Considerations for Empirically-Derived Default Attenuation Factors for Vapor Intrusion Screening

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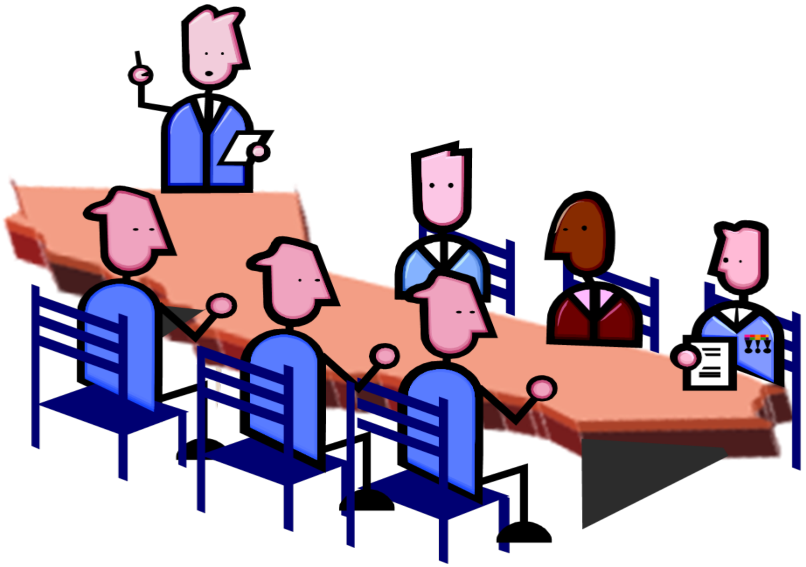
Outline

- Background
  - Database
  - Methods for AF Derivation
- Key Take Aways
  - Data Filtering
  - Data Pairing
- Recommendations & Path Forward

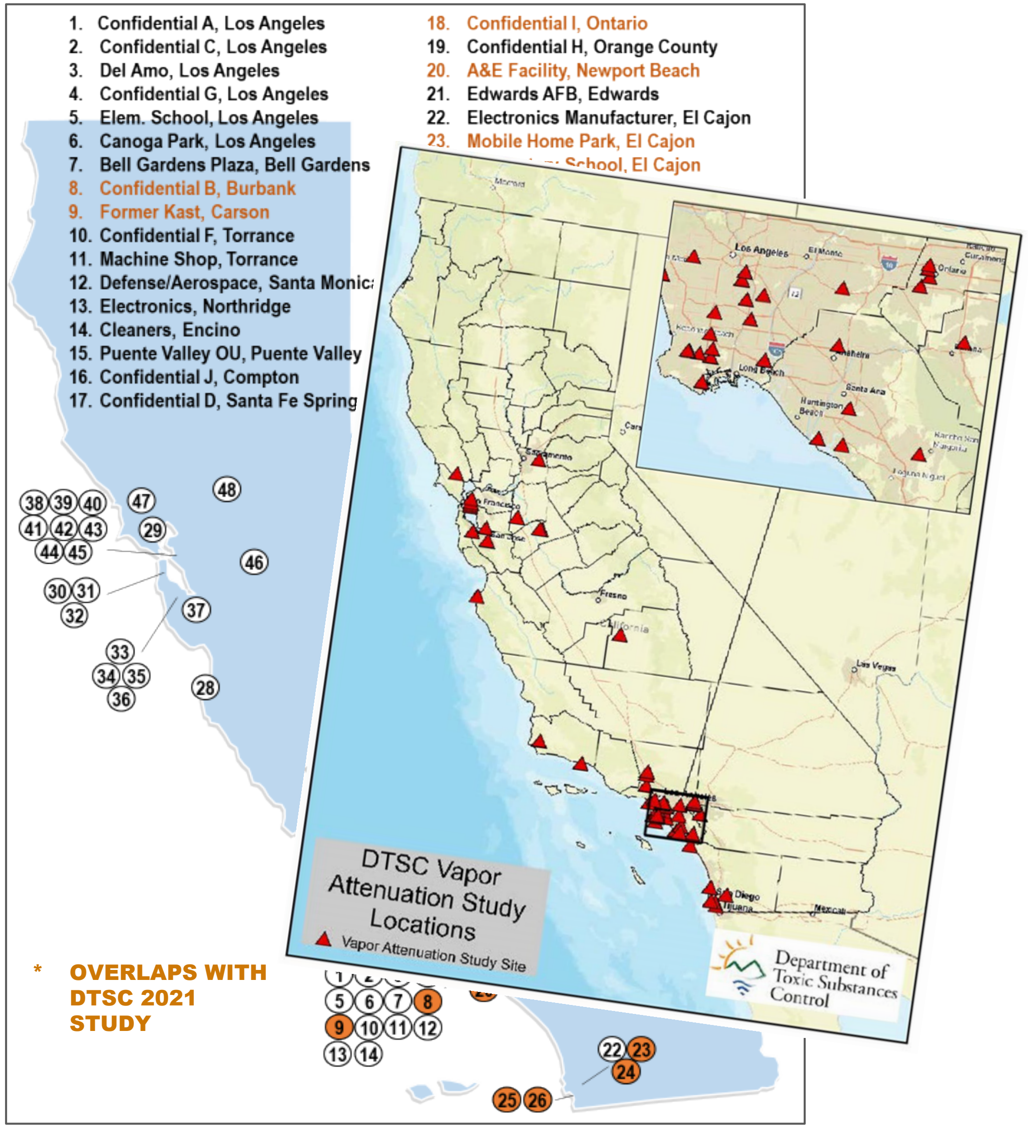


<u>GOAL</u>: share findings and insights from an empirical AF study that could be used in support of technically defensible AFs for VI screening

Background: California Database – General Stats

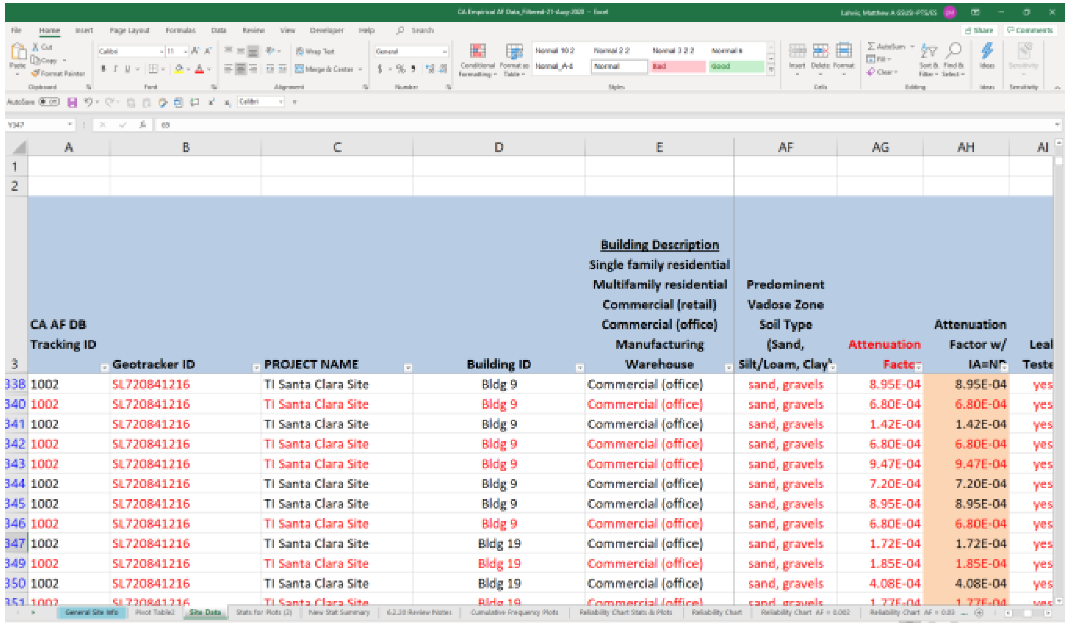
- Geotracker/Envirostor review, consultant project files
- combined (unfiltered) database population:
  14,686 IA/SV data pairs, 836 bldgs, 124 sites
  - L&E: 8,415 IA/SV data pairs, 495 bldgs, 34 sites (L&E, 2021)
  - L&E (add): 3,124 IA/SV data pairs, 120 bldgs, 38 sites
  - DTSC: 4,424 IA/SV data pairs, 206 bldgs, 52 sites
- other info:
  - <u>primarily non-residential sites</u> (79% = 86/109) located in urban metropolitan areas (LA, San Francisco) -- residential (21% = 23/109)
  - 67 sites w/ sub-slab, 83 sites w/ soil gas
  - 35 chemicals (primarily TCE and PCE)
  - 4 sites from US EPA database

Stats vary depending on filtering



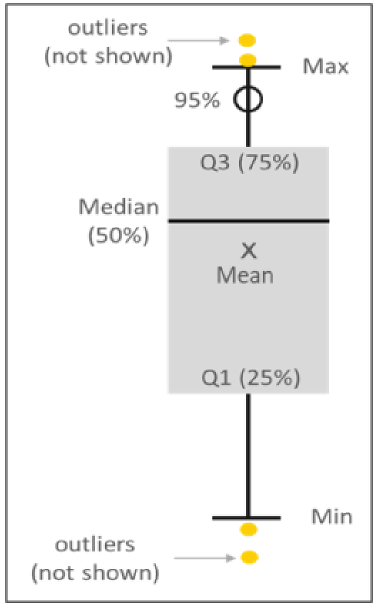
Background: California Database – Key Variables

- land use (e.g., residential, commercial, industrial, school)
- building type/use: (e.g., retail, manufacturing, storage, office, warehouse, school; single-family homes, multi-family buildings)
- foundation type (slab on grade, crawl space)
- building size (square footage)
- vapor concentration (indoor air, outdoor/ambient air, subsurface vapor – subslab or soil gas) and DLs
- subsurface sample type (soil gas, subslab)
- soil-gas sample depth
- predominant vadose zone soil type
- surrounding surface cover (pavement, open ground)
- sampling dates (indoor, outdoor/ambient, and subsurface vapor) and indoor air sample duration (8, 12, or 24 hour)
- subsurface sample distance relative to indoor air and building perimeter
- HVAC operation during sampling (on, off, not reported)
- QA/QC measures (leakage, vacuum loss, tracer identification, preferential pathway, background source, etc.)



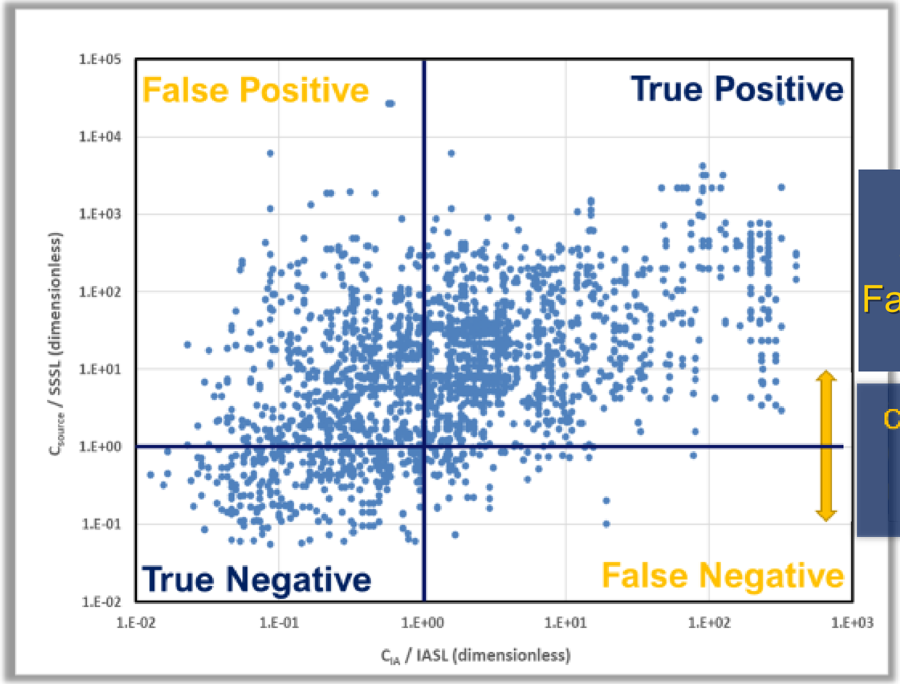
	CA AF DB Tracking ID	Geotracker ID	PROJECT NAME	Building ID	Building Description Single family residential Multifamily residential Commercial (retail) Commercial (office) Manufacturing Warehouse	Predominent Vadose Zone Soil Type (Sand, Silt/Loam, Clay	Attenuation Facto	Attenuation Factor w/ IA=NI	Leal Teste
338	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	8.95E-04	8.95E-04	yes
340	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	6.80E-04	6.80E-04	yes
341	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	1.42E-04	1.42E-04	yes
342	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	6.80E-04	6.80E-04	yes
343	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	9.47E-04	9.47E-04	yes
344	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	7.20E-04	7.20E-04	yes
345	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	8.95E-04	8.95E-04	yes
346	1002	SL720841216	TI Santa Clara Site	Bldg 9	Commercial (office)	sand, gravels	6.80E-04	6.80E-04	yes
347	1002	SL720841216	TI Santa Clara Site	Bldg 19	Commercial (office)	sand, gravels	1.72E-04	1.72E-04	yes
349	1002	SL720841216	TI Santa Clara Site	Bldg 19	Commercial (office)	sand, gravels	1.85E-04	1.85E-04	yes
350	1002	SL720841216	TI Santa Clara Site	Bldg 19	Commercial (office)	sand, gravels	4.08E-04	4.08E-04	yes
351	1002	SL720841216	TI Santa Clara Site	Bldg 19	Commercial (office)	sand, gravels	1.77E-04	1.77E-04	yes

Background: 3 Methods for AF Derivation (USEPA 2012)



METHOD 1:

Descriptive Statistics (USEPA approach)



AF defined by acceptable % of False Negatives and False Positives

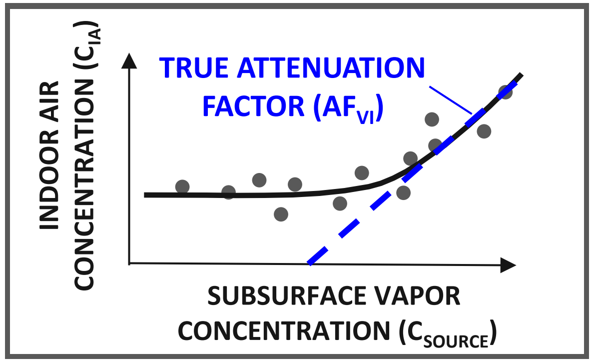
changing AF shifts data up/down

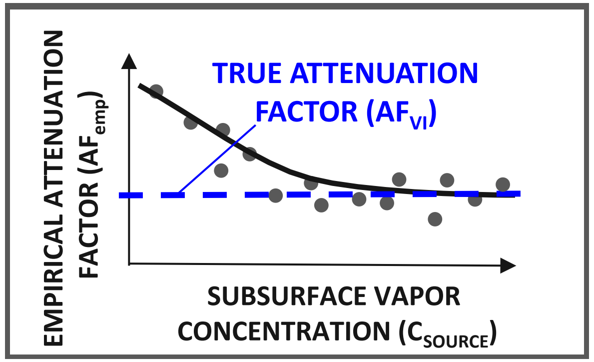
METHOD 2:

Reliability Analysis - USEPA (2015), Appendix A3.6)

$$AF_{emp} = \frac{C_{IA}}{C_{SOURCE}} = AF_{VI} + \frac{C_{BGRD}}{C_{SOURCE}}$$

AF_{emp} = measured AF
AF_{VI} = actual AF





METHOD 3

Theoretical Relations (presented in USEPA 2012)

US EPA, 2012. EPA's Vapor Intrusion Database: Evaluation and characterization of attenuation factors for chlorinated volatile organic compounds and residential buildings. US Environmental Protection Agency Office of Solid Waste and Emergency Response, EPA 530-R-10-002, March 16, 2012. Washington, D.C. (https://www.epa.gov/sites/production/files/2015-09/documents/oswer_2010_database_report_03-16-2012_final_witherratum_508.pdf)

US EPA, 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. US Environmental Protection Agency Office of Solid Waste and Emergency Response, OSWER Publication 9200.2-154, June 2015. Washington, D.C. https://www.epa.gov/sites/production/files/2015-09/documents/oswer-vapor-intrusion-technical-guide-final.pdf

Background: 3 Methods for AF Derivation - Differences

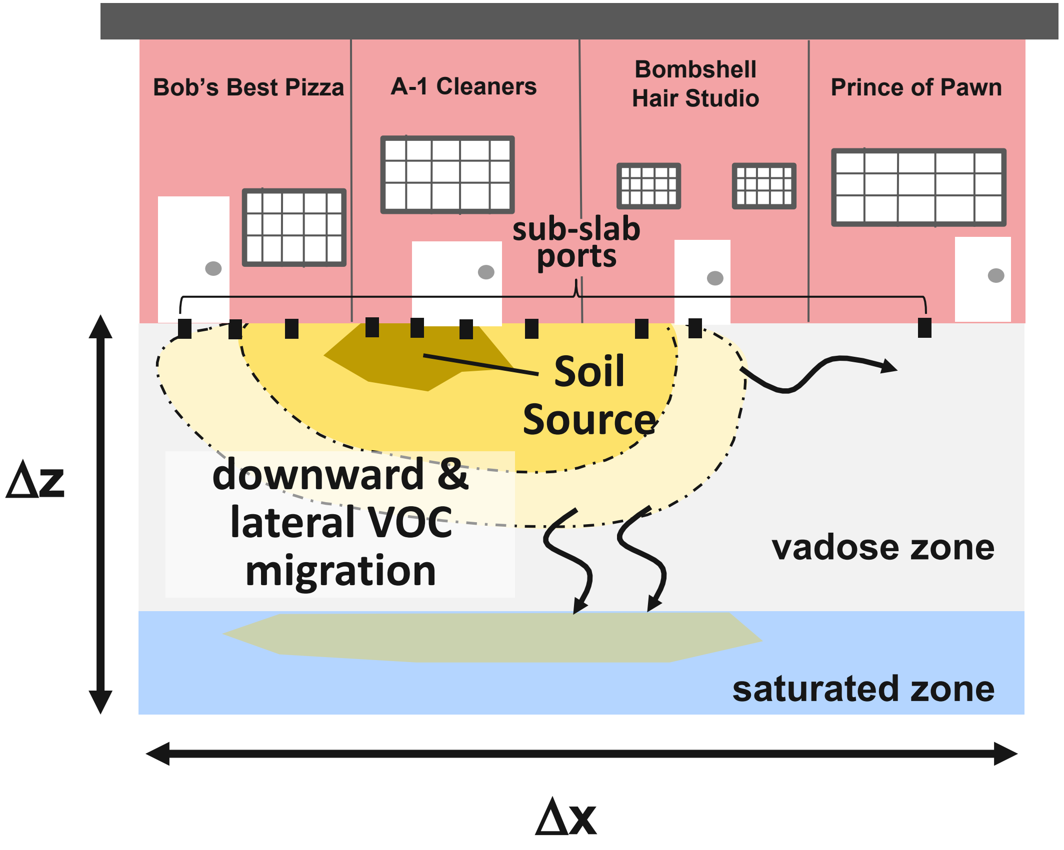
Method	Pros	Cons
Method 1: Descriptive Statistics (e.g. 95th %ile)	Approach ultimately used by USEPA (least likely to draw attention) AF sensitivity to specific variables is more easily visualized and assessed	95^{th} %ile AFs can be strongly affected by small #s of data points (e.g., outliers), especially for small population (n < 30) data sets AF can be sensitive to data filtering (e.g., particularly, C_{SOURCE} - requires agency decision/consensus)
Method 2: Reliability Analysis	More risk-based approach (better identifies false negatives and false positives) AF dependence on C_{SOURCE} and C_{BGKD} is reduced	Draws attention to an "acceptable" % of false negatives – requires agency decision/consensus Requires a relatively large population of data (i.e., cannot be used to assess AF sensitivity to certain variables)
Method 3: Theoretical Relations	Could be used to eliminate data where the AF is dependent on C_{SOURCE}	AF is less definitive because asymptotes where AF is no longer correlated with C_{SOURCE} (or C_{IA} is correlated with C_{SOURCE}) can be difficult to identify

KEY POINT

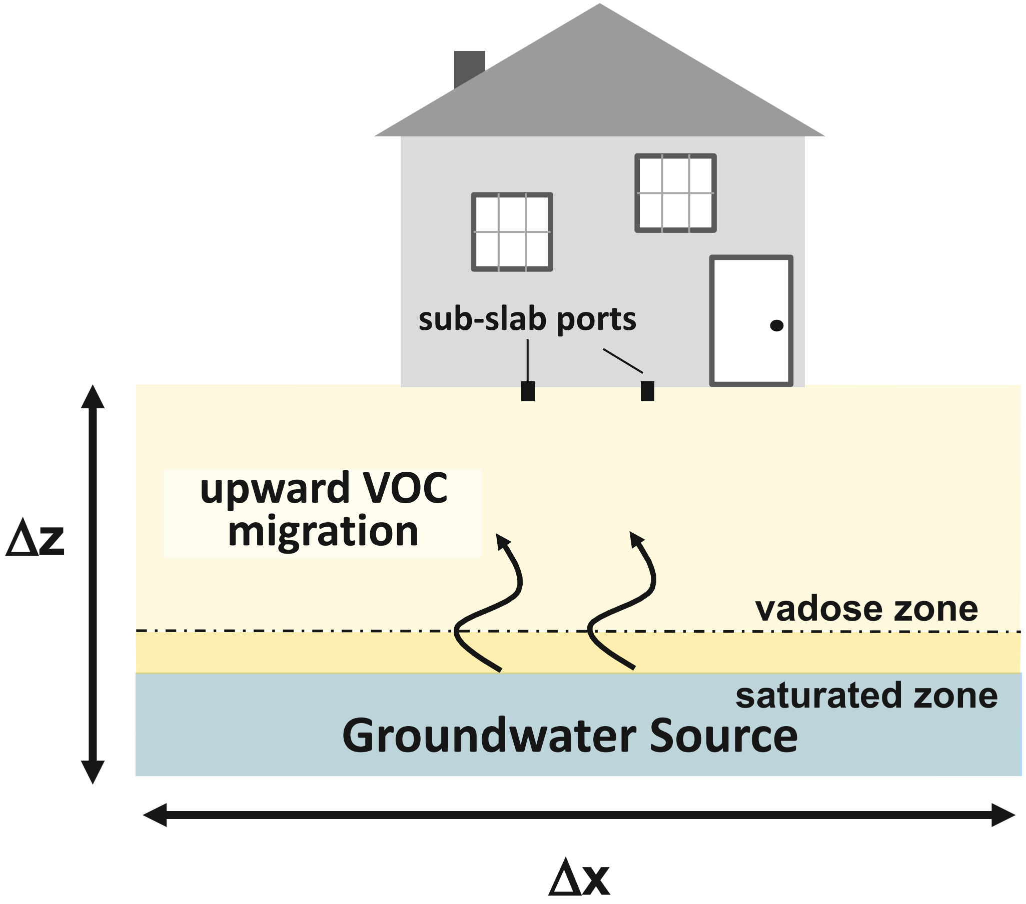
- **Applying all 3 methods for AF derivation could serve as "multiple lines of evidence"**

AF Derivation Must Account for Site Types (Non-Residential vs. Residential)

NON-RESIDENTIAL
(point source - shallow-soil)

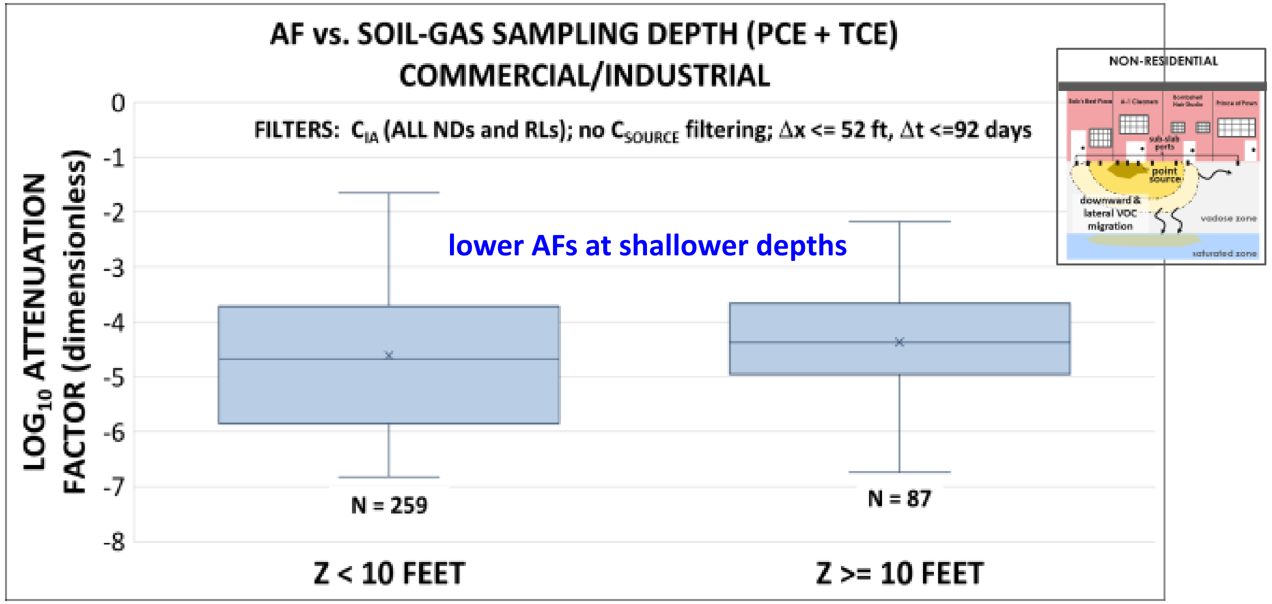


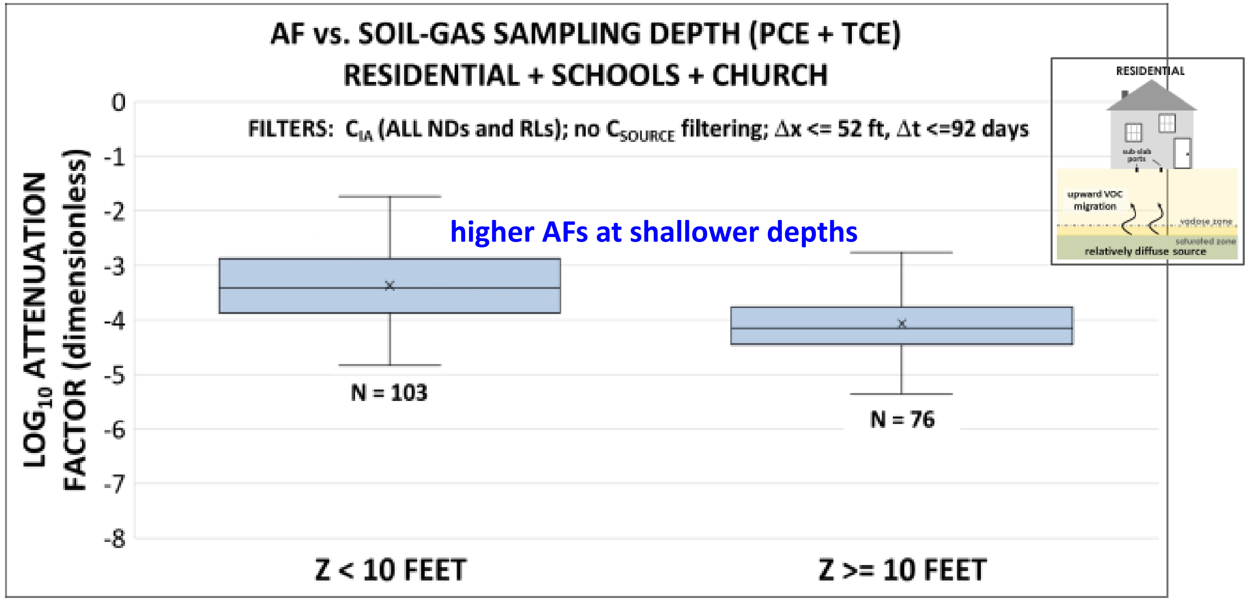
RESIDENTIAL
(diffuse source – groundwater)



GENERALIZATION ONLY - SOURCE TYPES AND SITE TYPES OVERLAP

Background – AFs Differ With Depth as a Function of Site Type (Filtered PCE and TCE Data)





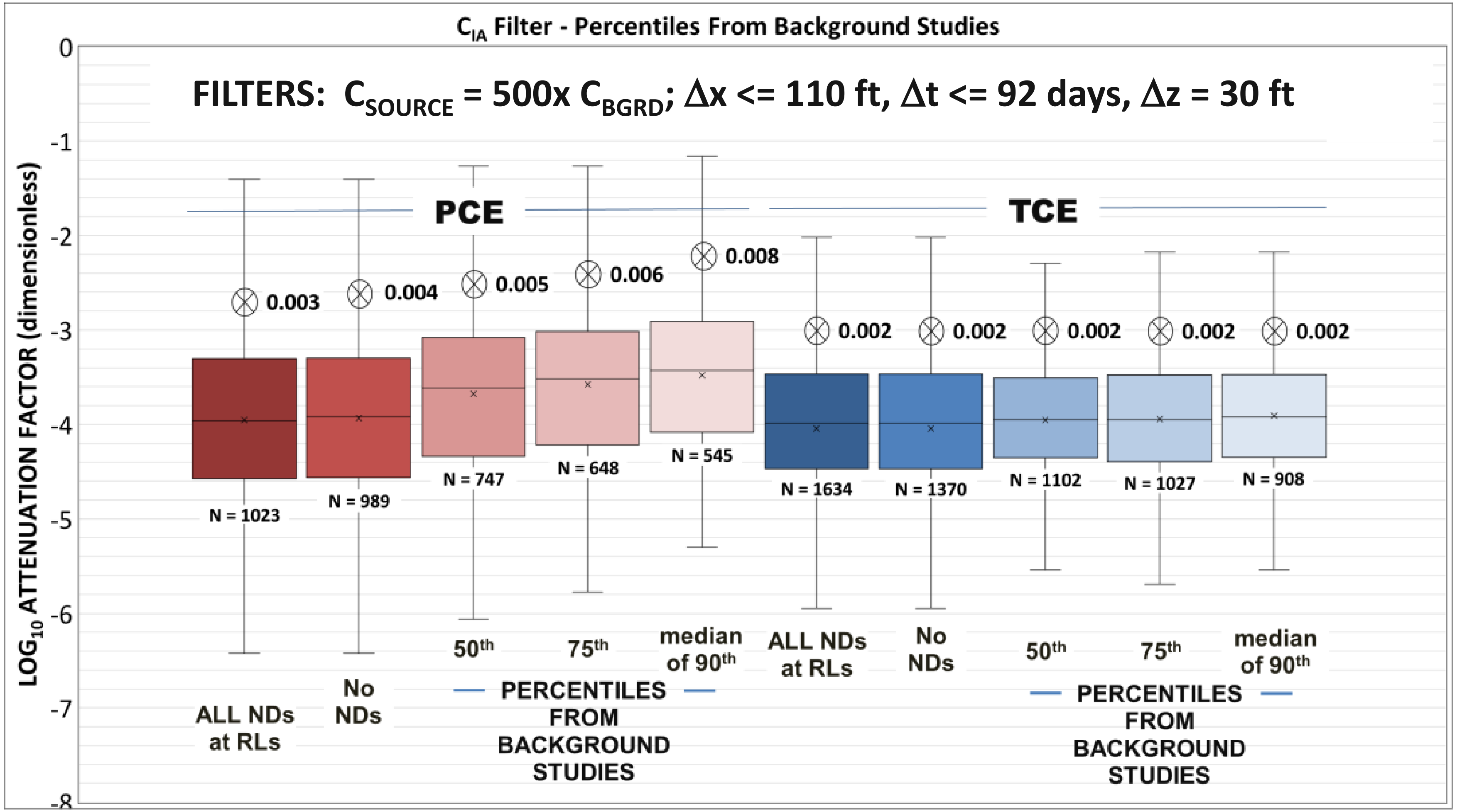
Z = DEPTH BELOW LAND SURFACE
N = NUMBER OF INDOOR AIR – SUBSURFACE VAPOR DATA PAIRS
C_{IA} = CONCENTRATION IN INDOOR AIR
C_{SOURCE} = CONCENTRATION IN SUBSURFACE VAPOR

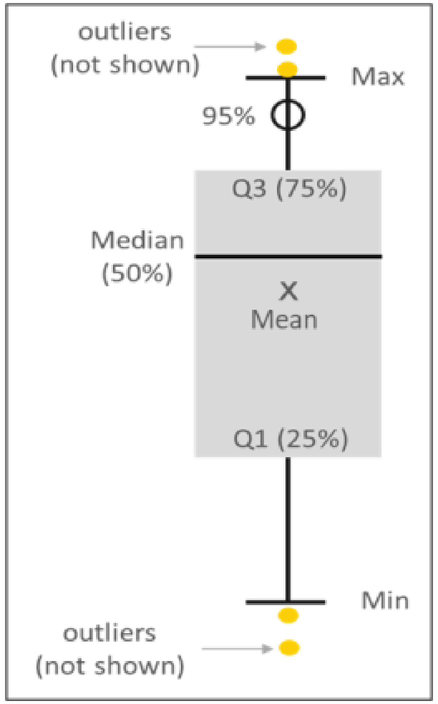
Δx = LATERAL OFFSET DISTANCE BETWEEN INDOOR AIR AND SUBSURFACE VAPOR SAMPLING LOCATIONS
Δt = TIME LAG BETWEEN INDOOR AIR AND SUBSURFACE VAPOR SAMPLING

- lower AFs at shallower depths (higher C_{SOURCE}) at non-residential sites… vice versa at residential sites
- greater variability in AFs (non-residential sites) related to greater variability in C_{SOURCE} (lateral and vertical) and C_{IA} (air-exchange/HVAC operation, building size)

GENERALIZATION ONLY - SOURCE TYPES AND SITE TYPES OVERLAP

C_{IA} Filtering Is Chemical Dependent



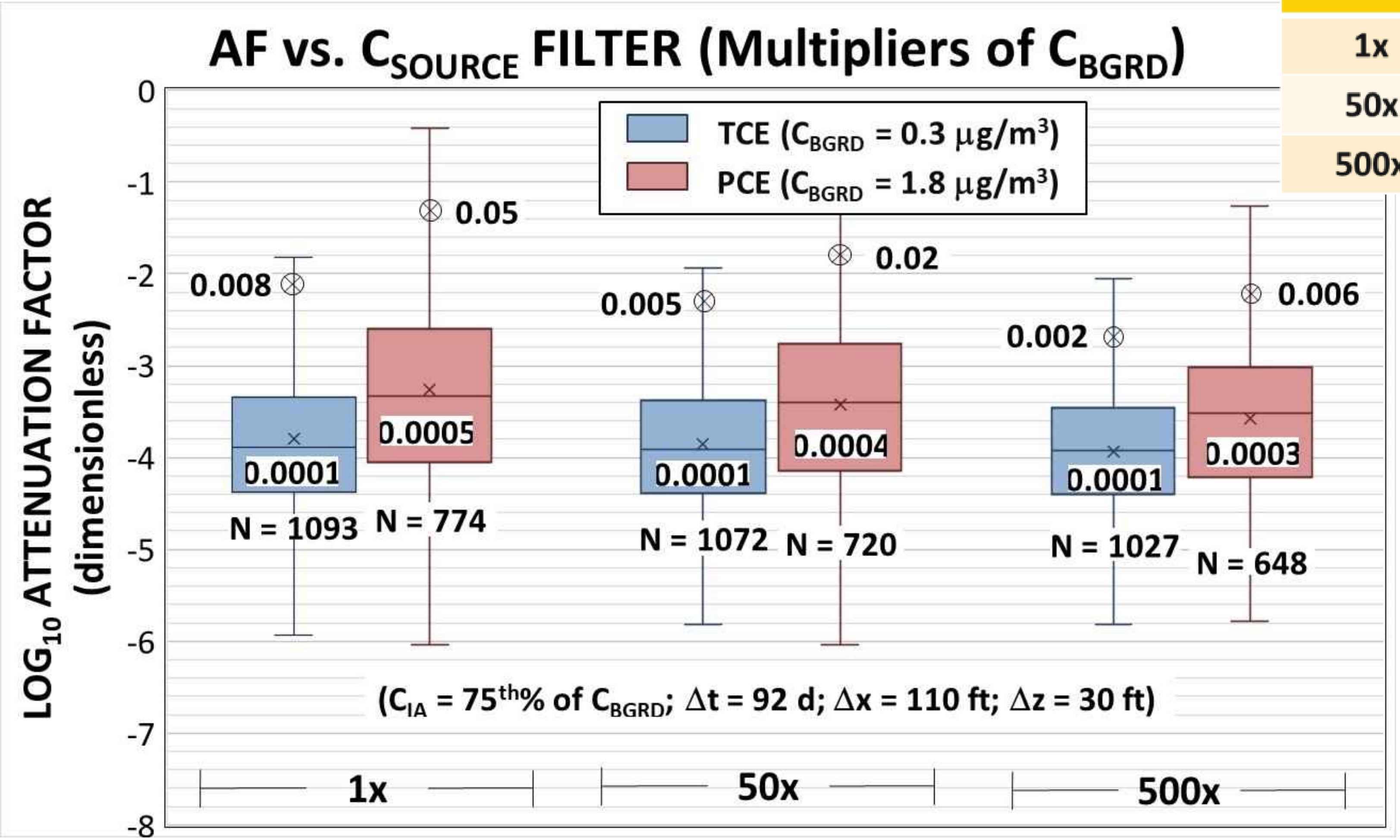


KEY POINT

- High percentages (e.g., > 50%) of data are removed by C_{IA} filtering
- AF distributions for PCE are more affected by C_{IA} filtering (and more variable) than TCE

95th %ile AFs Are Highly Sensitive to C_{SOURCE} Filtering (PCE, Especially)

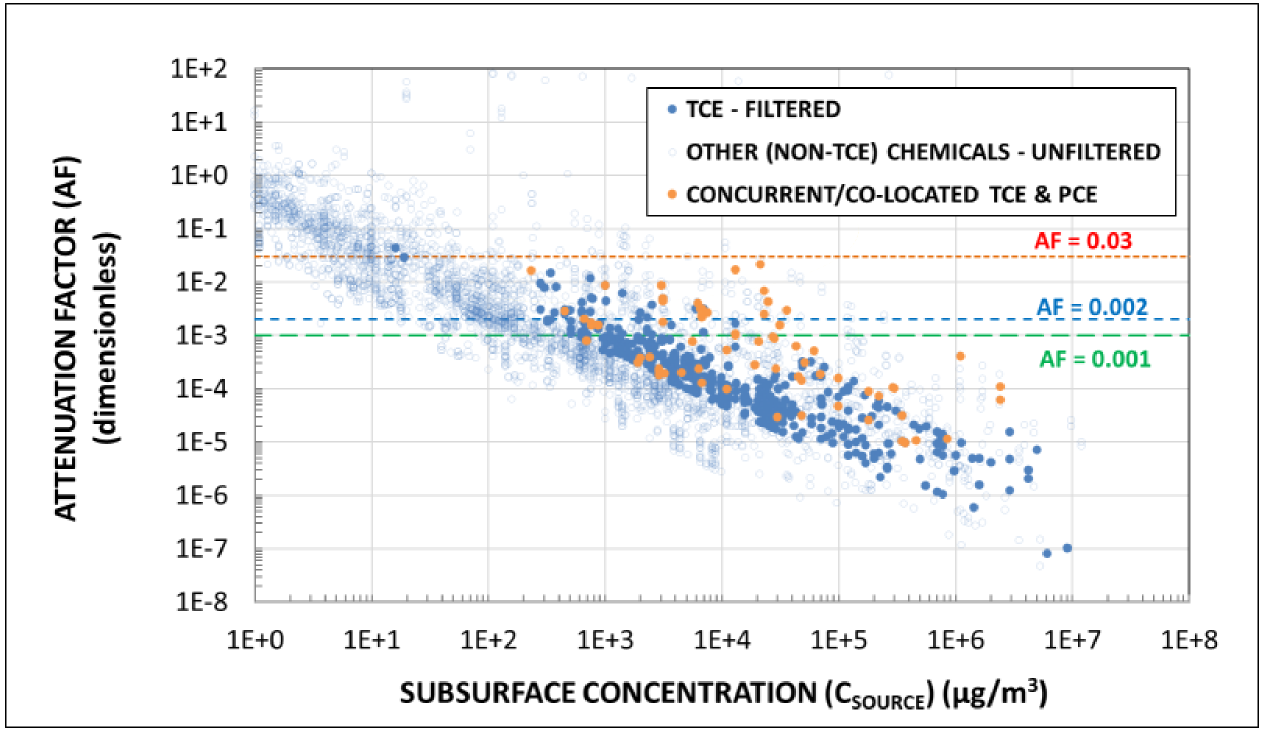
Multiplier	PCE C_{SOURCE} FILTER ($\mu g/m^3$)	TCE C_{SOURCE} FILTER ($\mu g/m^3$)
1x	1.8	0.3
50x	90	15
500x	900	150

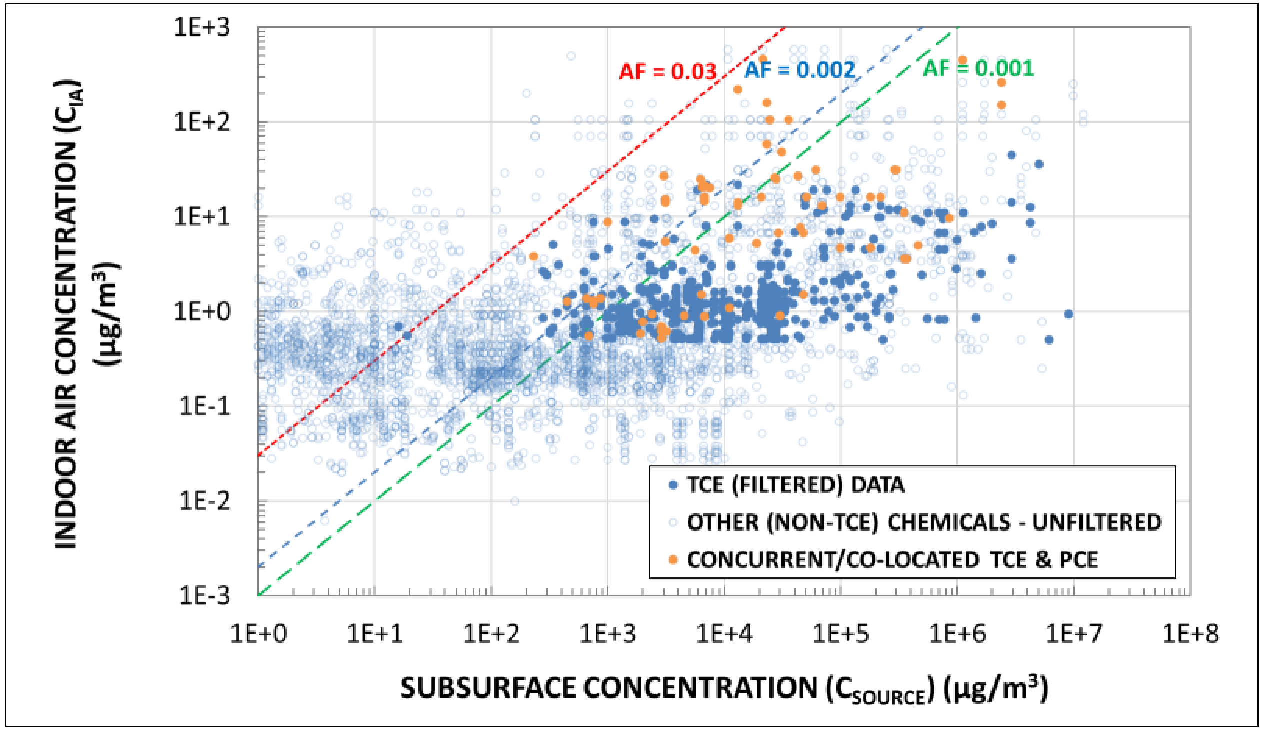


KEY POINT

- C_{SOURCE} filtering has greater affect on median and 95th %iles of PCE than TCE
- median AFs for TCE are relatively unaffected by C_{SOURCE} filtering

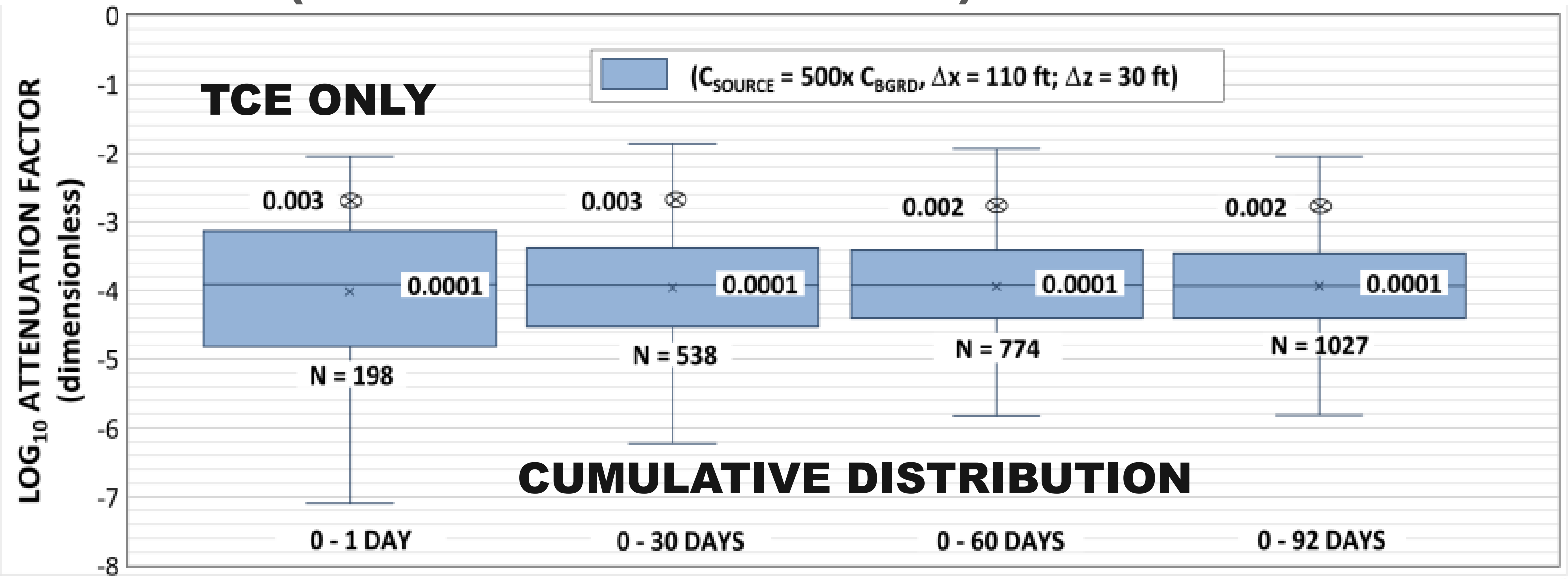
Sensitivity to Source Vapor Concentration (C_{SOURCE})

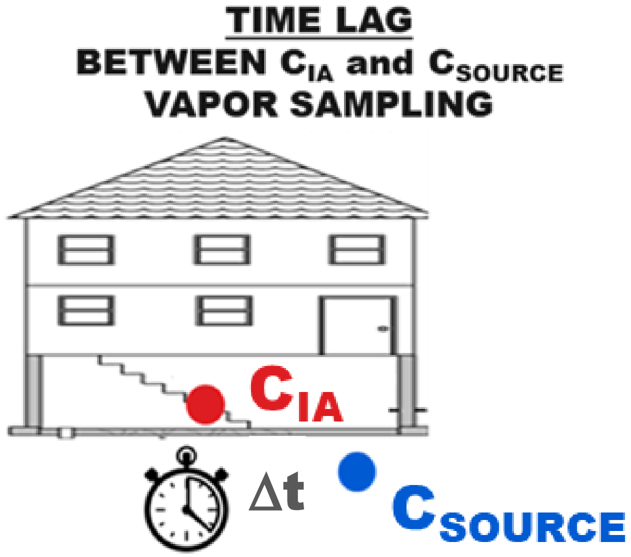


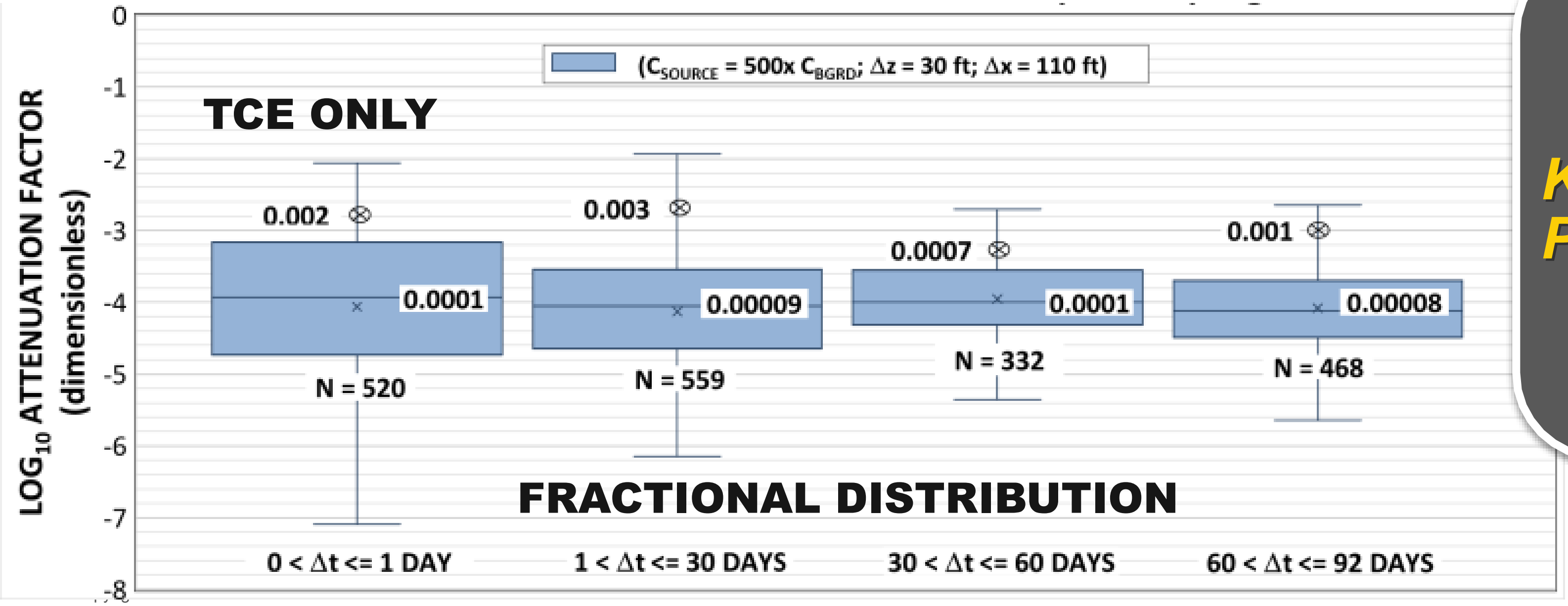


- AFs decrease with increasing C_{SOURCE}, attributed to spatiotemporal variabilities potentially linked to:
  - inability to account for airflow/air exchange or sample where vapors enter buildings
  - background (non-VI sources)
  - preferential pathways
  - slab integrity
- more or “better” (concurrent/co-located) data does not appear to improve relations

AF Sensitivity to Δt
(Filtered TCE Database)







KEY POINT

- Δt is not an important variable in AF derivation
- little sensitivity to Δt consistent w/ conceptual model of fluctuating air flow across building foundations

AF Sensitivity to Meteorological Events

CONTINUOUS MONITORING @ NON-RESIDENTIAL BUILDING (SAN BERNADINO, CALIFORNIA)

Barometric Pressure

Differential Pressure

C_{SOURCE}

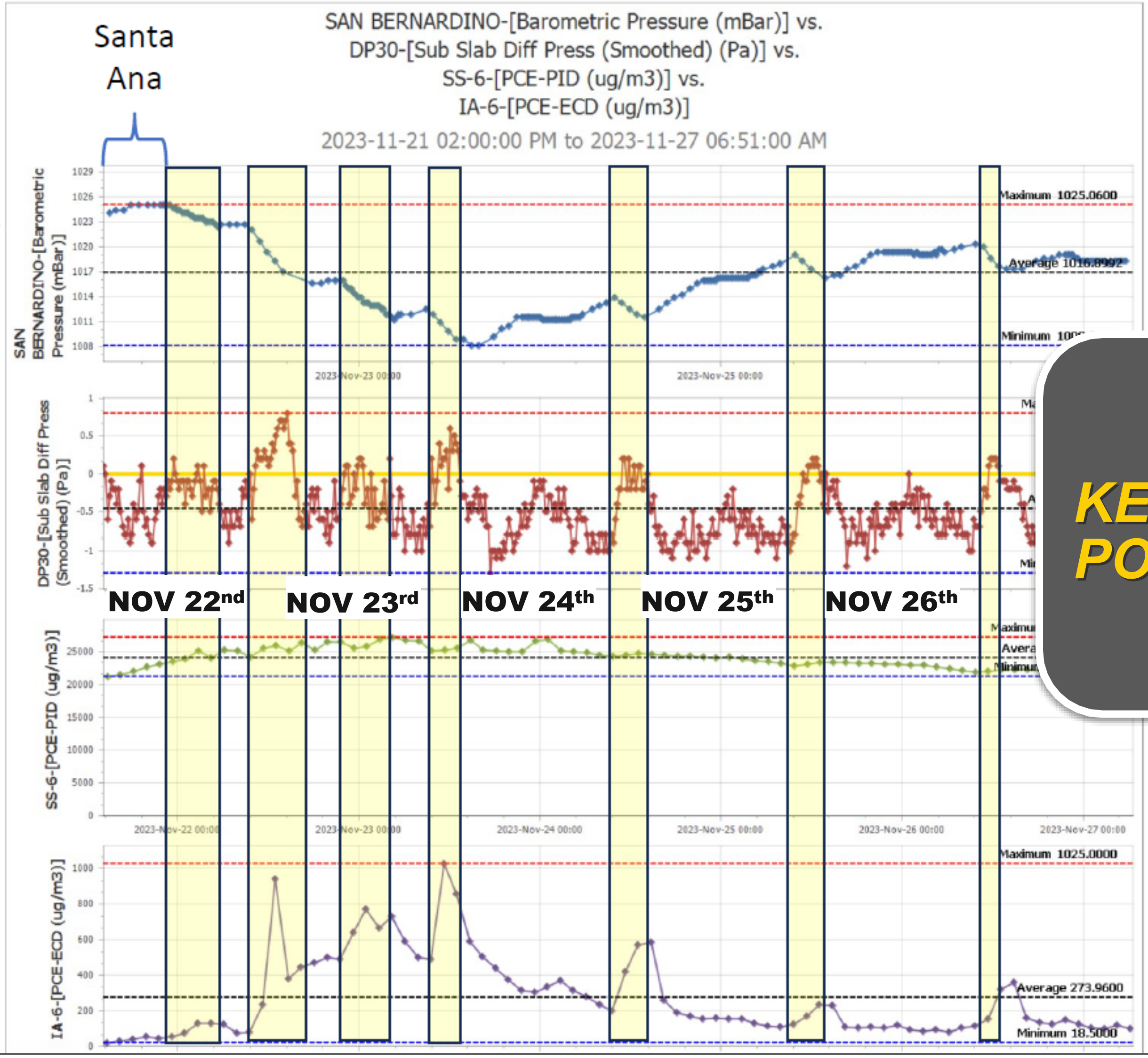
<10% rise in PCE_{SS} concentrations

PCE_{SS}

C_{IA}

OoM (100 – 1,000 µg/m³) spikes (hrs) in PCE_{IA} concentrations

PCE_{IA}

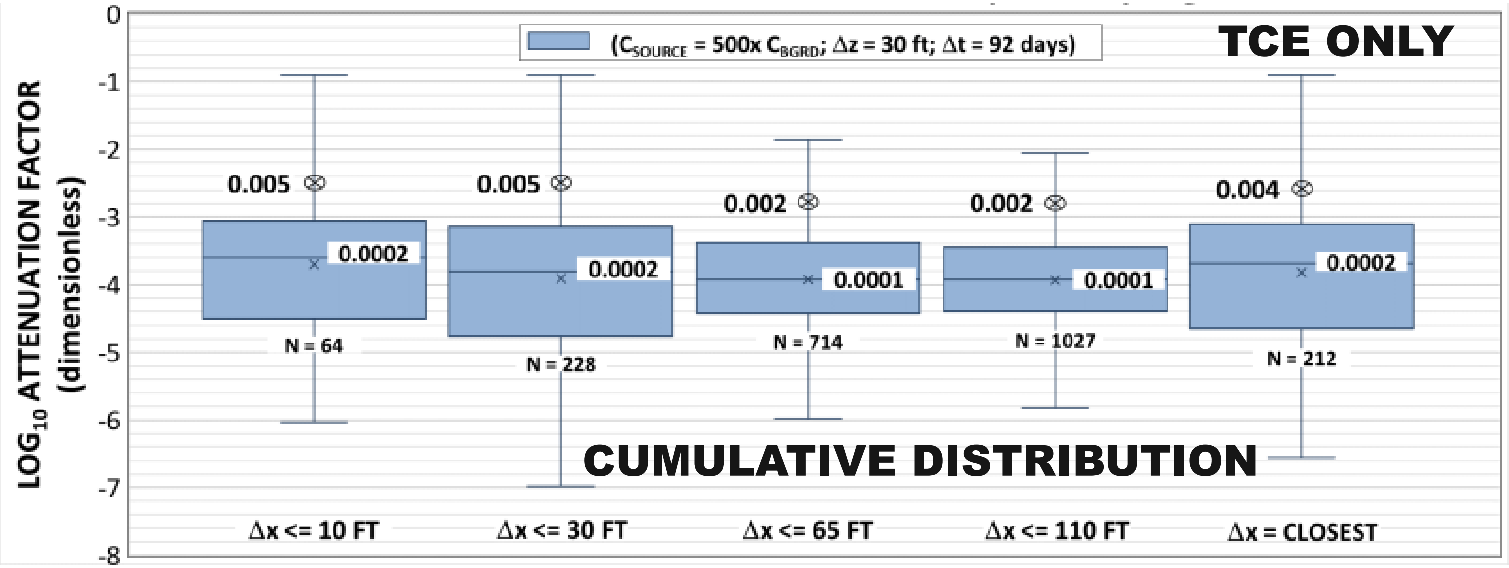


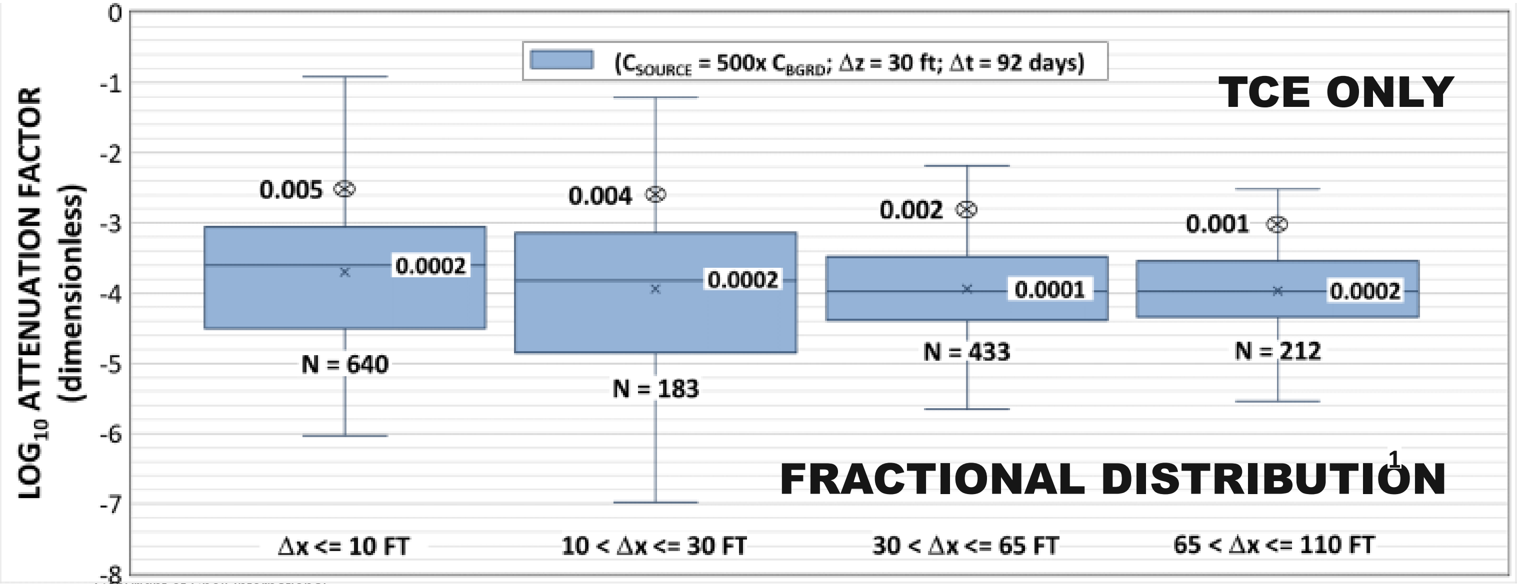
KEY POINT

C_{IA} can spike during low and relatively rapid drops in BP, while C_{SOURCE} remains relatively constant

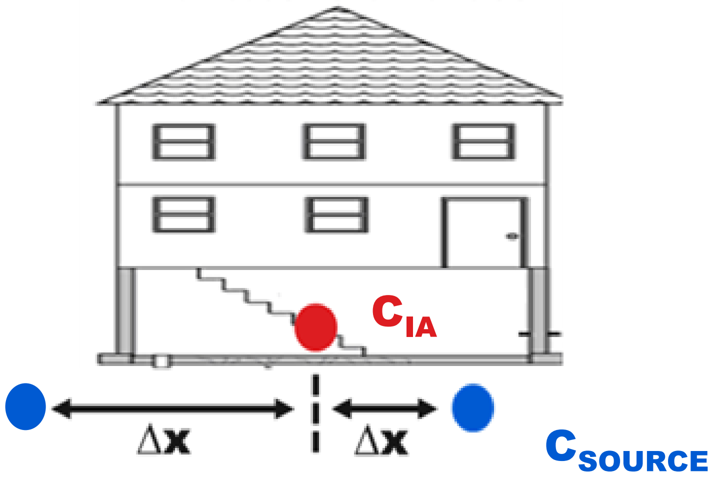
Data from Kram (2023)

AFs Are Poorly Correlated With Δx
(Filtered TCE Database)





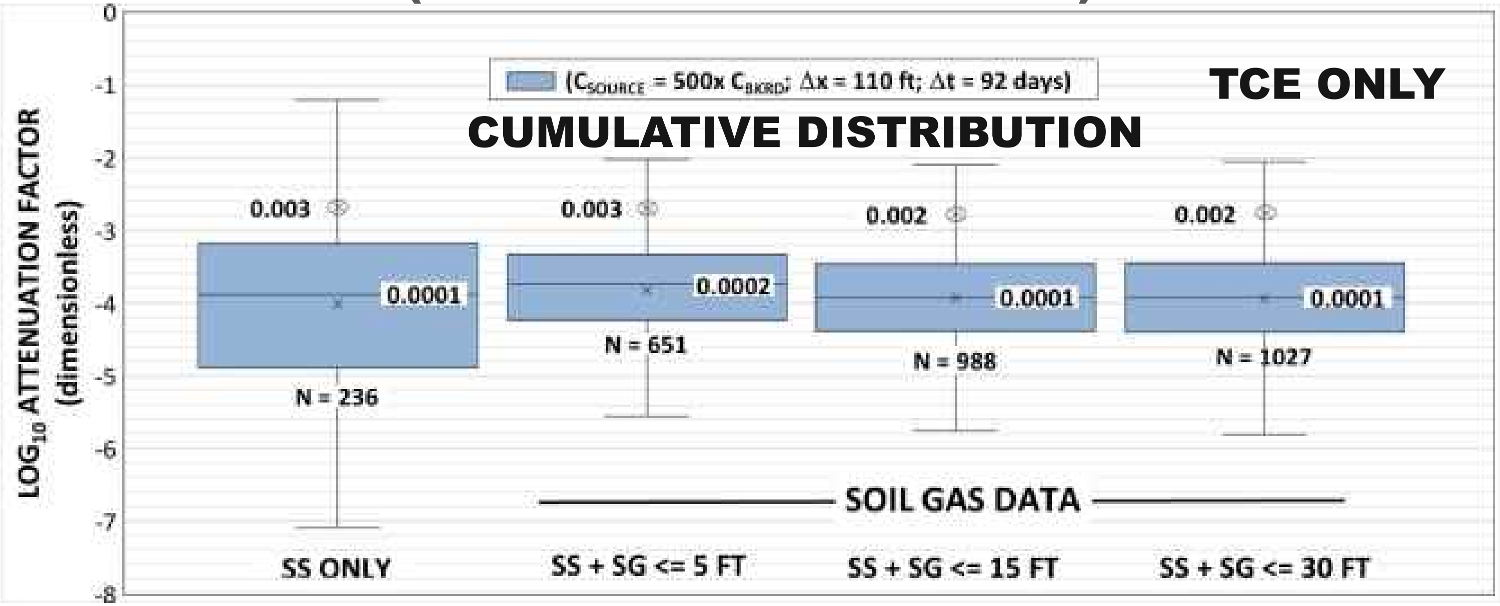
LATERAL OFFSET BETWEEN C_{IA} and C_{SOURCE} VAPOR SAMPLES

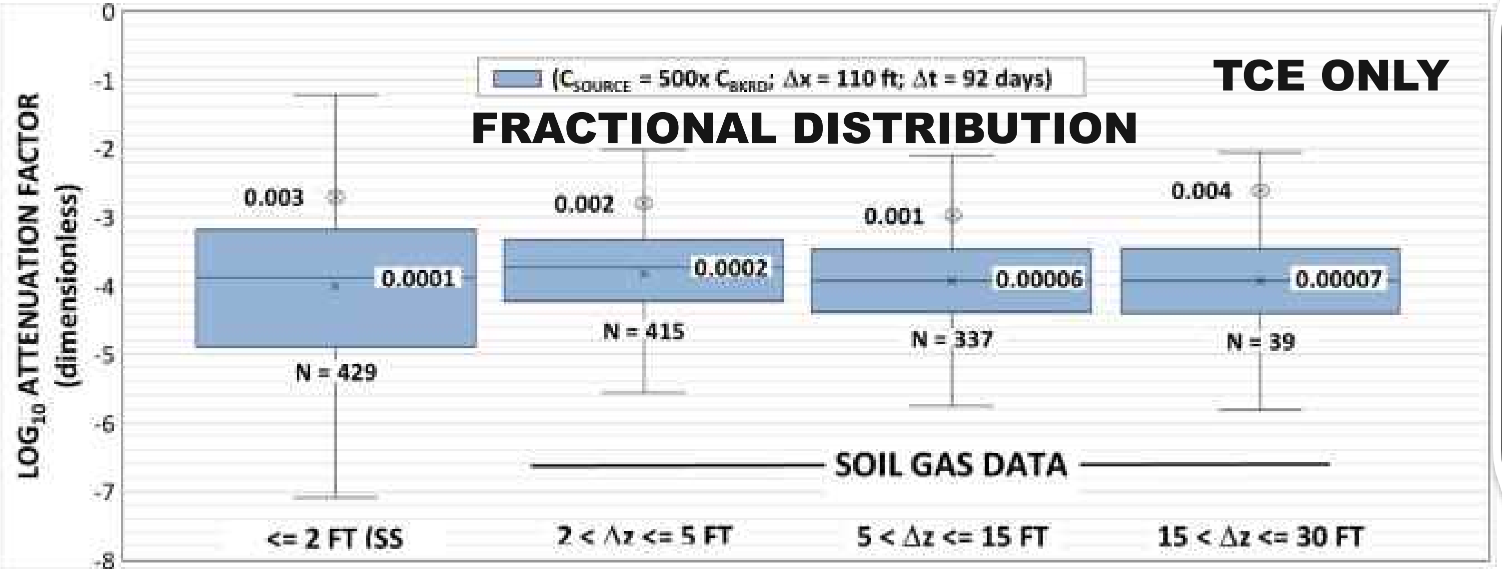


KEY POINT

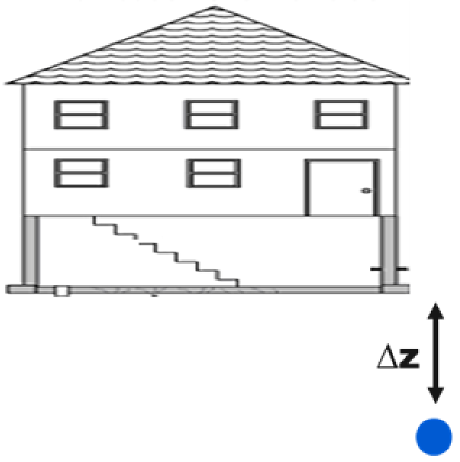
- limited sensitivity of AF to Δx observed because Δx is independent of source location

AF Sensitivity to Δz
(Filtered TCE Database)





VERTICAL OFFSET BETWEEN C_{SOURCE} AND BASE OF BUILDING FOUNDATION

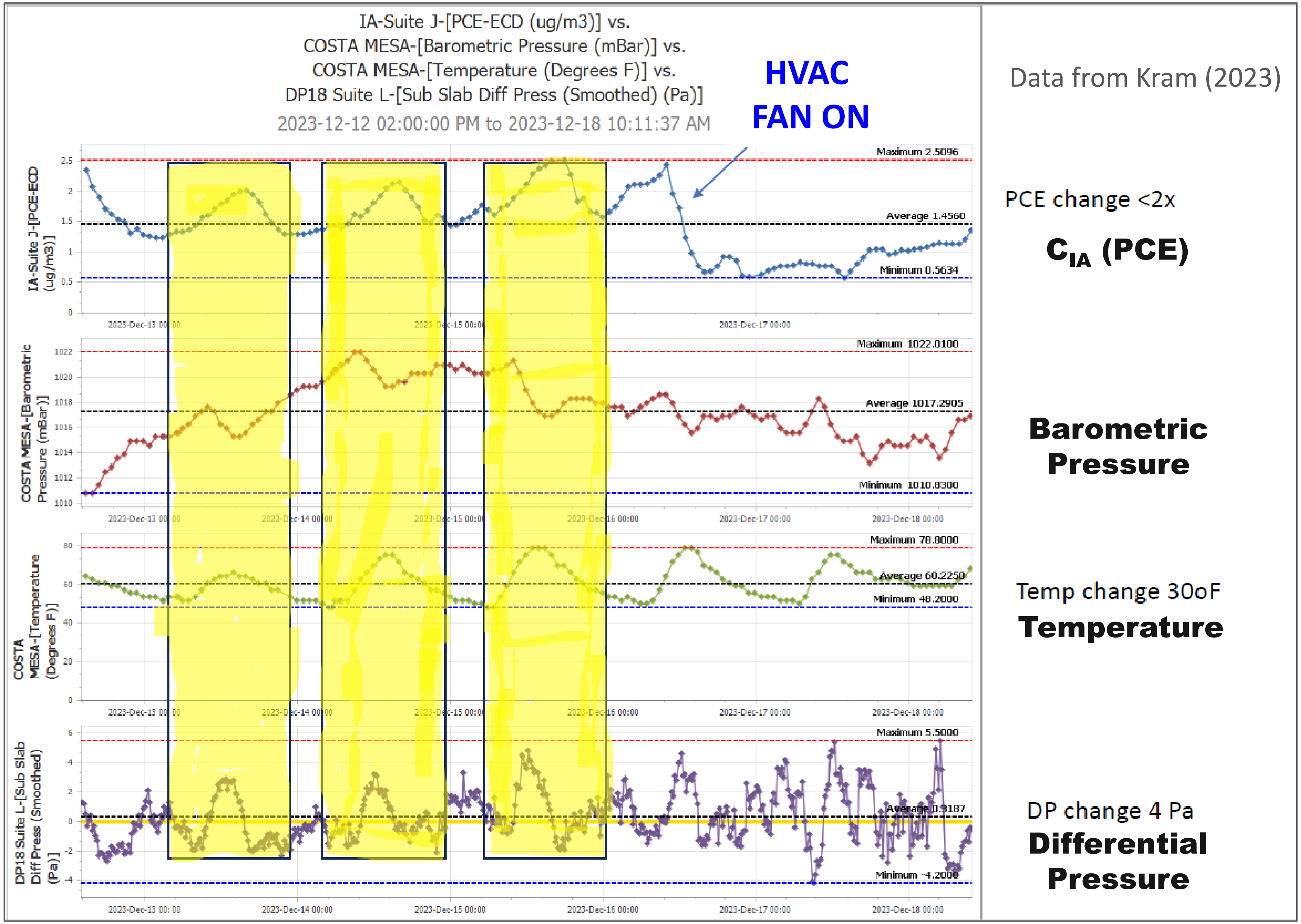


KEY POINT

- median AFs based on soil-gas data decrease slightly with higher Δz (higher C_{SOURCE} concentrations at residential sites w/ soil-gas data and GW sources?)
- AFs based on soil-gas data are less variable than AFs based on sub-slab data

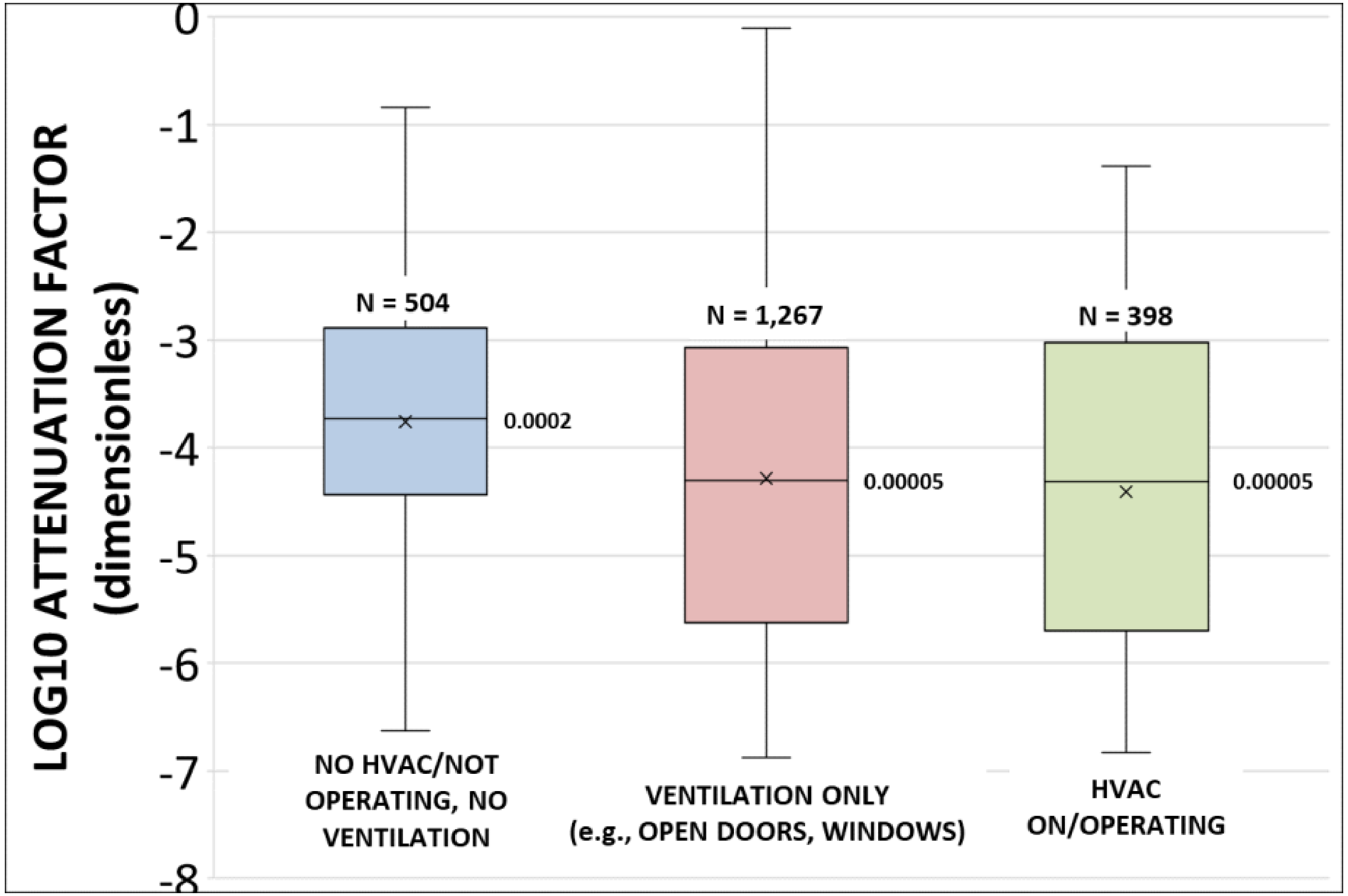
C_{IA} Are Somewhat Sensitive to HVAC Operation

CONTINUOUS MONITORING @ NON-RESIDENTIAL BUILDING: (COSTA MESA, CALIFORNIA)



DOES HVAC OPERATION GET FACTORED INTO AF DERIVATION?

AF Sensitivity to HVAC
(Filtered PCE + TCE Database)



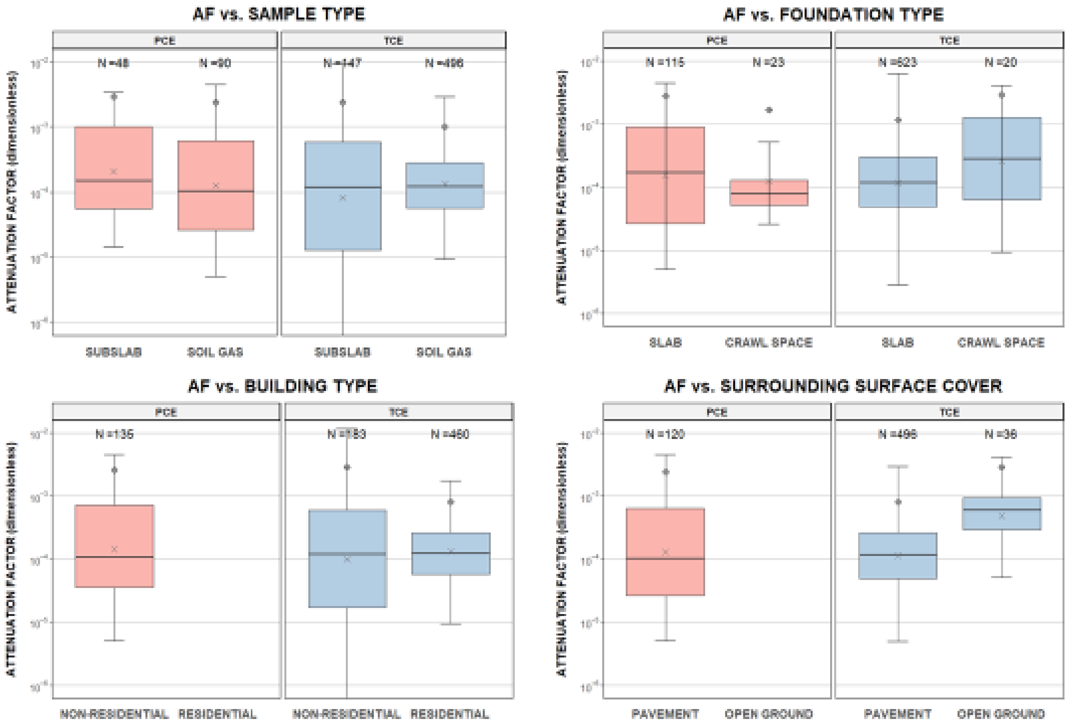
C_{IA} **w/ NDs at RLs, NO** C_{SOURCE} **< DLs, NO Δt, Δx, Δz FILTERING**

KEY POINT

- ventilation and HVAC operation results in decreased AF (~ 4x for the selected dataset)

AF Sensitivity Analysis (Descriptive Statistics) (Filtered TCE Database)

- compare AF distributions to assess empirical AF dependence on different variables on
  - building and foundation type
  - sample type
  - soil gas sampling depth
  - surrounding surface cover
  - HVAC operation
  - distance to building perimeter
  - distance between indoor and subsurface sample location
  - time between indoor and subsurface sample collection
- **median and 95th percentile AFs vary by less than an order of magnitude for broad range of variables**
- more sophisticated multivariate or individual site/bldg. analyses could be performed

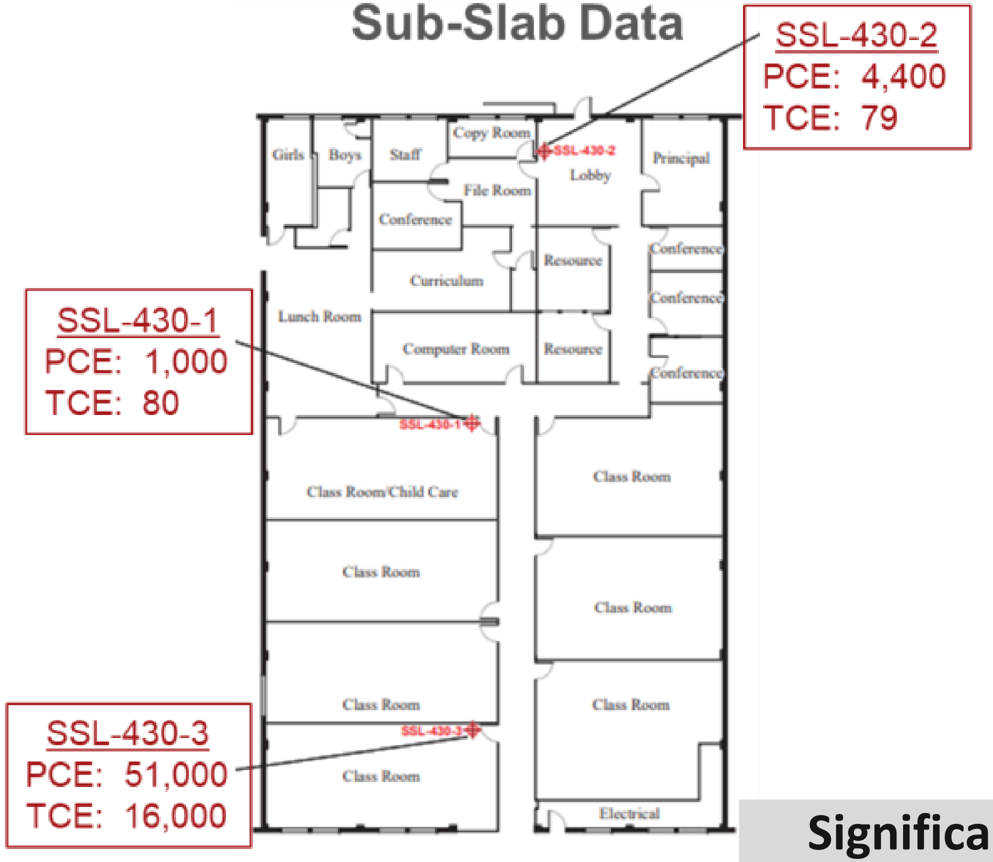


KEY POINT

- **limited sensitivity to other key variables potentially affected by sensitivity to C_{SOURCE}**

Spatial Variability of C_{SOURCE} and C_{IA} Data Affects Building-Specific AF Calculations

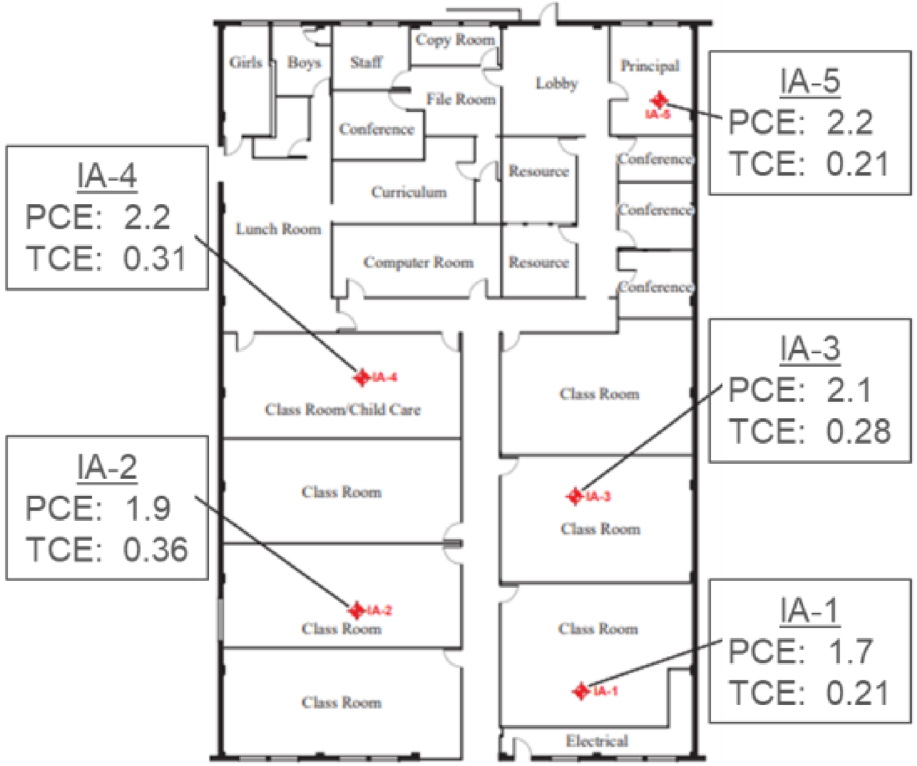
Sub-Slab Data



Significant variability in C_{SOURCE}

CVOC Source

Indoor Air Data



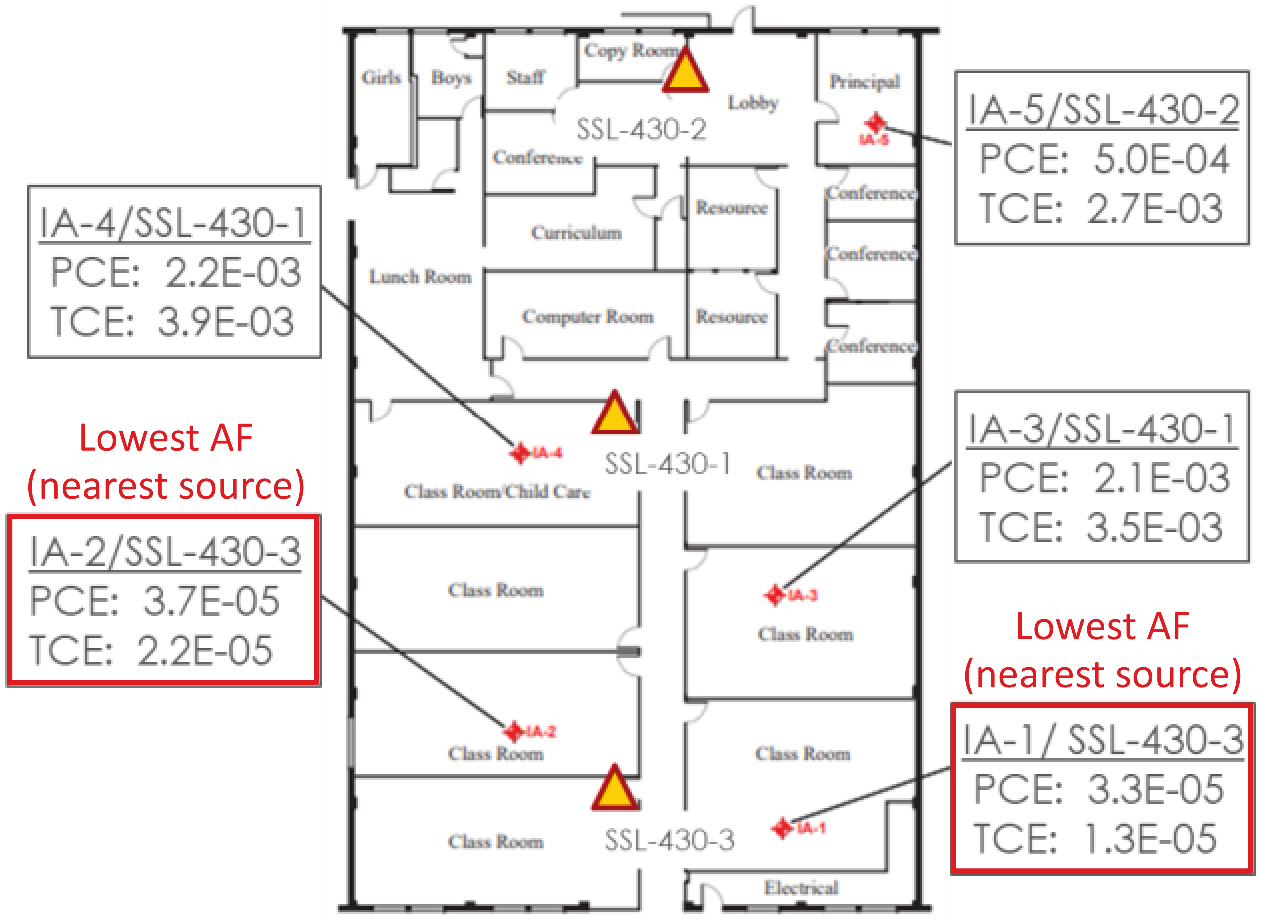
Little variability in C_{IA}

CVOC Source

Spatial Variability of C_{SOURCE} and C_{IA} Data Affects Building-Specific AF Calculations

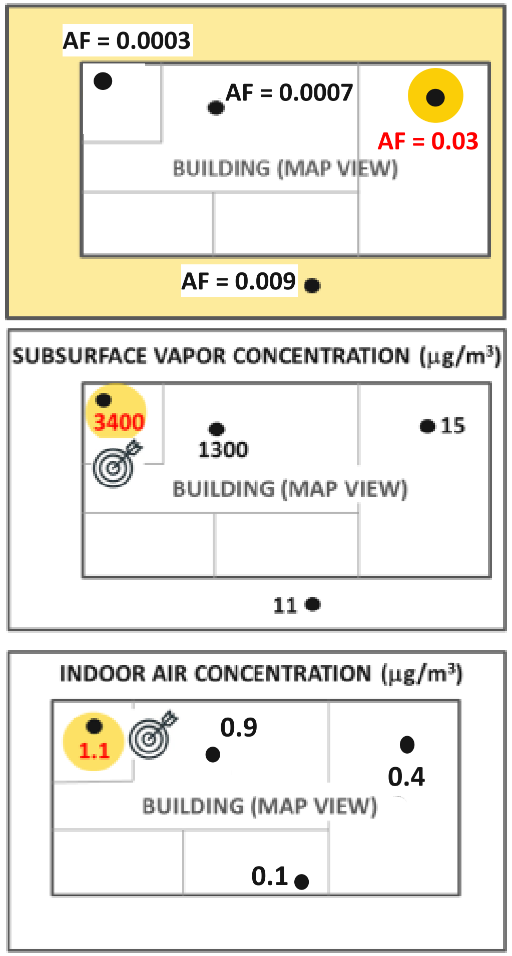
- AFs closer to source are more than an order of magnitude lower than AFs away from source
- maximum AFs are not representative of VI exposure

Attenuation Factors



CVOC Source

Data Pairing Options for Deriving Building-Specific AFs



OPTION 1:
individual AF data

OPTION 2:
individual C_{SOURCE} and C_{IA} data

Option 1 (AF analysis)

- median (minimal bias)
- maximum or 95%ile (inconsistent with VI risk assessment)

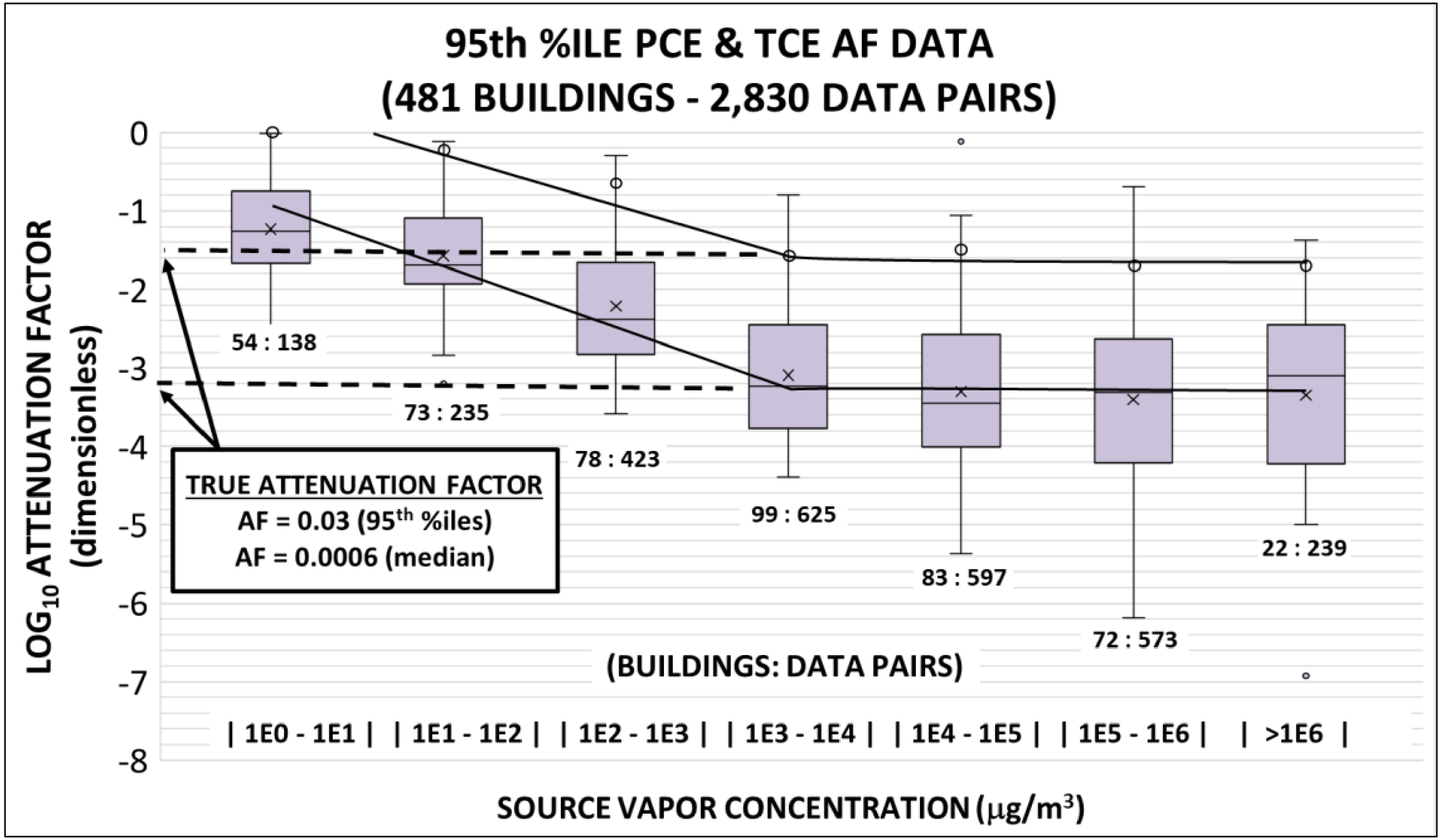
Option 2 (C_{SOURCE}, C_{IA} analysis)

- median (minimal bias)
- maximum C_{SOURCE} and C_{IA} data
  - consistent with VI risk assessment, VI screening, and how site-specific target (clean-up) levels would be defined
  - targets location where there is the highest potential mass flux into building (max C_{SOURCE})
  - "conservative" AF for site screening because it captures worst-case indoor air (exposure) condition for individual buildings reported in the database

KEY POINT

- **defining 1 AF per building greatly reduces the vapor data population available to derive an AF (requires a very large database)**
- **multiple options available to address data pairing; preference for using maximum C_{SOURCE} and C_{IA} data**

Method 3: Theoretical AF vs. C_{SOURCE} Relations Become More Apparent Using Building Specific AFs
(Filtered PCE + TCE Data)



Considerations

- a multiple-lines-of-evidence approach to AF derivation using all 3 methods
- technical defensible filtering that factors in:
  - the AF method
  - AF sensitivity to key variables
  - chemical type (depending on method)
  - site CSM (residential vs. non-residential)

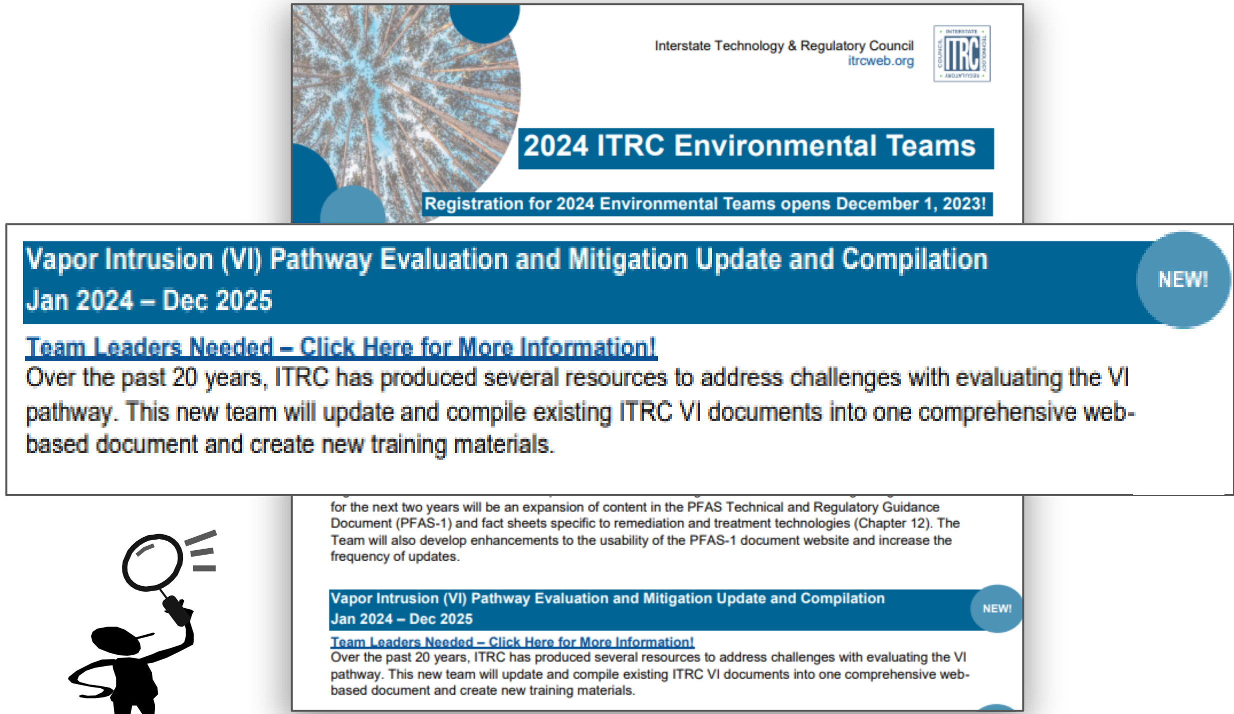
  and is not based on strict adherence to vapor sampling requirements stipulated in regulatory guidance (e.g., Δt, Δx)
- AFs based on building-specific C_{IA} and C_{SOURCE} help eliminate some of the spatiotemporal variability and ambiguities associated with multiple data pairs for given buildings… preference for 95^{th} %ile or maximum C_{IA} and C_{SOURCE} values
- AF derivation must account for differences associated with site type (non-residential vs. residential)

Path Forward - Solicitation

NATIONAL EMPIRICAL AF STUDY (2023 – 2024)

- broad geographical coverage
- seeking consultant support:
  - uploading VI site data into master database
  - data analysis and publication in peer-reviewed literature
- GOAL:
  - address limitations of US EPA 2012 study
  - assess sensitivities to key variables
  - opportunity for regulatory uptake through ITRC (2024) VI Project (NEW)
- kicked off August 2024 -- Geosyntec, Jacobs, AECOM, ERM, TRC, Ramboll, GSI, WSP, H&A

ITRC VI PROJECT (2024 – 2025)


Interstate Technology & Regulatory Council
itrcweb.org

2024 ITRC Environmental Teams

Registration for 2024 Environmental Teams opens December 1, 2023!

Vapor Intrusion (VI) Pathway Evaluation and Mitigation Update and Compilation
Jan 2024 – Dec 2025

NEW!

Team Leaders Needed – Click Here for More Information!

Over the past 20 years, ITRC has produced several resources to address challenges with evaluating the VI pathway. This new team will update and compile existing ITRC VI documents into one comprehensive web-based document and create new training materials.

for the next two years will be an expansion of content in the PFAS Technical and Regulatory Guidance Document (PFAS-1) and fact sheets specific to remediation and treatment technologies (Chapter 12). The Team will also develop enhancements to the usability of the PFAS-1 document website and increase the frequency of updates.

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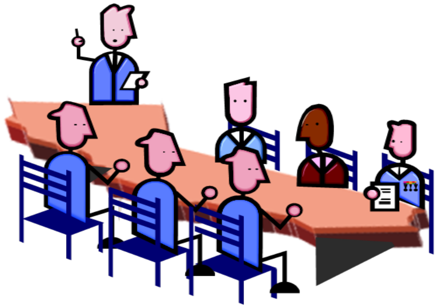

CAL EPA PROJECT (2024+)