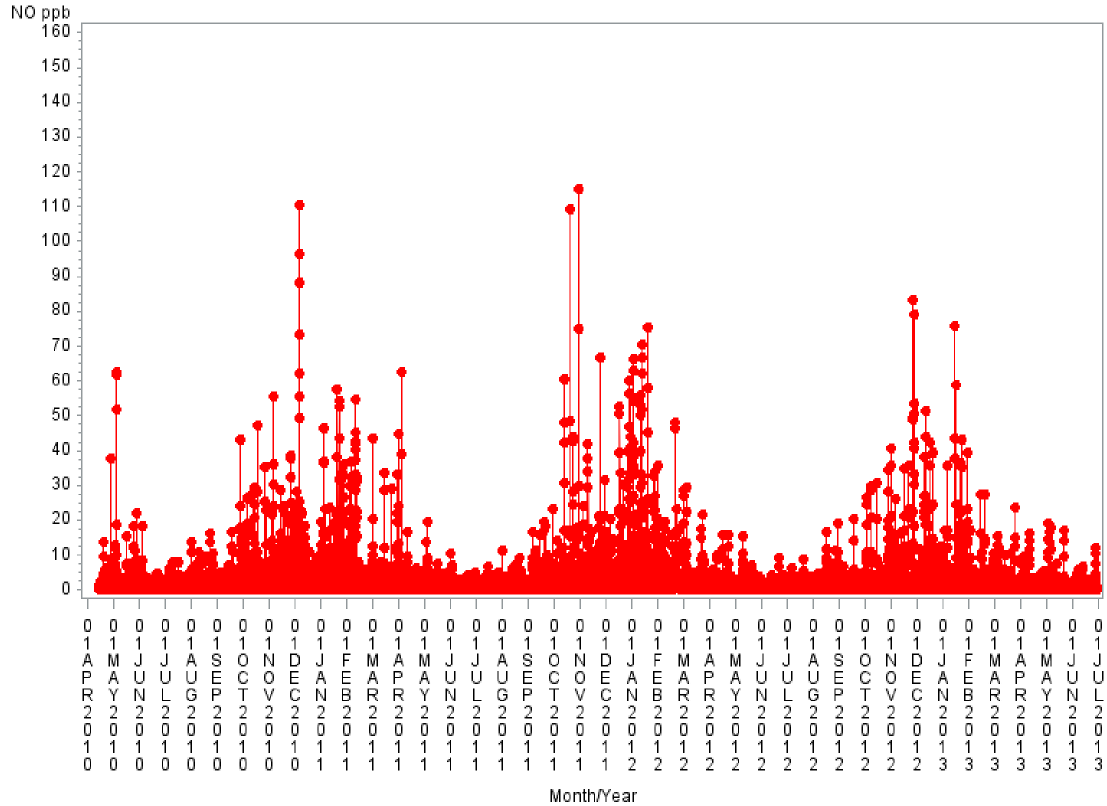


Figure 68 Keller hourly NO_2 data April 2010 – June 2013

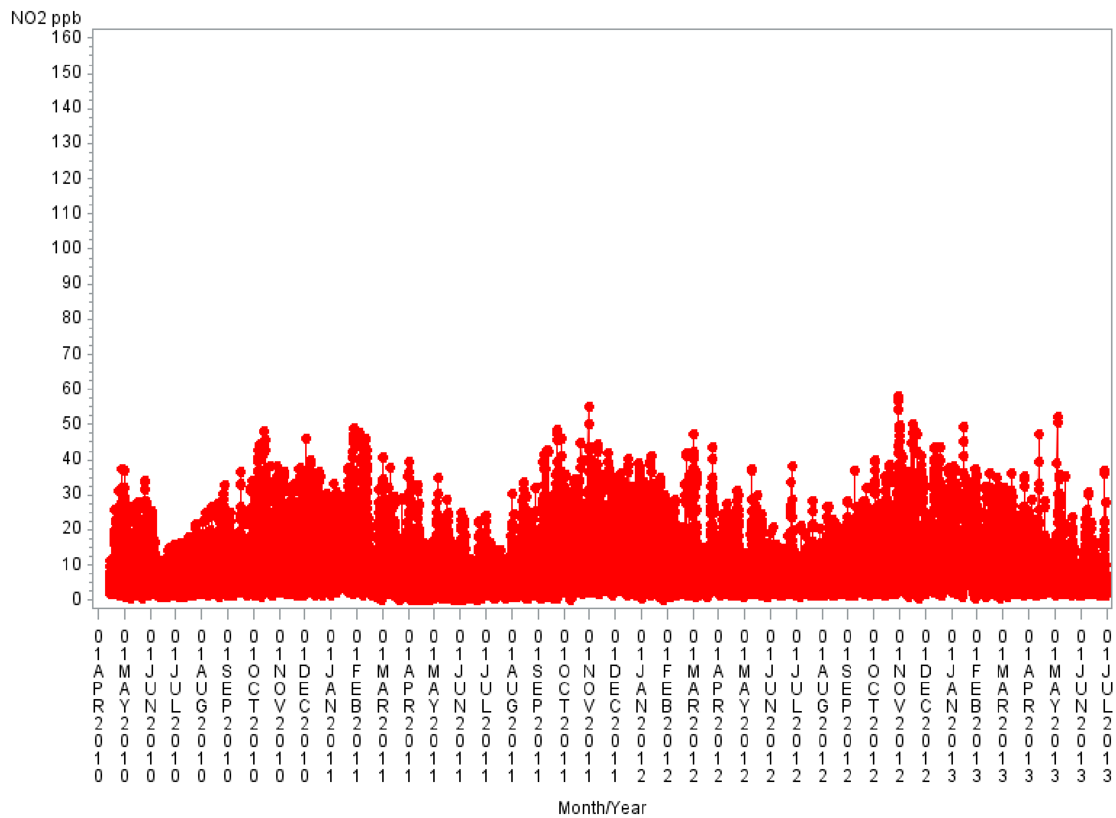


Figure 69 Eagle Mountain Lake mean NOx, NO_2, and NO by month, April 2010 – June 2013

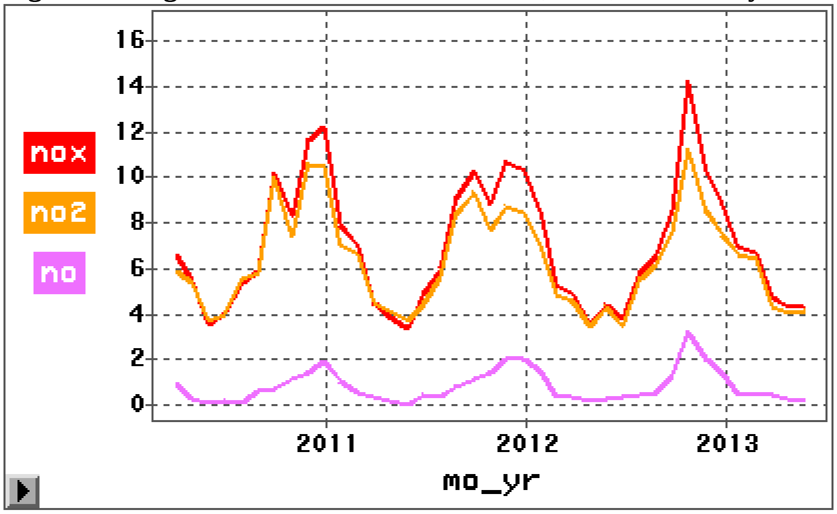


Figure 70 Parker County mean NOx, NO_2, and NO by month, April 2010 – March 2013

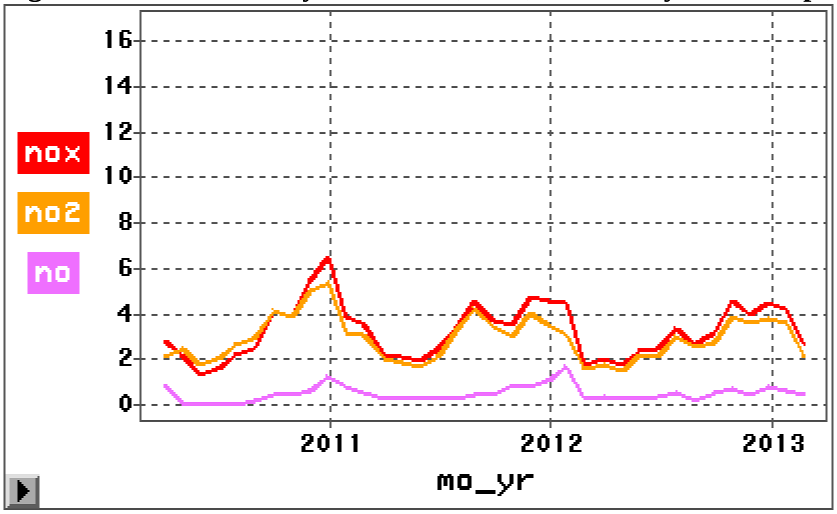
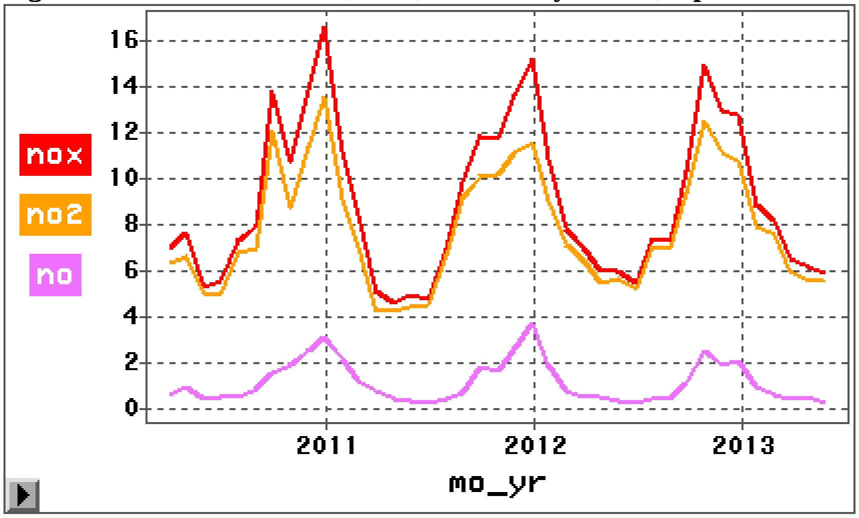


Figure 71 Keller mean NOx, NO_2, and NO by month, April 2010 – June 2013



4. Conclusions and Recommendations

There is very likely more information that can be gleaned from the data presented in this report.

1. Specifically, comparisons could be drawn to other monitors in the region, in particular the long-running Hinton and Fort Worth Northwest auto-GCs. For example, the table below shows a comparison for the annual statistics benzene from October 1, 2011 – September 30, 2012 (prepared for another project) for 26 auto-GCs operating for most of that time period in Texas, ranked on mean concentration. The two project auto-GCs, and a handful of other Barnett Shale sites, are in the bottom quartile of the list.

Site	Number samples	Max 1-hr ppbV	Max 24-hr ppbV	Mean ppbV
Hous. Lynchburg Ferry	5,847	57.191	6.466	0.953
Hous. Channelview	7,556	84.127	5.236	0.527
CC Oak Park	7,205	21.471	2.557	0.377
Hous. HRM-3 Haden Rd	7,303	15.735	1.554	0.331
Houston Clinton	6,957	11.933	1.226	0.322
Hous. Deer Park	6,871	22.852	2.083	0.313
Hous. Cesar Chavez	7,260	5.240	1.461	0.308
BPA Beaumont-Downtown	7,590	23.883	1.513	0.284
Odessa Hays	7,512	6.776	0.951	0.276
CC Palm	7,370	87.410	7.186	0.275
BPA Nederland HS	7,610	11.578	1.369	0.271
Houston Milby Park	7,690	5.845	1.130	0.263
El Paso Chamizal	7,646	7.106	1.533	0.255
Hous. Wallisville Rd	7,542	19.577	4.931	0.222
El Paso Delta	7,726	3.443	0.850	0.190
Fort Worth Northwest	7,341	2.067	0.574	0.172
Texas City 34th St	7,379	11.987	0.898	0.166
DFW Decatur Thompson	7,741	5.369	0.433	0.159
Dallas Hinton	7,712	16.536	0.900	0.149
CC Solar Estates	7,555	3.692	0.673	0.148
DFW DISH Airfield	7,772	1.391	0.475	0.141
DFW Everman Johnson	7,493	1.303	0.429	0.132
DFW Eagle Mountain Lake	7,652	0.818	0.407	0.131
Hous. Danciger	7,284	11.894	1.828	0.129
DFW Flower Mound Shiloh	7267	0.906	0.442	0.125
Hous. Lake Jackson	7238	0.972	0.322	0.081

2. Other comparisons may be more valuable, excluding sites near refineries and chemical plants, or including air toxics canister sites in the comparison.
3. More work could be done also to compare the NOx data across the region instead of only among the three project sites.
4. Another valuable form of analysis would be source apportionment with principal component analysis, as was included in a monthly report.
5. Some of the temporal assessment, such as the diurnal patterns, could be done taking the month of the year into effect, as we observed that both hour of the day and month of the year have significant effects.

If the TCEQ would identify some specific questions to be answered though more data analysis, UT CEER would be happy to study them if within reasonable bounds.