Virginia Military Base Case Study for AEHS

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Project Team

- Funded ESTCP Program ER-201504
- Hosting: Naval Facilities Engineering Command
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Conceptual Site Model – Building B

- Degreasers (including TCE) historically used to clean parts.
- Depth to GW ~40 ft
- TCE detected in subslab soil vapor at a maximum concentration of **7,000,000 µg/m3** (1,300,000 ppb) indicating residual dense non-aqueous phase liquid (DNAPL) may be present in the vicinity of this sample location.
- Observed spatial variability in subslab soil vapor ~1 to 2 orders of magnitude consistent with the potential presence of localized pockets of DNAPL and/or elevated soil VOC concentrations beneath portions of the building.
- Main source area of soil contamination located immediately adjacent to and beneath the building and subslab soil vapor concentrations of TCE and previously conducted MIP investigation indicate soil contamination and pockets of DNAPL may also be present beneath the building.

Building Descriptions

Building A

- Built in 1941, Actively used until 2012; constructed of concrete blocks on a concrete slab elevated above grade, 50,700 ft^{2},
- Degreasers (including TCE) were reportedly used to clean parts
- preferential pathways: Utility conduits to dirt foundations serve as preferential pathway. Floor drains in some areas, cracks in concrete floor
- Unheated/uncooled at time of sampling, occupants and most equipment relocated; ceiling height 35’ in open spaces, 10 to 12’ in enclosed areas; hole at the end of the building.

Building B

- Built in 1919 of concrete blocks on elevated concrete slab; actively used until 2012
- One story, large open areas, some offices, storage; ceiling height 35 ft; 53,000 ft^2
- Floor drains in some areas, cracks in concrete floor
- Unheated/uncooled at time of sampling, occupants and most equipment relocated

Conceptual Site Model Building A

- Constructed of concrete blocks on a concrete slab elevated above grade in 1919
- Depth to groundwater ~40 ft
- Degreasers (including TCE) were reportedly used to clean parts
- Soil contamination located immediately adjacent to and beneath the building.
- Spatial variability in subslab soil vapor results ~1 to 3 orders of magnitude. Data consistent with the potential presence of localized pockets of DNAPL and/or elevated soil VOC concentrations beneath portions of the building
- Pipe chases containing dirt floors identified during the HAPSITE and the preferential pathways investigation
- Cracks in the floor sealed in an attempt to mitigate VI - March 2012

Site Climate Zone (International Energy Conservation Code (IECC)

- Temperature aspect based on degree-days – so a measure of full winter stack effect – and thus exposure. Also includes moisture considerations
- Along a coastal river/bay Climate Zones IECC Zone 4; Koppen CFa humid subtropical
- Groundwater concentrations of TCE up to 5,900 µg/l between buildings A and B

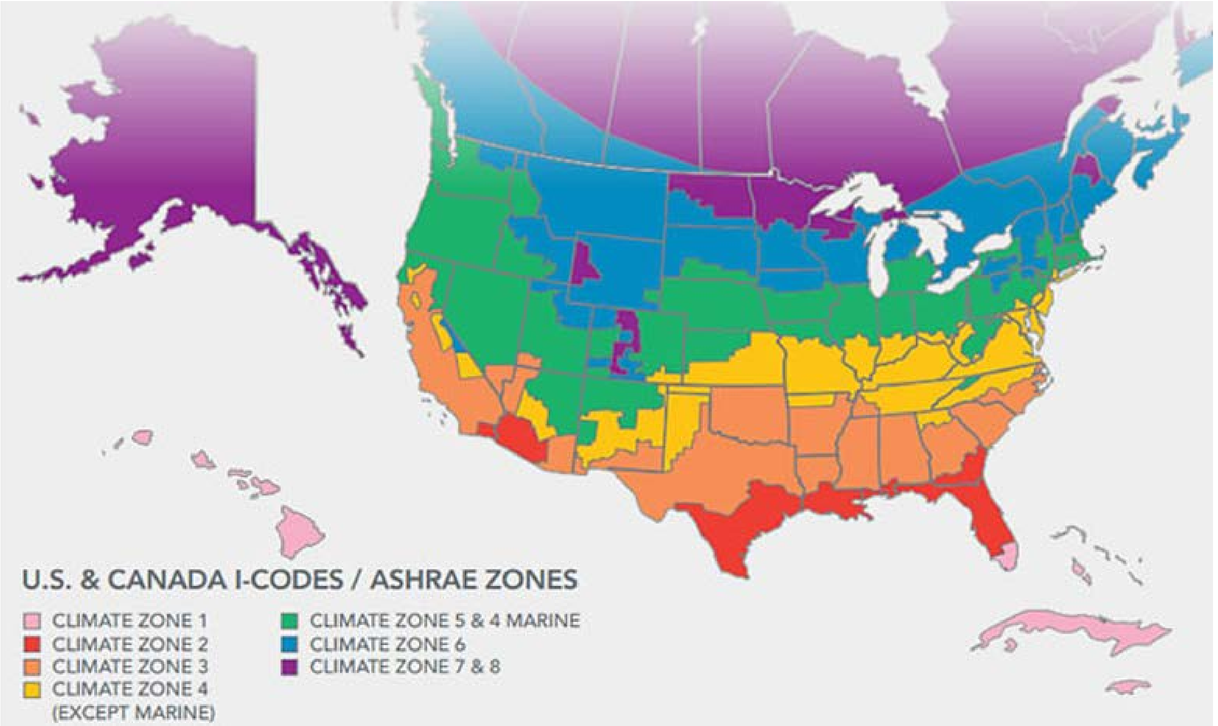
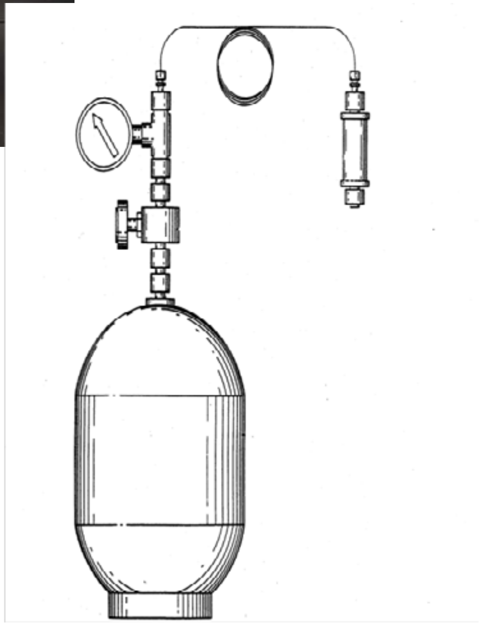


Figure reprinted from https://www.greenbuildingadvisor.com/article/climate-zone-map-including-canada

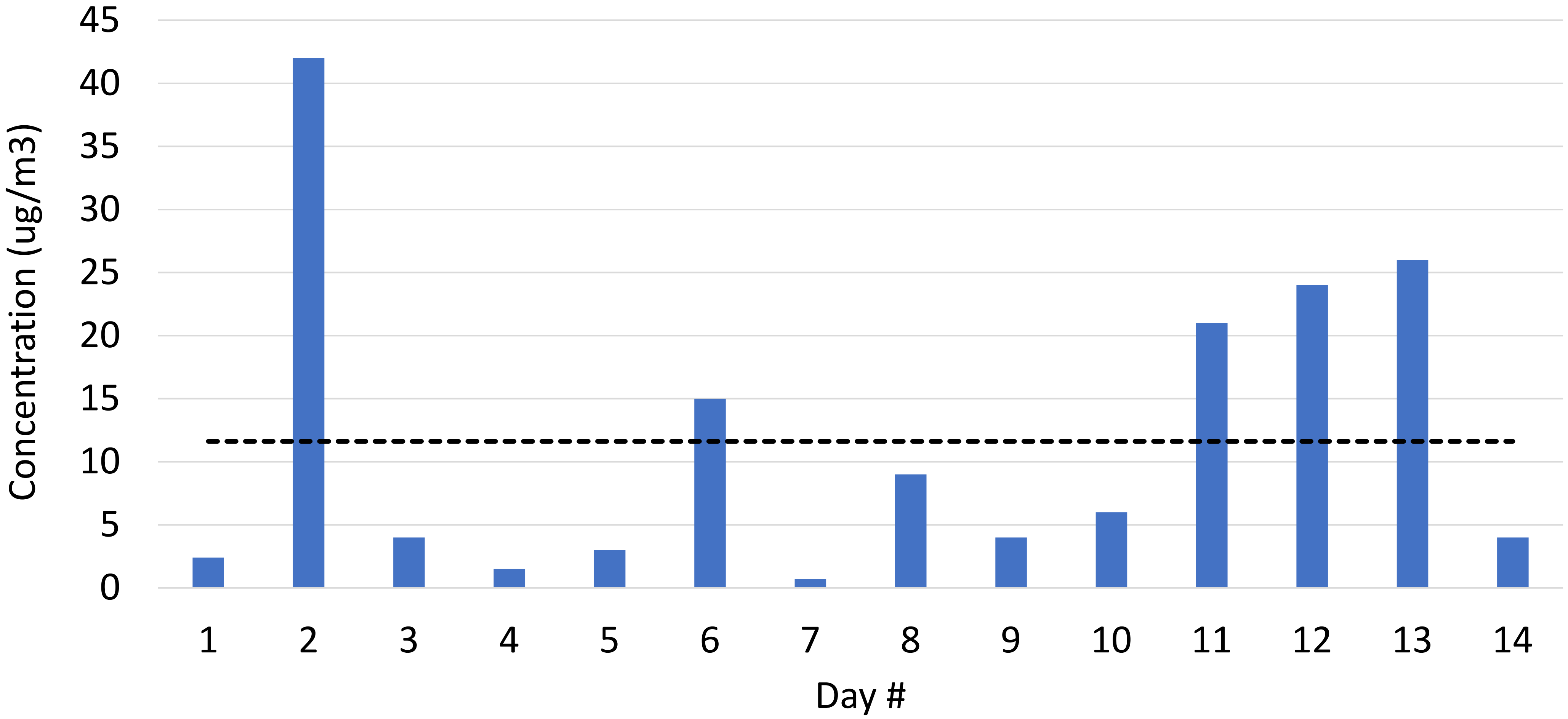
Flow Controllers

Diaphragm Flow Controller
(3.0 mL/min)



Capillary Flow Controller
(0.10mL/min & 0.31 mL/min)

VI Building Indoor Air: Example



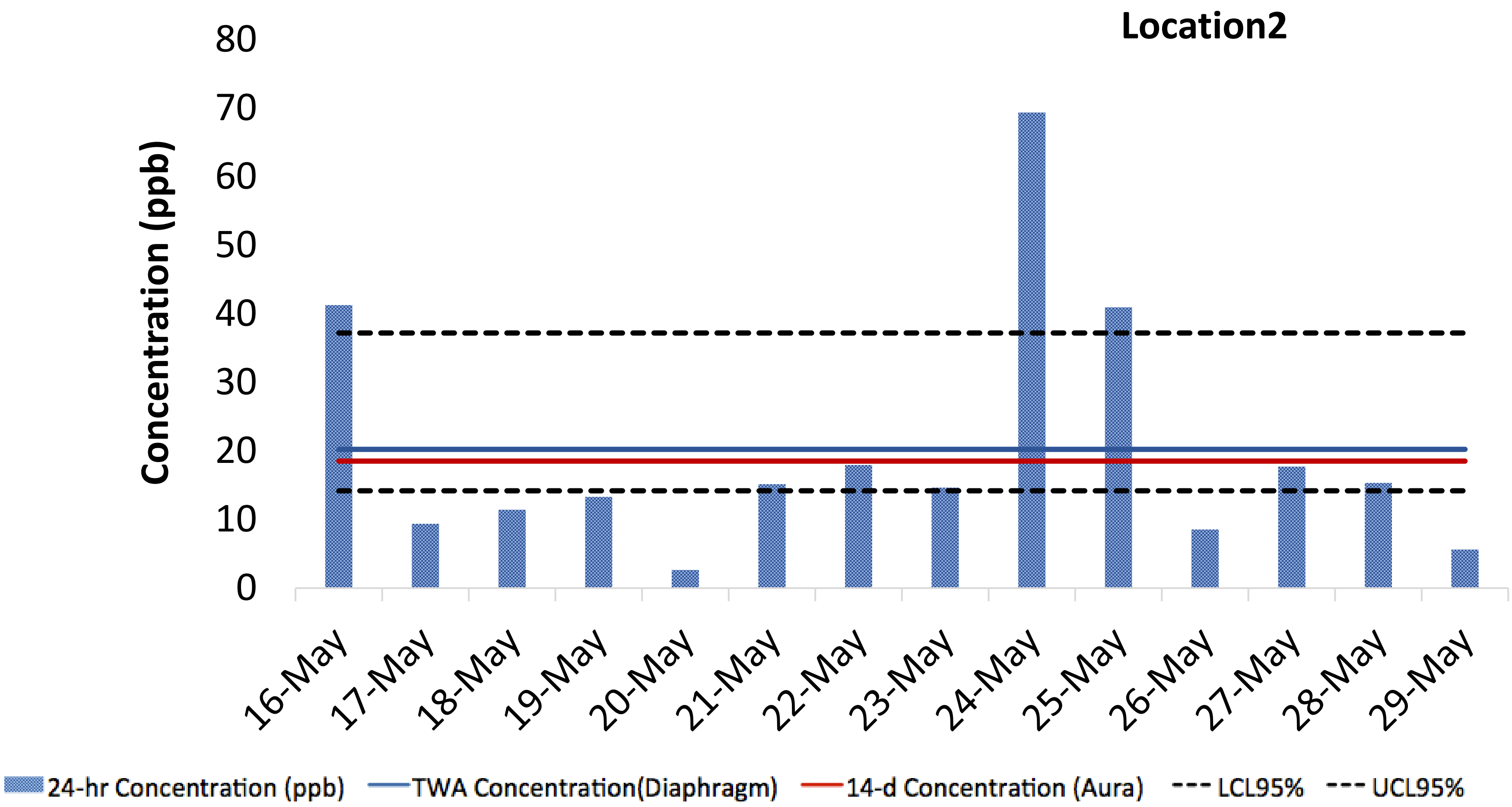
Key Points

- The capillary canister system was used to collect indoor air samples for **2 weeks in** 6L and 15L canisters.
- The capillary-canister system was also used with 1L, canisters to collect samples from the sub-slab.
- Performance was assessed by comparing results to daily **24-hr canister** samplers and passive diffusion samplers.
- Seasonal impacts on performance was evaluated.
- The results have been at least as accurate, precise, and complete as current standard practices at lower sampling cost and sample analytical cost.
- Capillary Canister system has been tested with 400mL and 1L canisters for 24 and 72 h respectively.

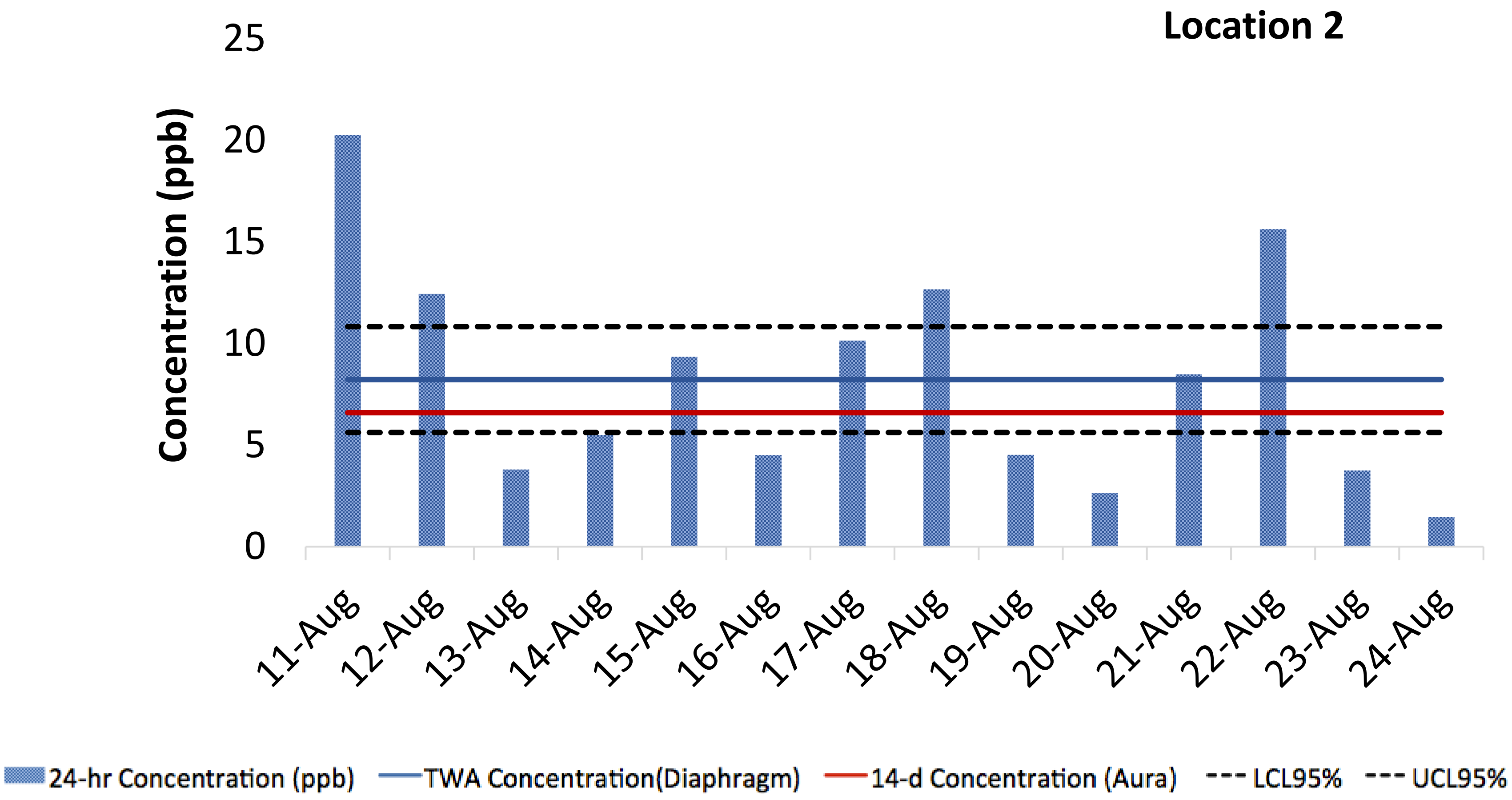
Test Design: Design & Layout

- Two buildings - 2 locations per building
- Two-week sampling period; ~quarterly, 6 rounds
- Sampling devices
  - Canisters with conventional diaphragm flow controllers (**24-hr sample time**)
  - Capillary flow controller providing **2 week integration**
- Other
  - Temperature
  - Relative humidity
  - Cross slab pressure
  - Direct-reading: VOCs

Example Temporal Trend – 24 hour samples May 2017

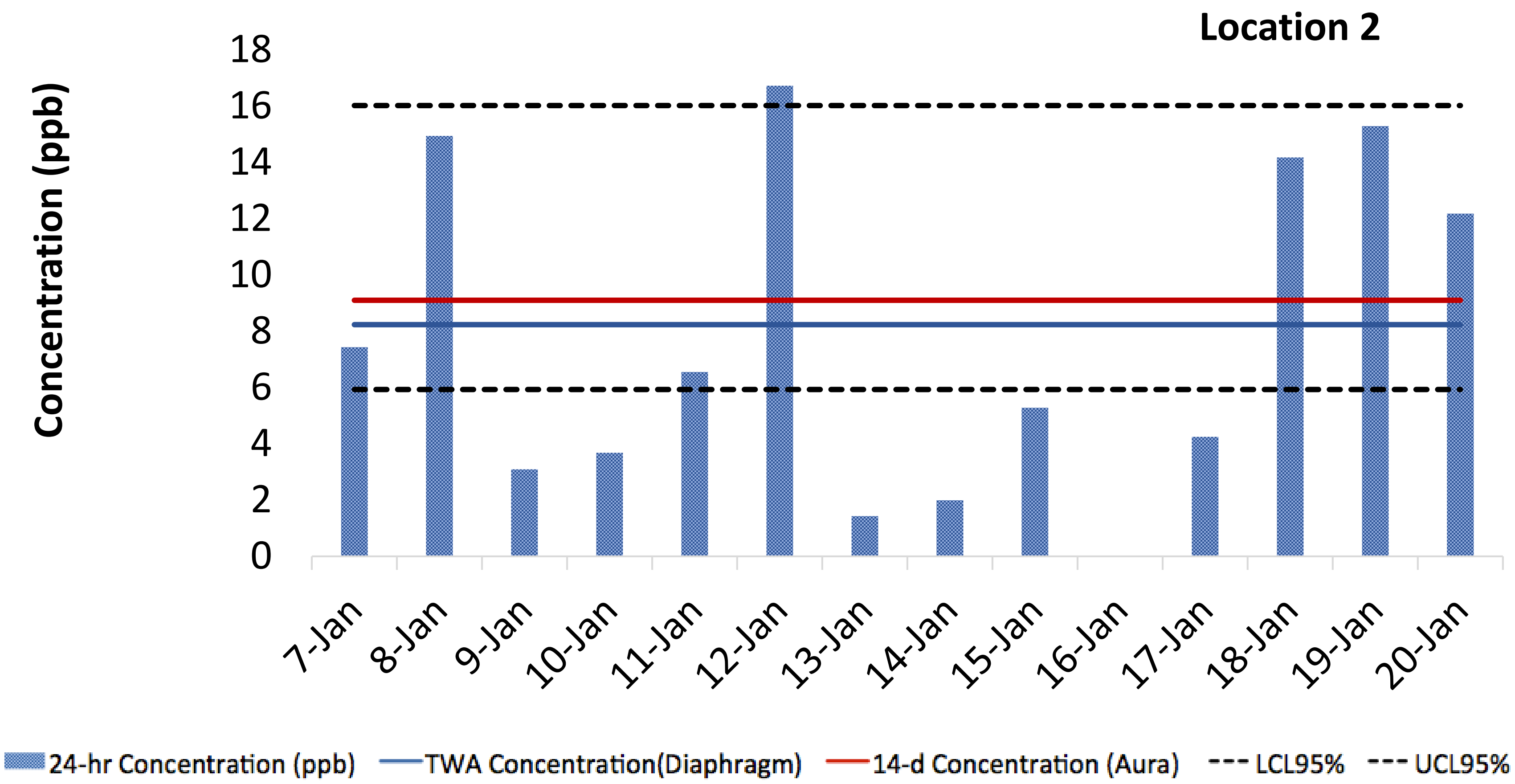


August 2017

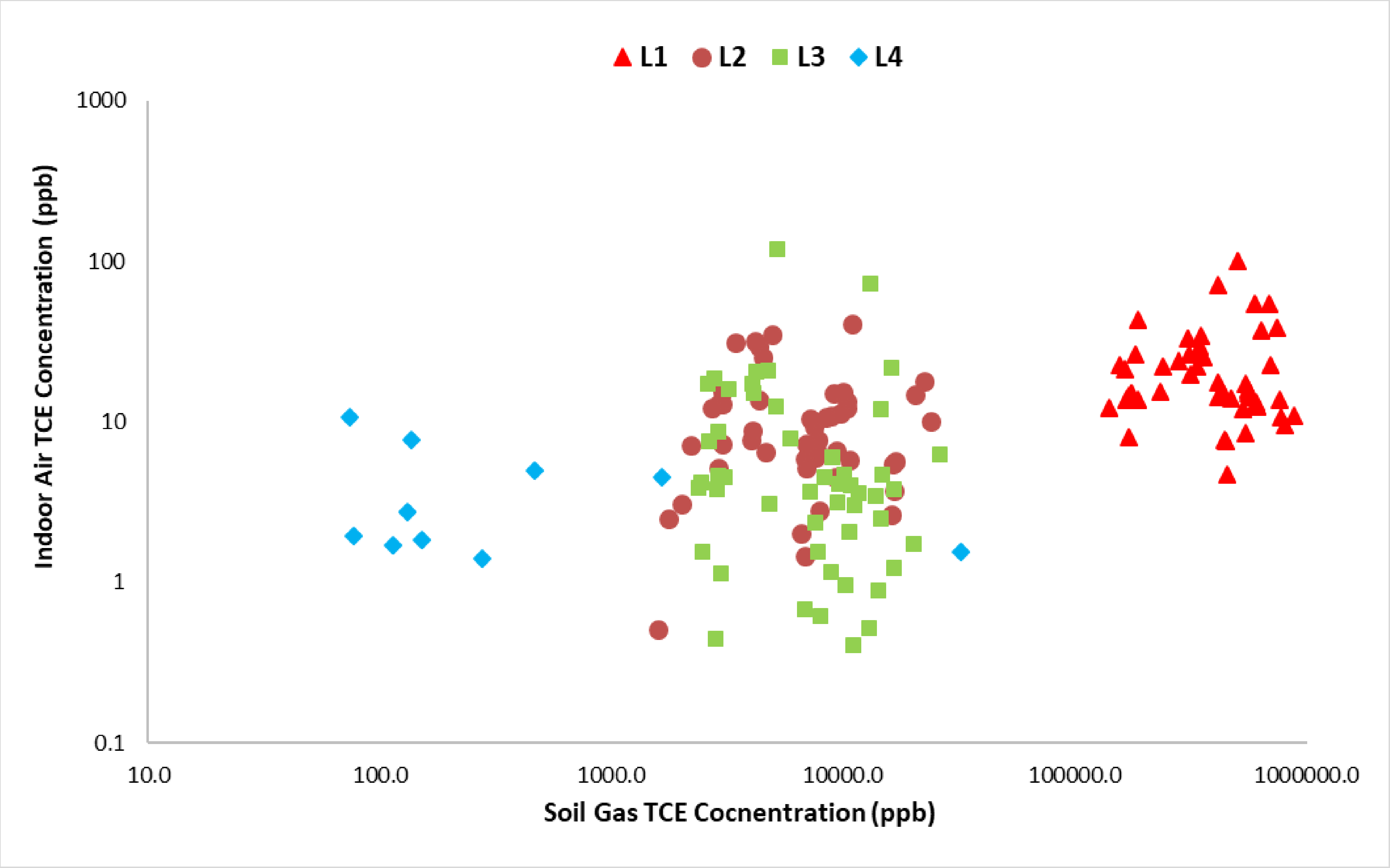


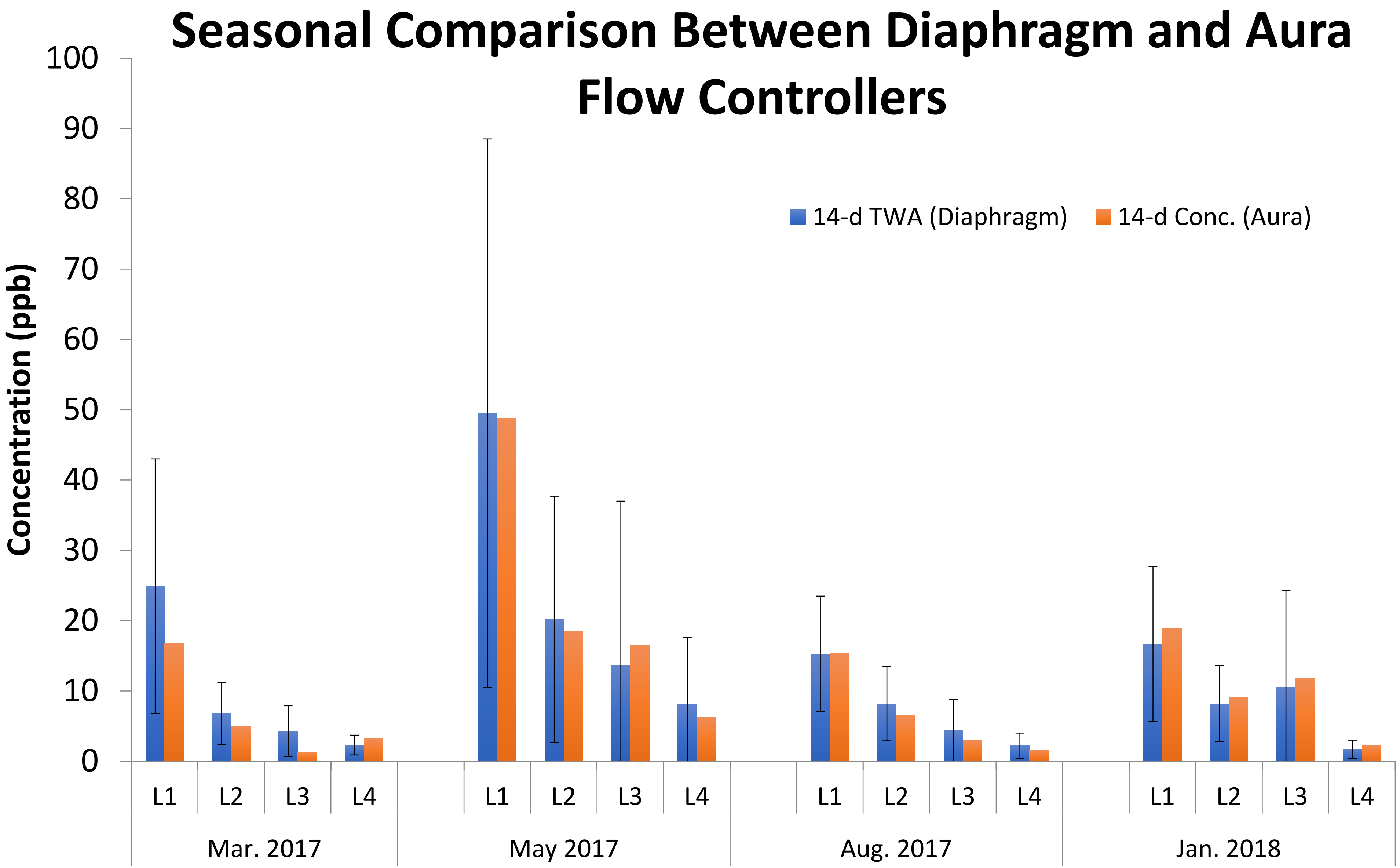
Location 2
Concentration (ppb)
25
20
15
10
5
0
11-Aug
12-Aug
13-Aug
14-Aug
15-Aug
16-Aug
17-Aug
18-Aug
19-Aug
20-Aug
21-Aug
22-Aug
23-Aug
24-Aug
24-hr Concentration (ppb)
TWA Concentration(Diaphragm)
14-d Concentration (Aura)
LCL95%
UCL95%

January 2018

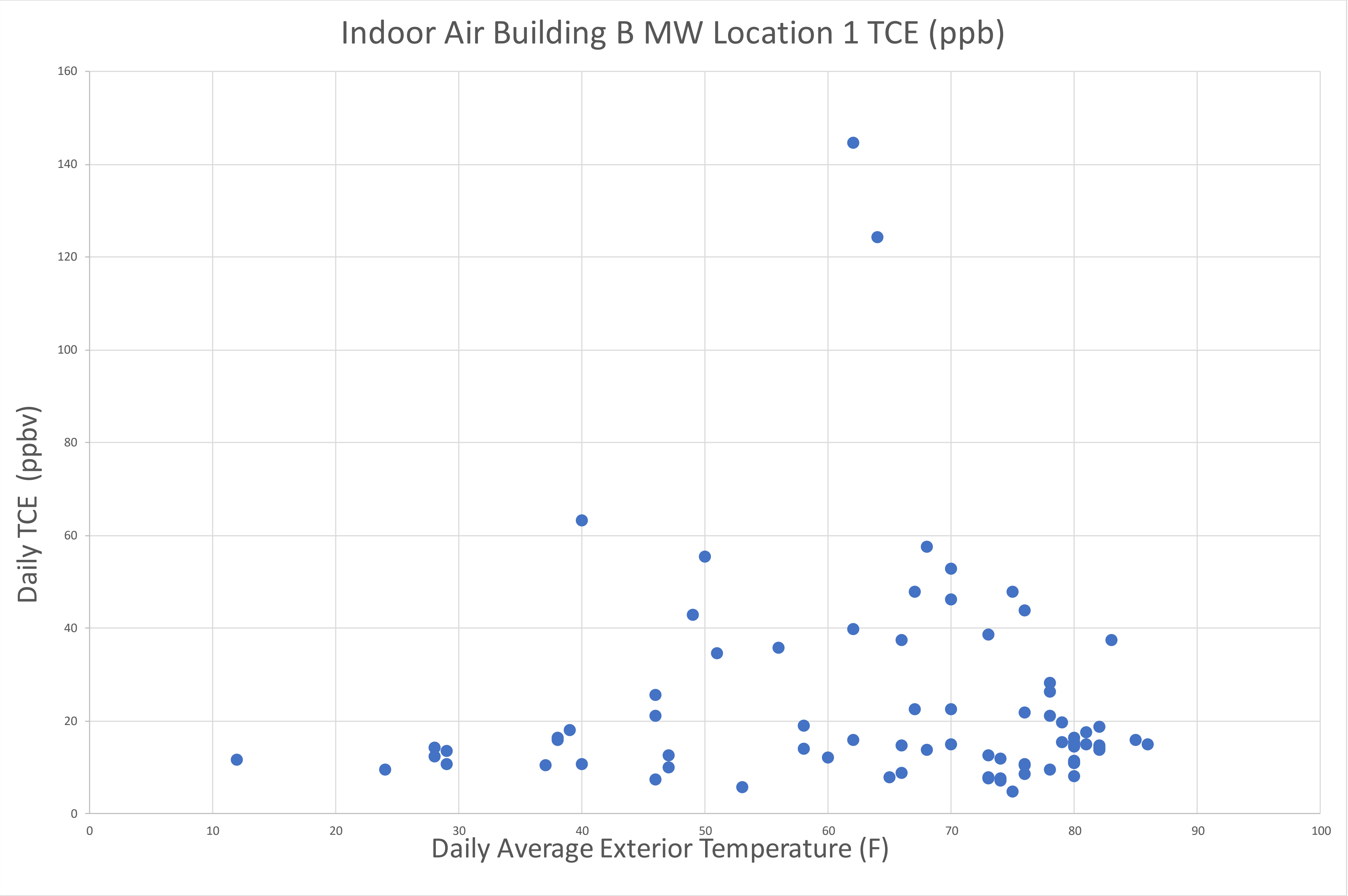


Indoor and sub-slab sample concentrations for all six sampling events

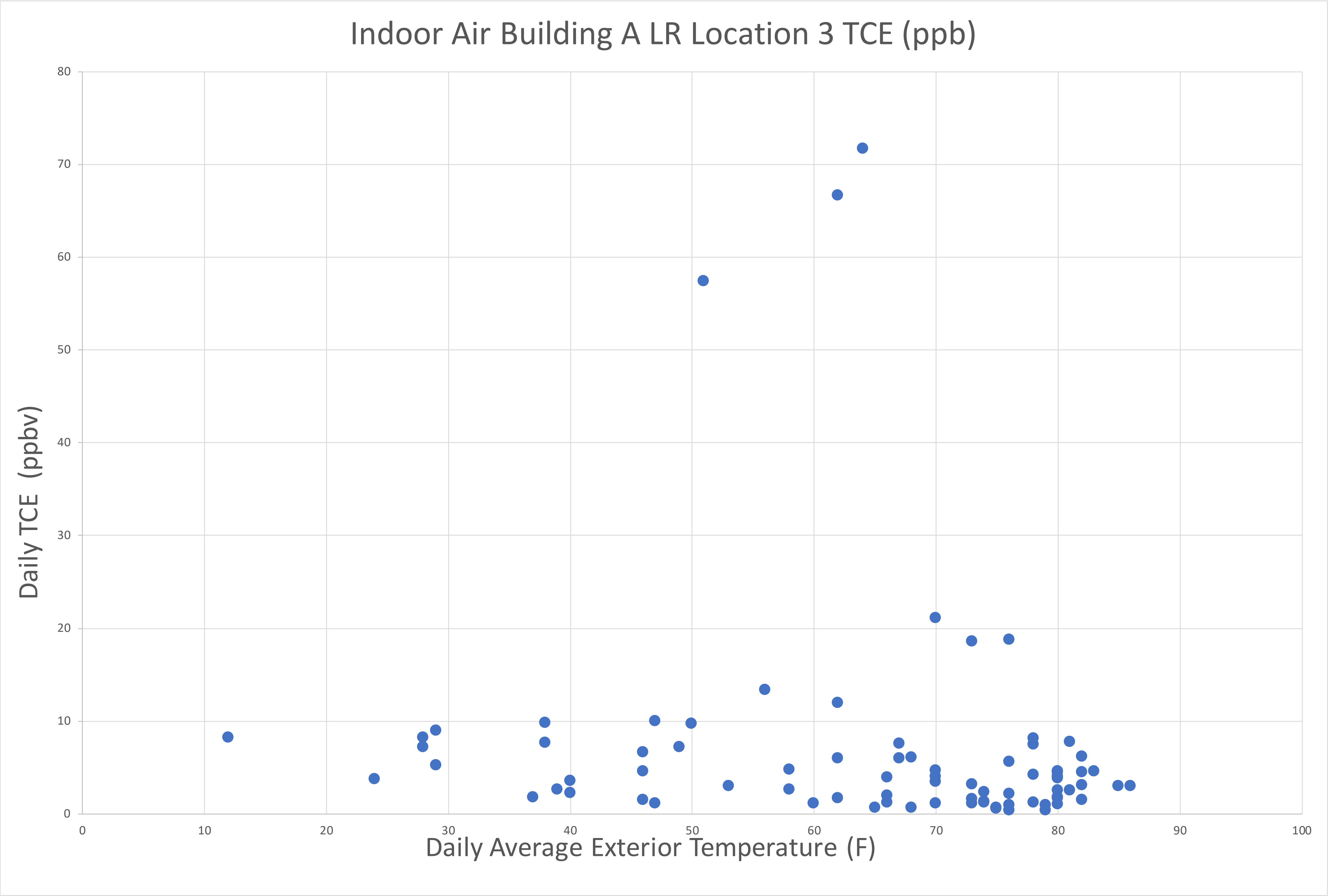



Seasonal Comparison Between Diaphragm and Aura Flow Controllers
14-d TWA (Diaphragm)
14-d Conc. (Aura)
Concentration (ppb)
100
90
80
70
60
50
40
30
20
10
0
L1
L2
L3
L4
Mar. 2017
May 2017
Aug. 2017
Jan. 2018

Temperature vs. Daily Average TCE



Temperature vs. Daily Average TCE



Round Comparisons – Indoor Air Over 14 Days

Means

Row Labels	Building B, MW Location 1 TCE (ppb)	Building B FO Location 2 TCE (ppb)	Building A LR Location 3 TCE (ppb)	Building A BR, Location 4 TCE (ppb)
March 2017	24.9	9.1	4.3	2.3
May 2017	49.5	21.3	13.7	8.2
Aug 2017	15.3	8.2	4.3	2.4
Jan 2018	16.7	6.7	10.5	1.7
May 2018	11.6	4.9	3.1	1.8
August 2018	20.3	9.4	5.4	3.4
Average	**22.8**	**10.0**	**6.8**	**3.3**

Standard Deviations

March 2017	18.9	6.1	3.7	1.5
May 2017	40.7	18.0	24.2	9.7
Aug 2017	8.5	5.5	4.6	2.3
Jan 2018	11.5	5.7	14.4	1.4
May 2018	4.7	3.2	2.1	1.4
August 2018	9.8	3.4	4.3	2.0

Seasonal Comparison at Four Locations; Indoor Air, over 14 Day Sampling Periods

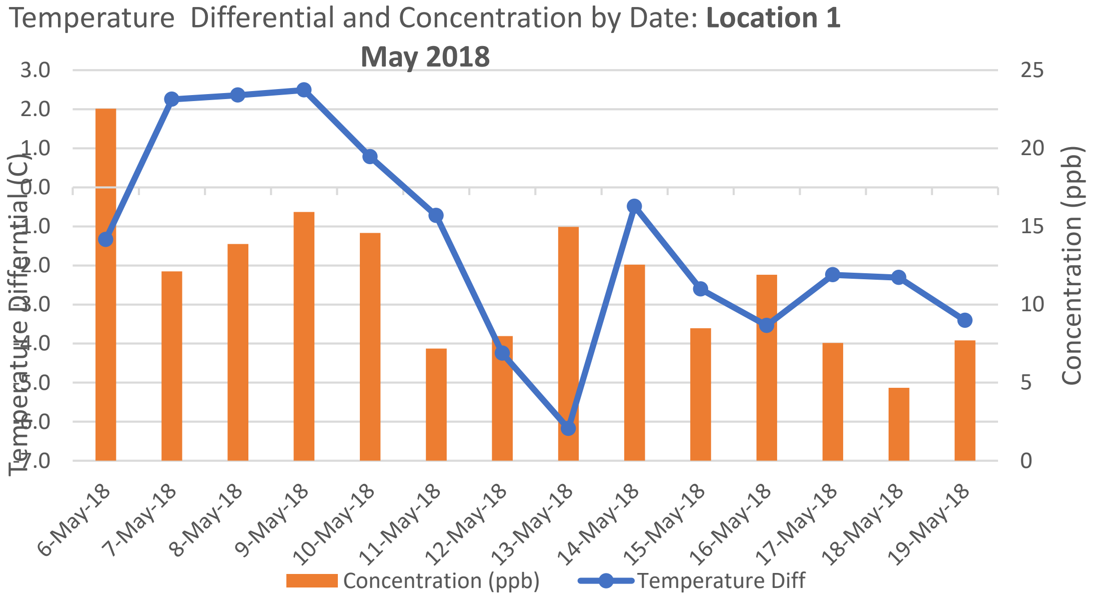
Means

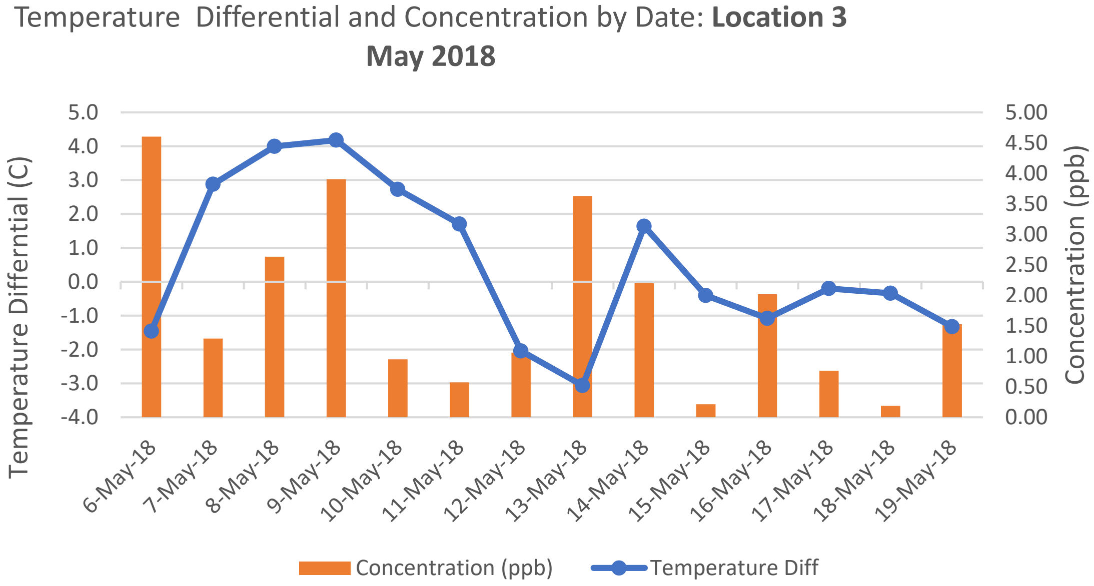
	Bulding B MW Location 1 TCE (ppb)	Building B FO Location 2 TCE (ppb)	Building A LR Location 3 TCE (ppb)	Building A BR Location 4 TCE (ppb)
Spring	28.2	11.8	7.0	4.1
Summer	17.7	8.8	4.8	2.9
Winter	16.7	6.7	10.5	1.7
Overall Mean	**22.8**	**10.0**	**6.8**	**3.3**

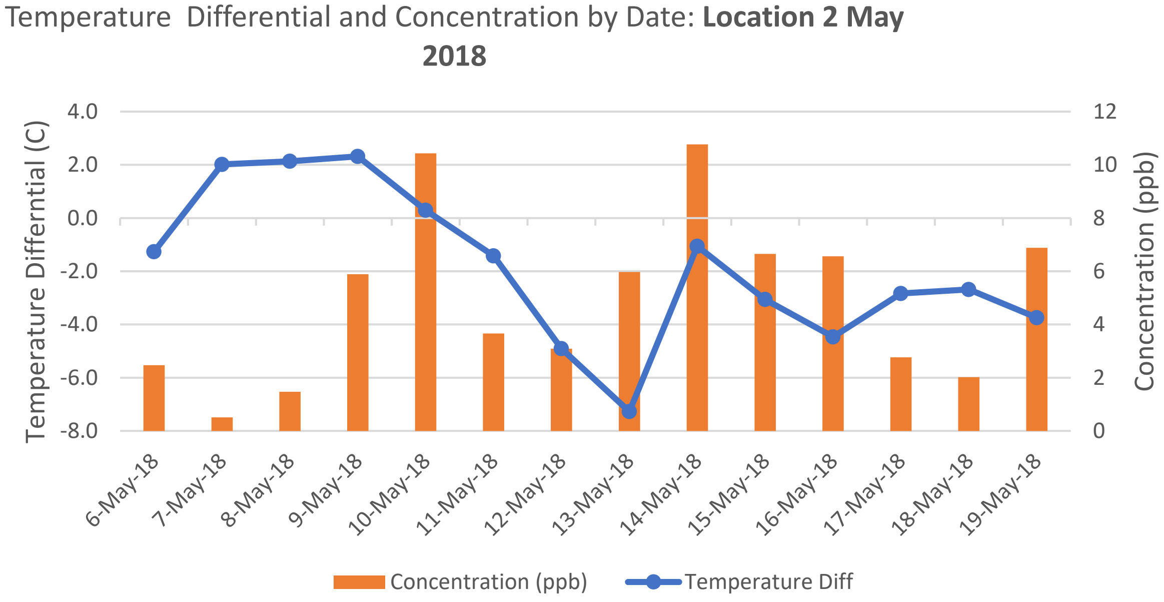
Standard Deviations

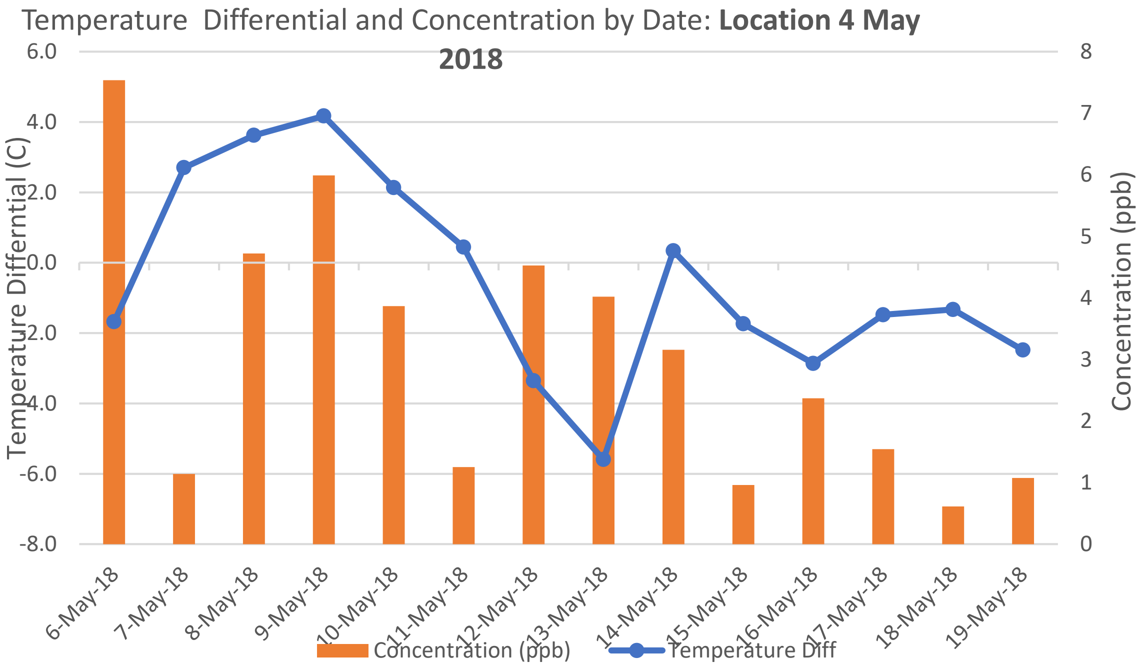
Spring	29.7	13.0	14.7	6.3
Summer	9.3	4.5	4.4	2.2
Winter	11.5	5.7	14.4	1.4

Four Locations, 14 Days, May 2018 TCE Concentration and Temperature Differential (inside-outside)

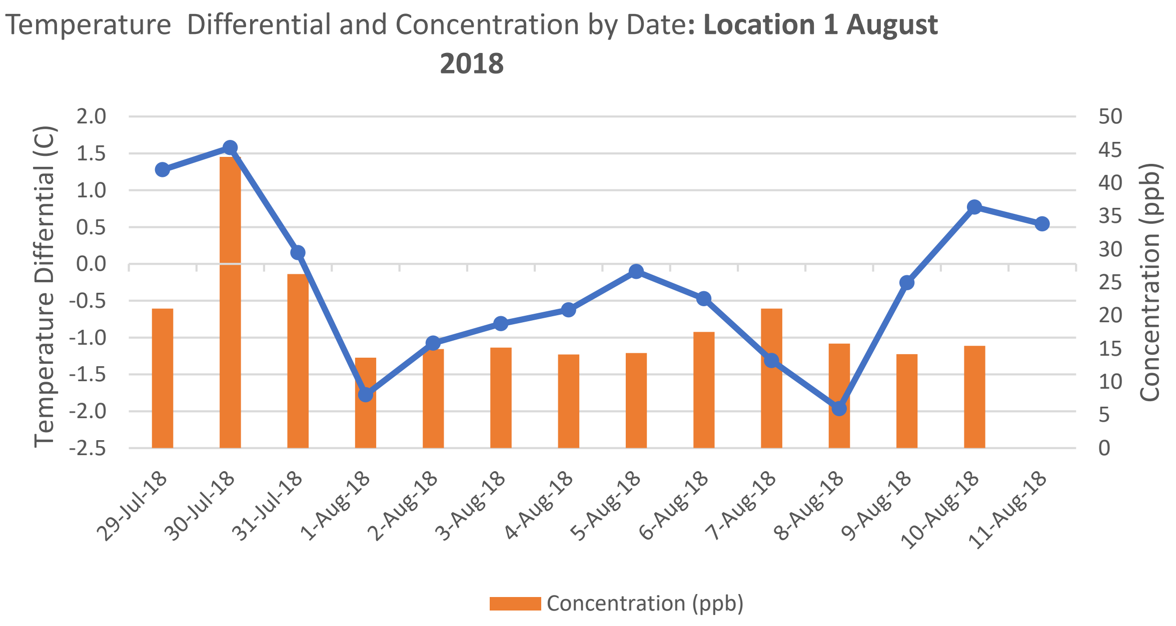


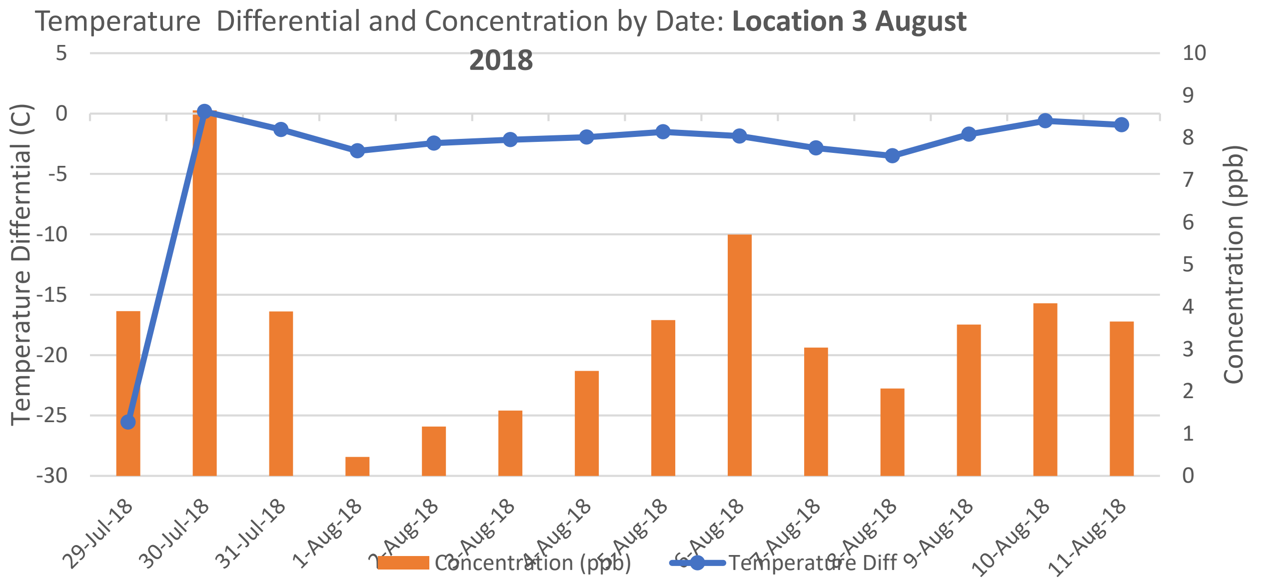


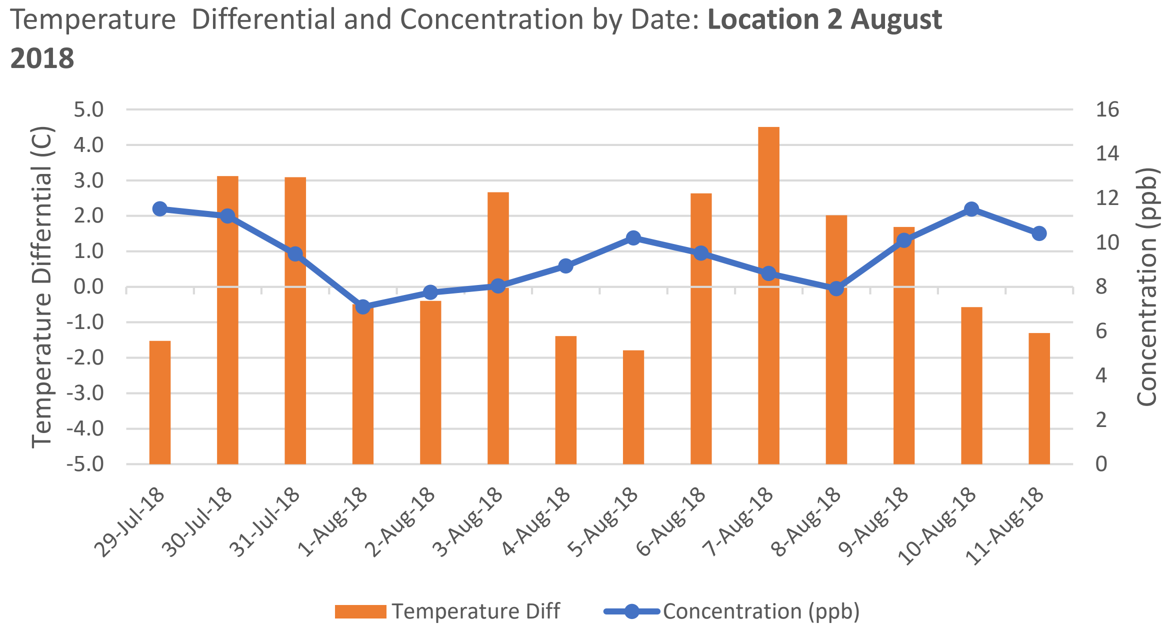


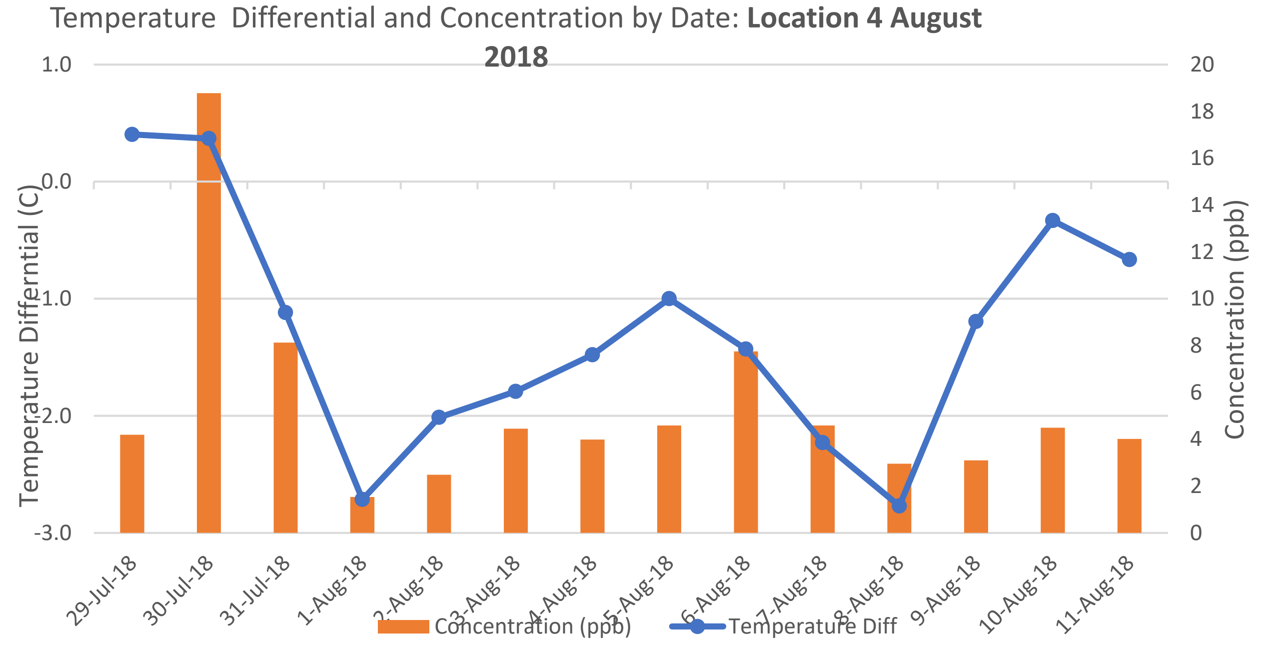


Four Locations, 14 Days, August 2018 TCE Concentration and Temperature Differential (inside-outside)

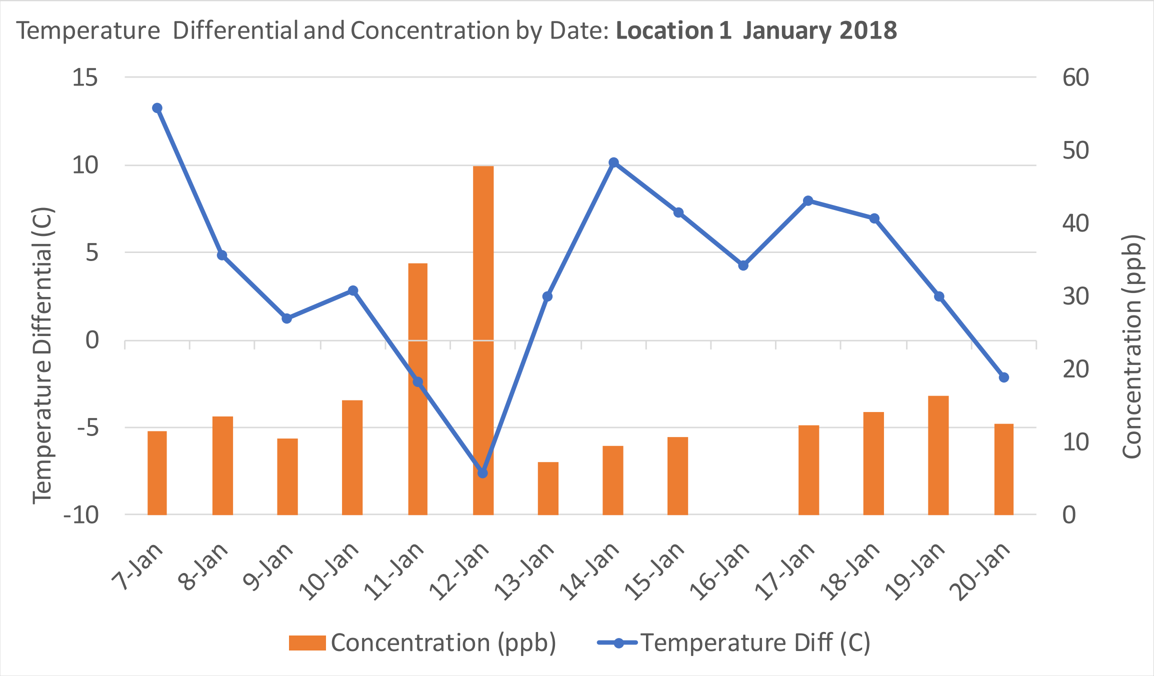


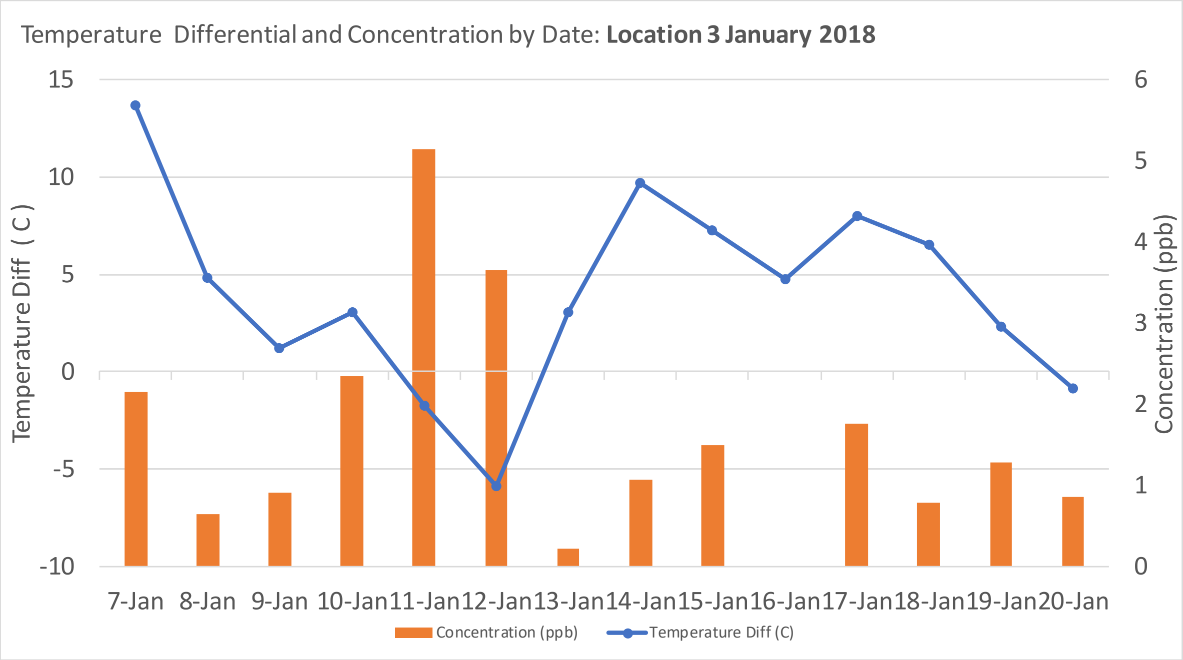


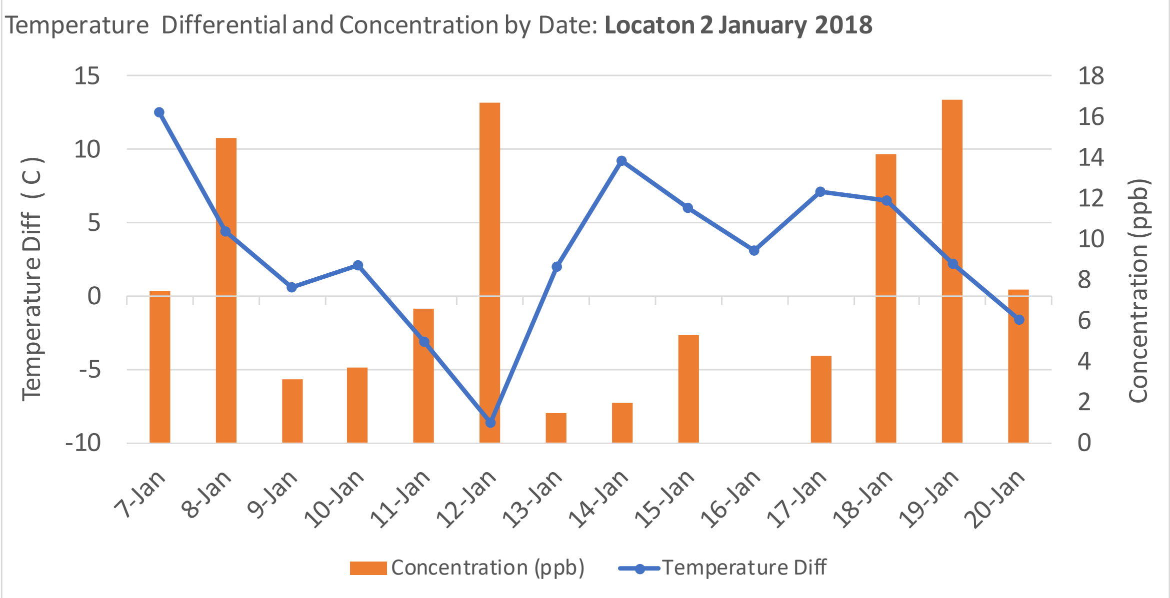


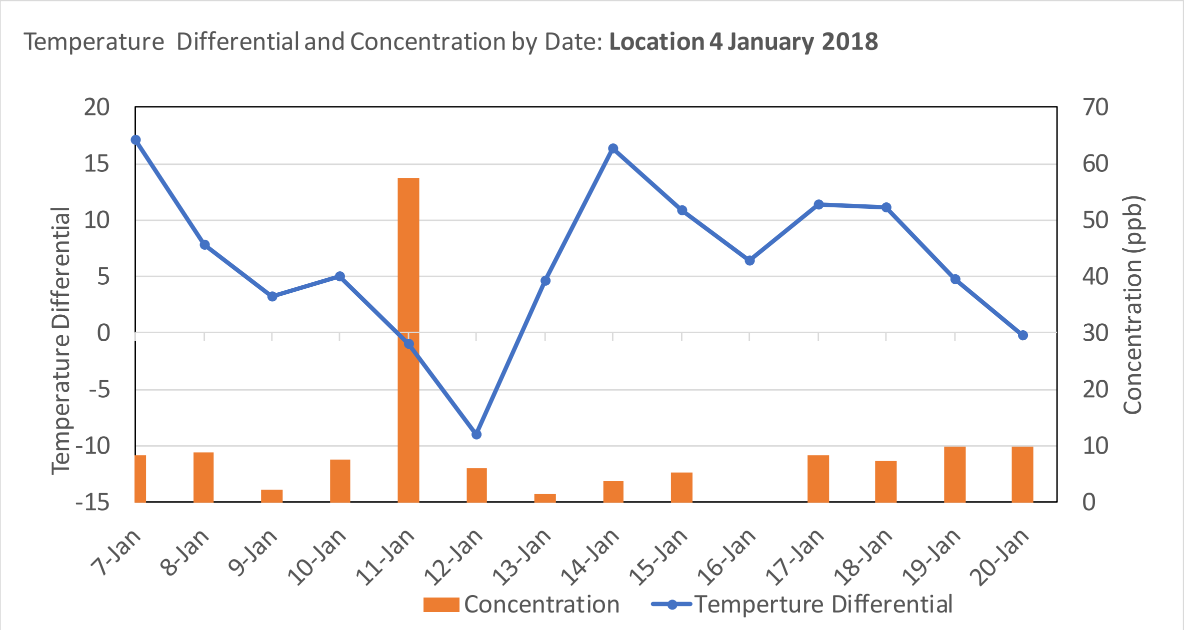


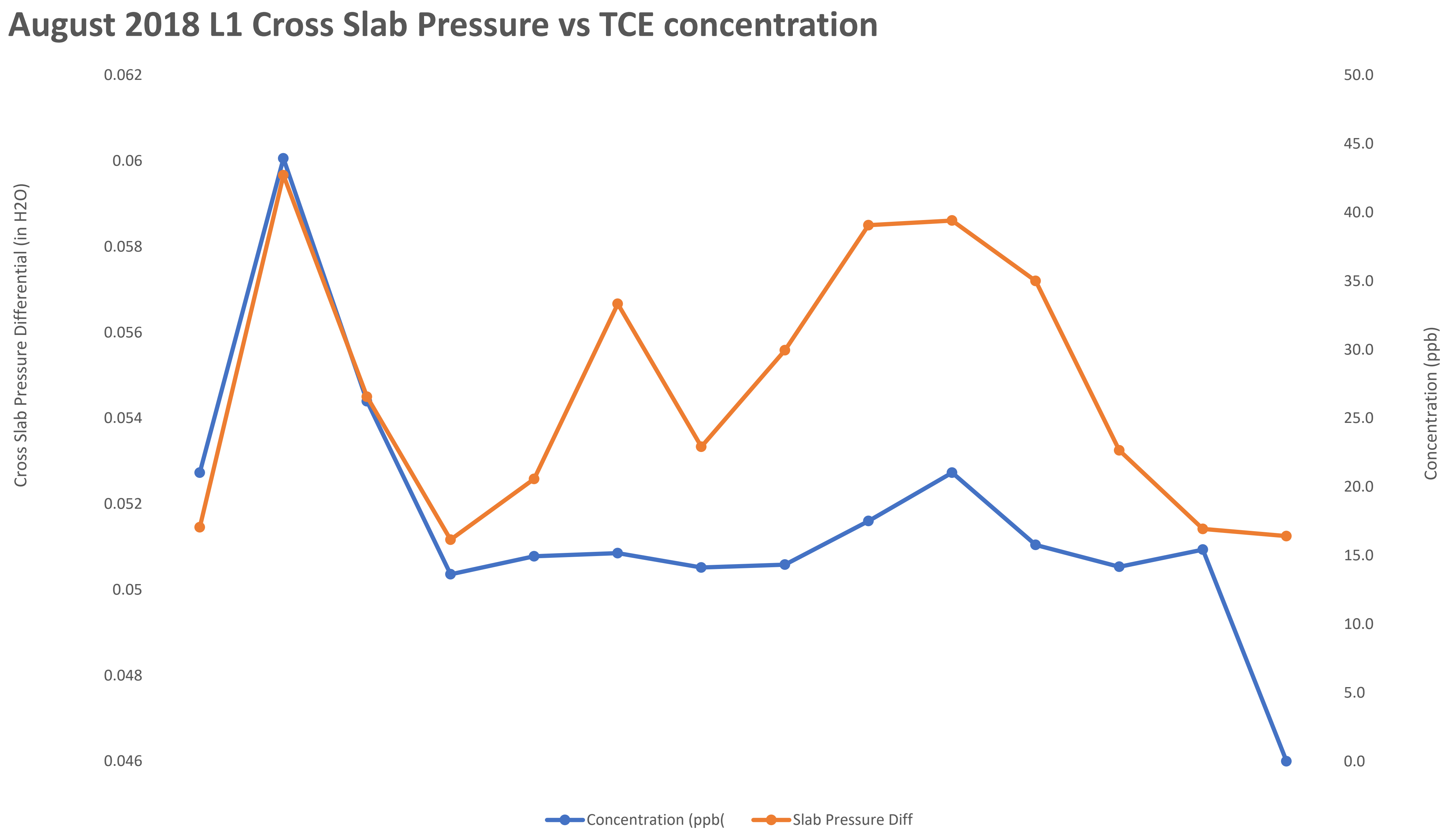
Four Locations, 14 Days, Jan 2018 TCE Concentration and Temperature Differential (inside-outside)









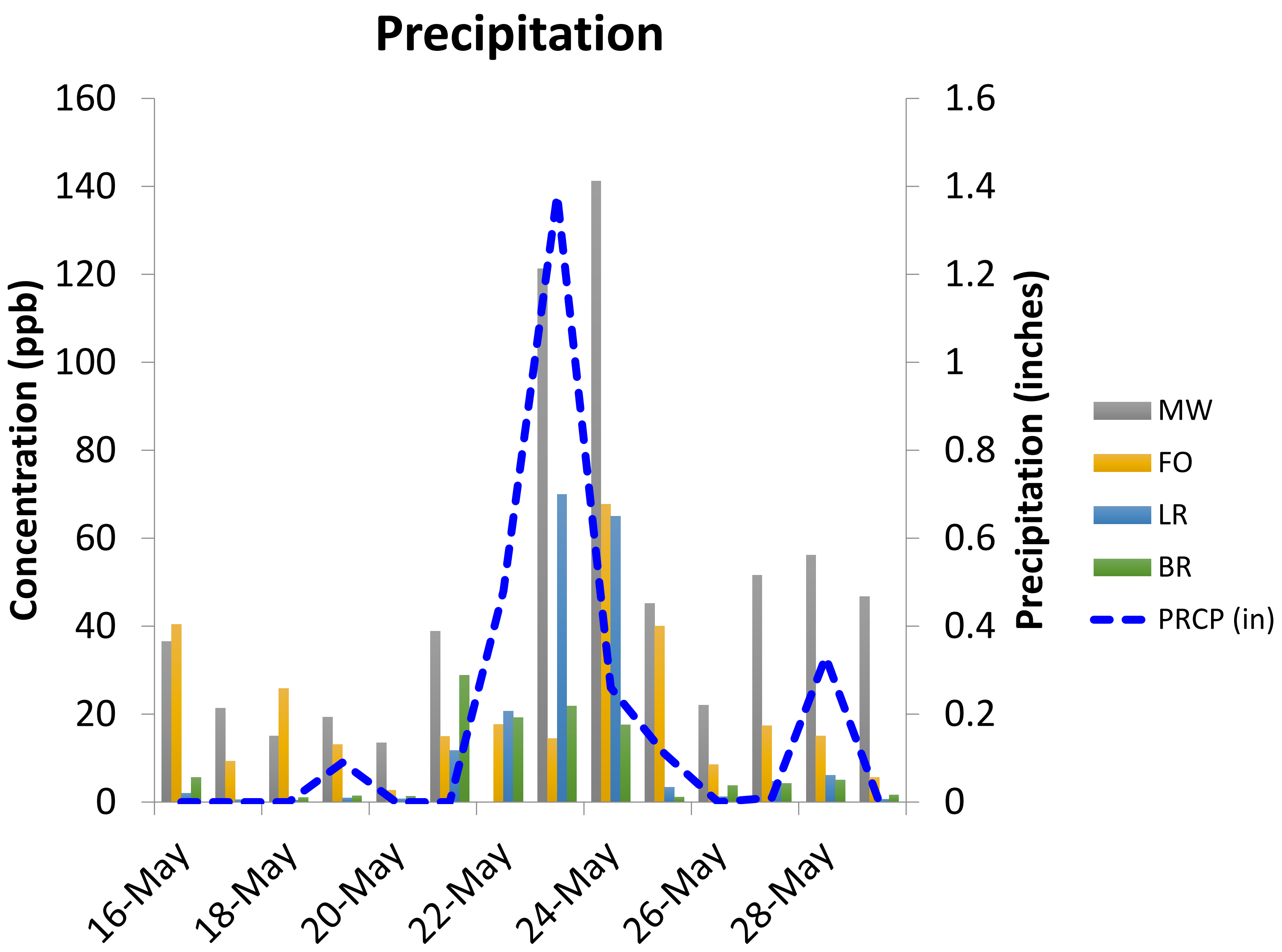


August 2018 L1 Cross Slab Pressure vs TCE concentration
0.062
0.06
0.058
0.056
0.054
0.052
0.05
0.048
0.046
Cross Slab Pressure Differential (in H2O)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Concentration (ppb)
Concentration (ppb(
Slab Pressure Diff

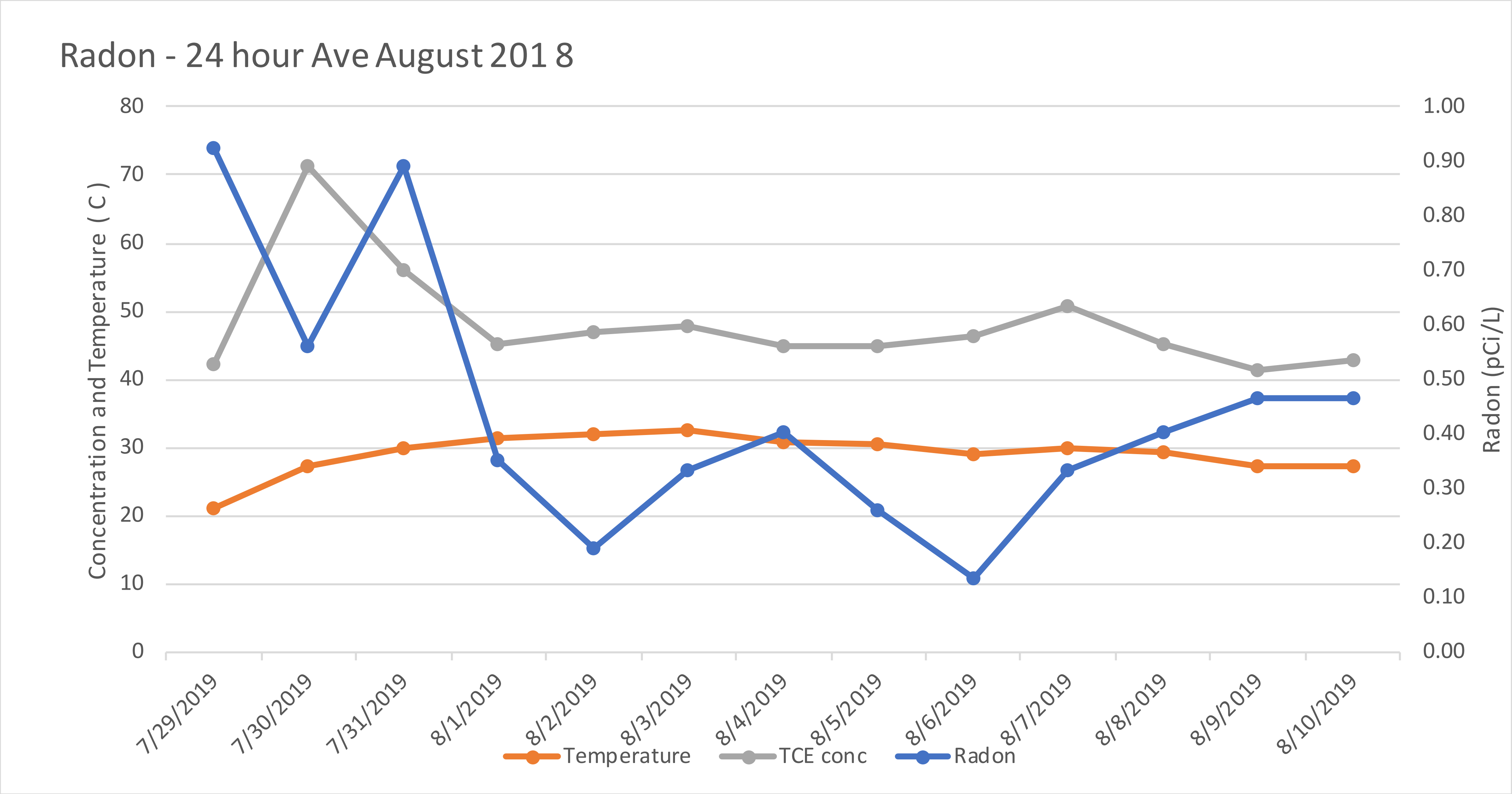
Literature – Support for Rain Effects but Temporal Prediction using Rainfall is Difficult

- **Indianapolis**: no significant relationship between the measured soil moisture or depth to water and indoor VOCs in time series analysis. Little evidence of a relationship between rain events and VOCs.
- **Sun Devil Manor**; Guo (2015 - dissertation), reported that VOC emissions increased during declining water table and decreased when water table rising.
- **Steinmacher** (2009) study at Hill AFB precipitation not significantly associated with percentage detections of TCE.
- **Illangeskare** “Vapor intrusion will likely spike in the near term during a rain event due to gas phase displacement from the initial infiltration front propagation. “A “washout effect” due to the "cleaner water" of the infiltration front diluting the "dirtier water" of the vadose was significant in the laboratory experiment and corroborated by the model, but was not readily observed in the rainfall scenarios…”.
- **Shen (2012):** Modeled effects – [VOC] go ↑ then ↓ after rain event, effects weaker at 1 meter

Precipitation vs. TCE Concentration in Highest Round (May 2017)



Radon Vs. TCE and Temperature, Building B Location L1, August 2018



Conclusions

- Neither the pattern between seasons, or pattern within one 14 day round of sequential samples fits the model of stack effect control (winter worst)
- Thermal mass of the building floor resulted in less fluctuation for the indoor versus outdoors temperatures.
- Apparent rainfall effect on indoor concentration at least in one case