Evaluation of Spatiotemporal Variability in Site-Specific Attenuation Factors

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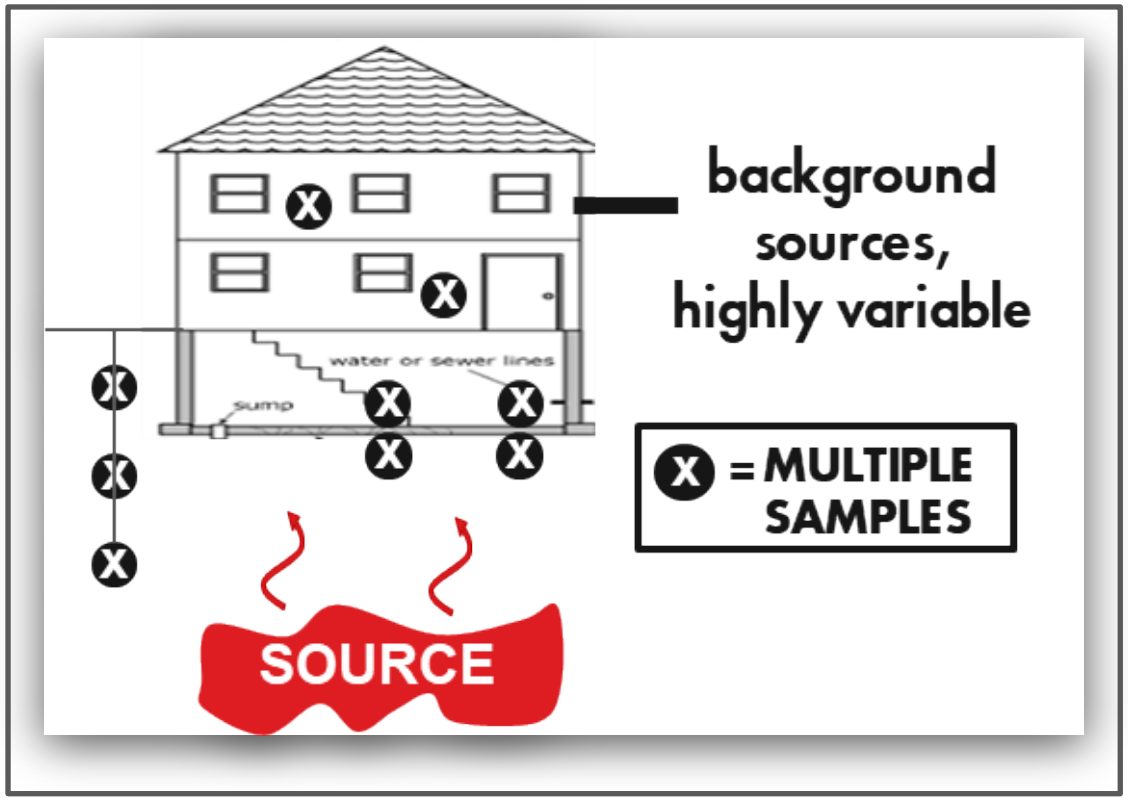
Overview

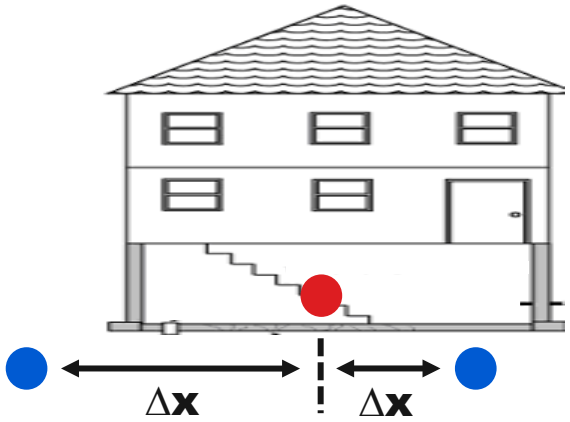
- regulatory agencies increasingly require **multiple** indoor air (IA) & subsurface (SS) vapor samples over time and space to address variability in vapor concentrations
- **concurrent** and **co-located** IA & SS vapor samples generally recommended for multiple-lines-of-evidence investigations
- little information reported on key factors that may affect vapor intrusion (VI)

VAPOR SAMPLING TO ADDRESS UNCERTAINTY

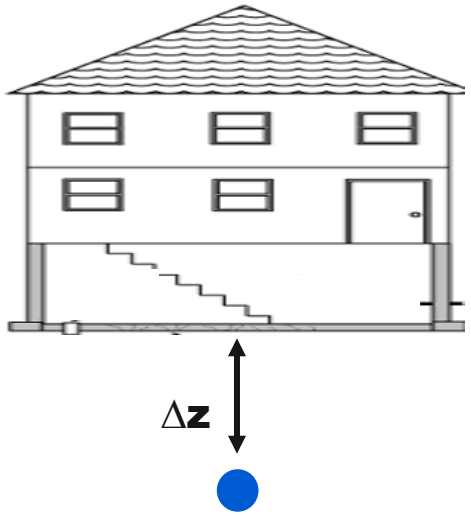


Conceptualization of Filtered Variables in AF Derivation

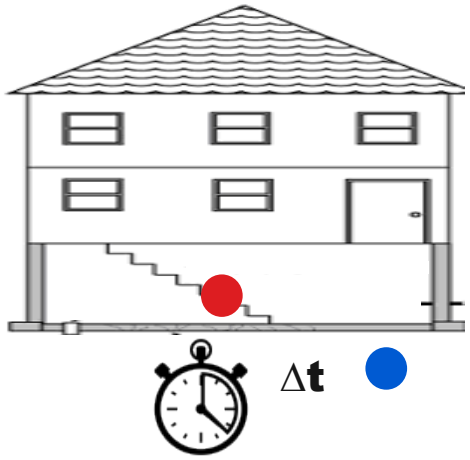
LATERAL OFFSET BETWEEN C_{IA} and C_{SOURCE} VAPOR SAMPLES



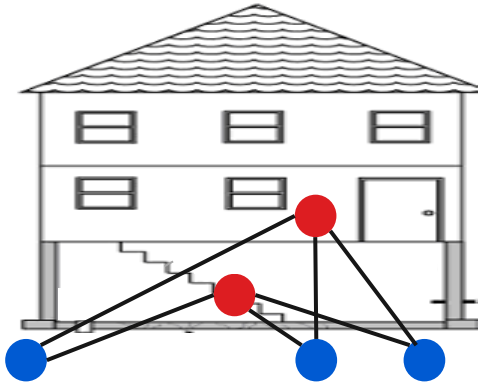
VERTICAL OFFSET BETWEEN C_{SOURCE} AND BASE OF BUILDING FOUNDATION



TIME LAG BETWEEN C_{IA} and C_{SOURCE} VAPOR SAMPLING



C_{IA} and C_{SOURCE} DATA PAIRING



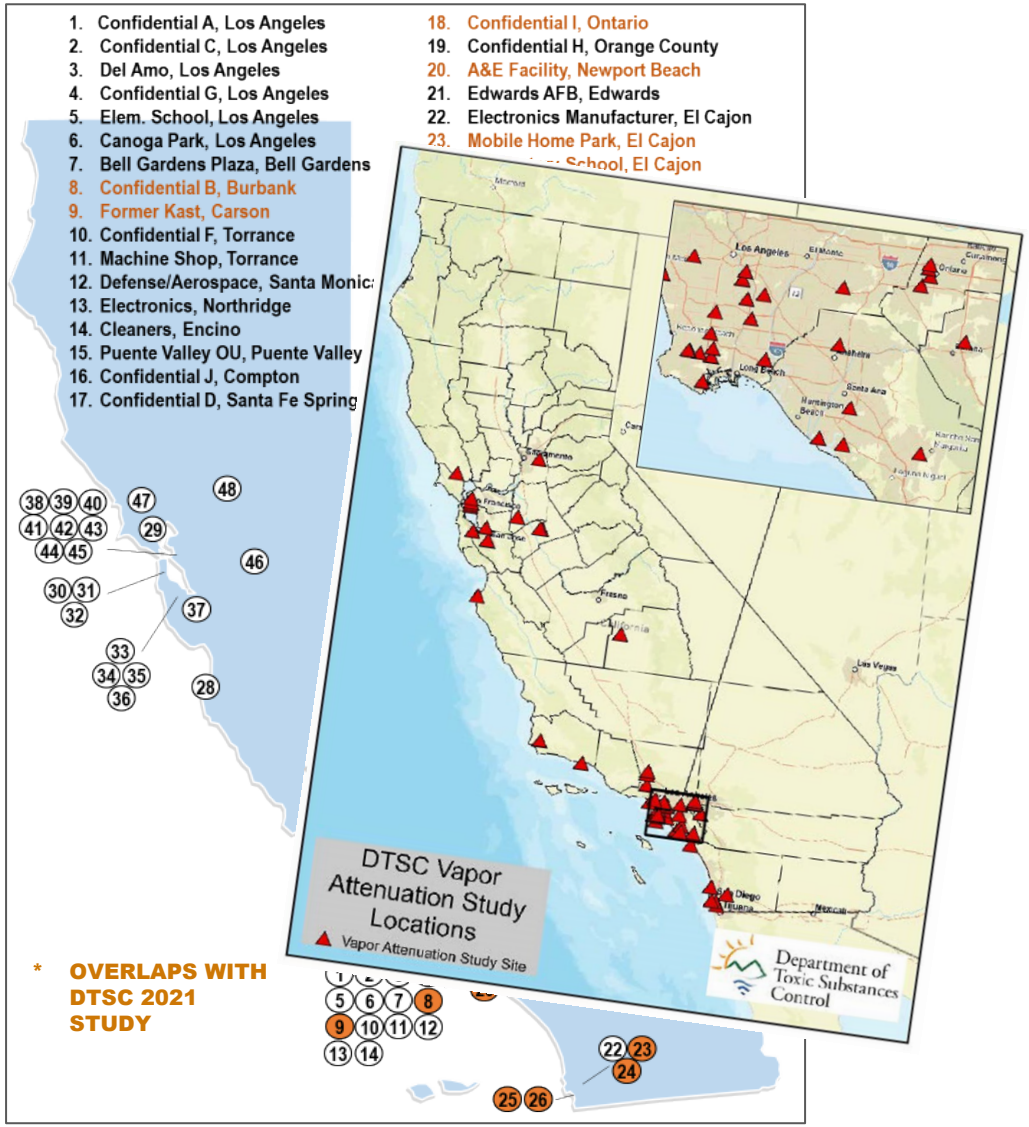
- INDOOR AIR SAMPLE (C_{IA})
- SUBSURFACE (SUB-SLAB OR SOIL-GAS) VAPOR SAMPLE (C_{SOURCE})

TERMINOLOGY

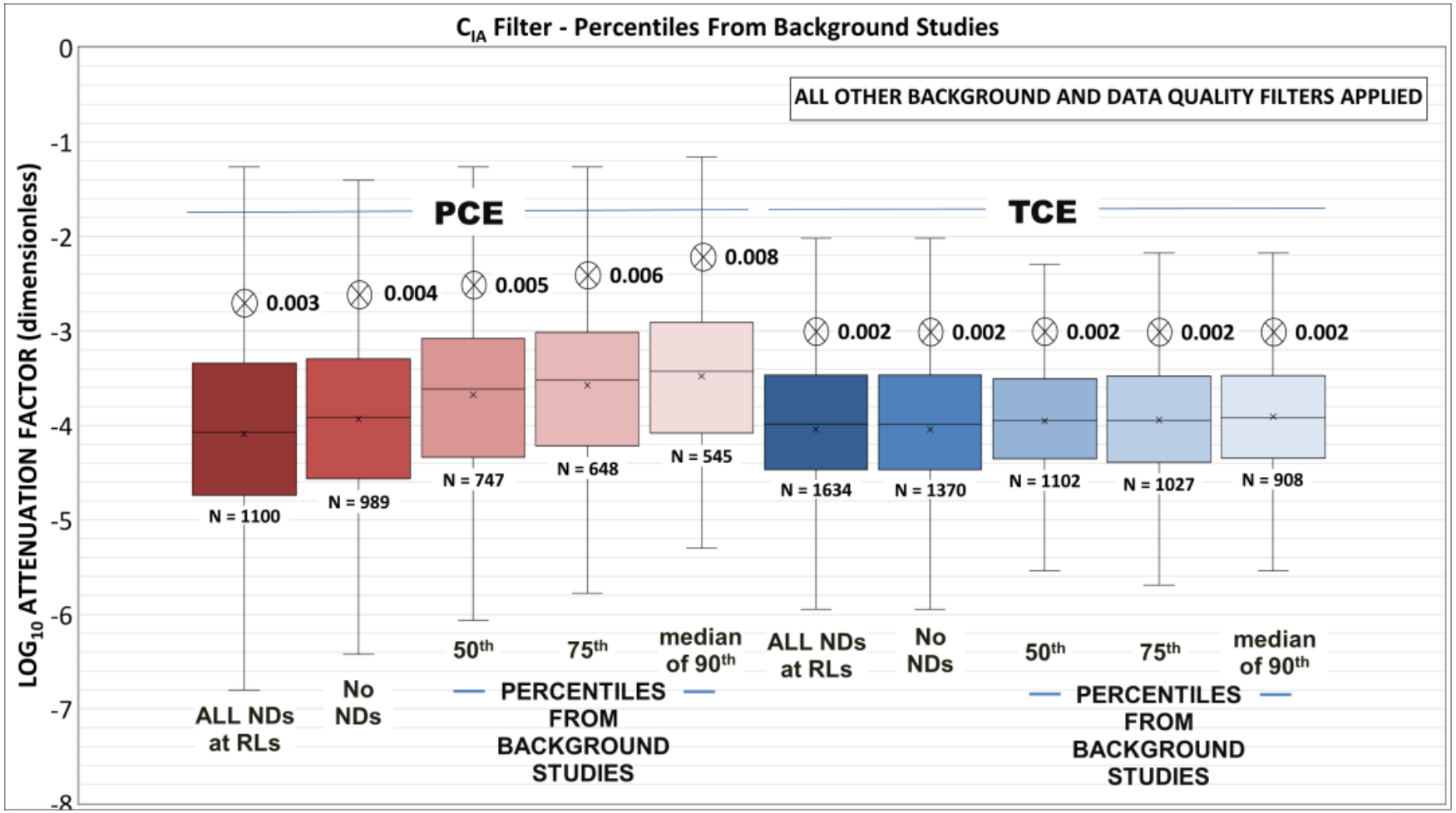
C_{IA}:	indoor air concentration
C_{SOURCE}:	vapor conc. in subsurface (soil gas, sub-slab)
C_{BGRD}:	background concentration in indoor air

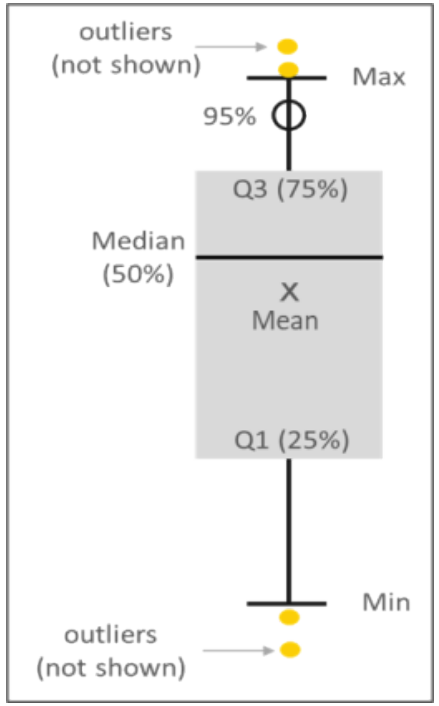
Unfiltered COMBINED Database – General Stats

- Geotracker/Envirostor review, some consultant project files
- 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:
  - 67 sites w/ sub-slab, 83 sites w/ soil gas
  - mainly located in urban areas (LA, San Francisco)
  - 35 chemicals (primarily TCE and PCE)
  - 4 sites from US EPA database



C_{IA} Filtering Relatively No Effect on AFs for TCE





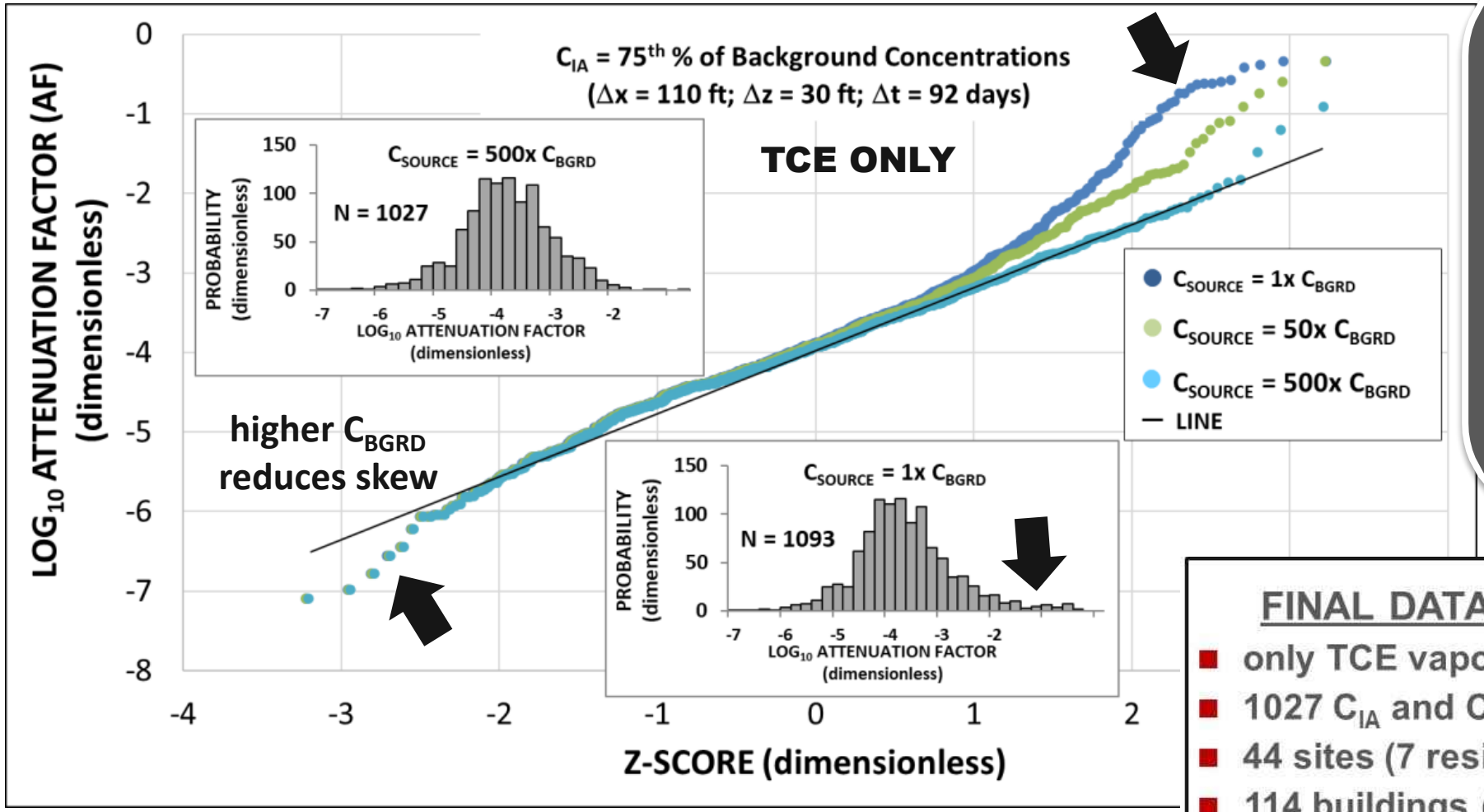
- C_{IA} filtering removes~50% of PCE+TCE data pairs
- AF distributions for PCE are more affected by background sources (and more variable) than TCE

KEY POINT

- **more low concentration TCE C_{IA} data could be included in AF analysis and assessment of factors affecting data filtering**
- **only TCE data used for AF analysis because of PCE sensitivity to background sources**

C_{SOURCE} Filtering Based on USEPA (2012) Methodology

higher multiplier minimizes low C_{SOURCE} causing skew



KEY POINT

most log-normally distributed AF data that preserves TCE data population achieved using:

C_{IA}: 75th %ile of C_{BGRD} (0.3 µg/m³)

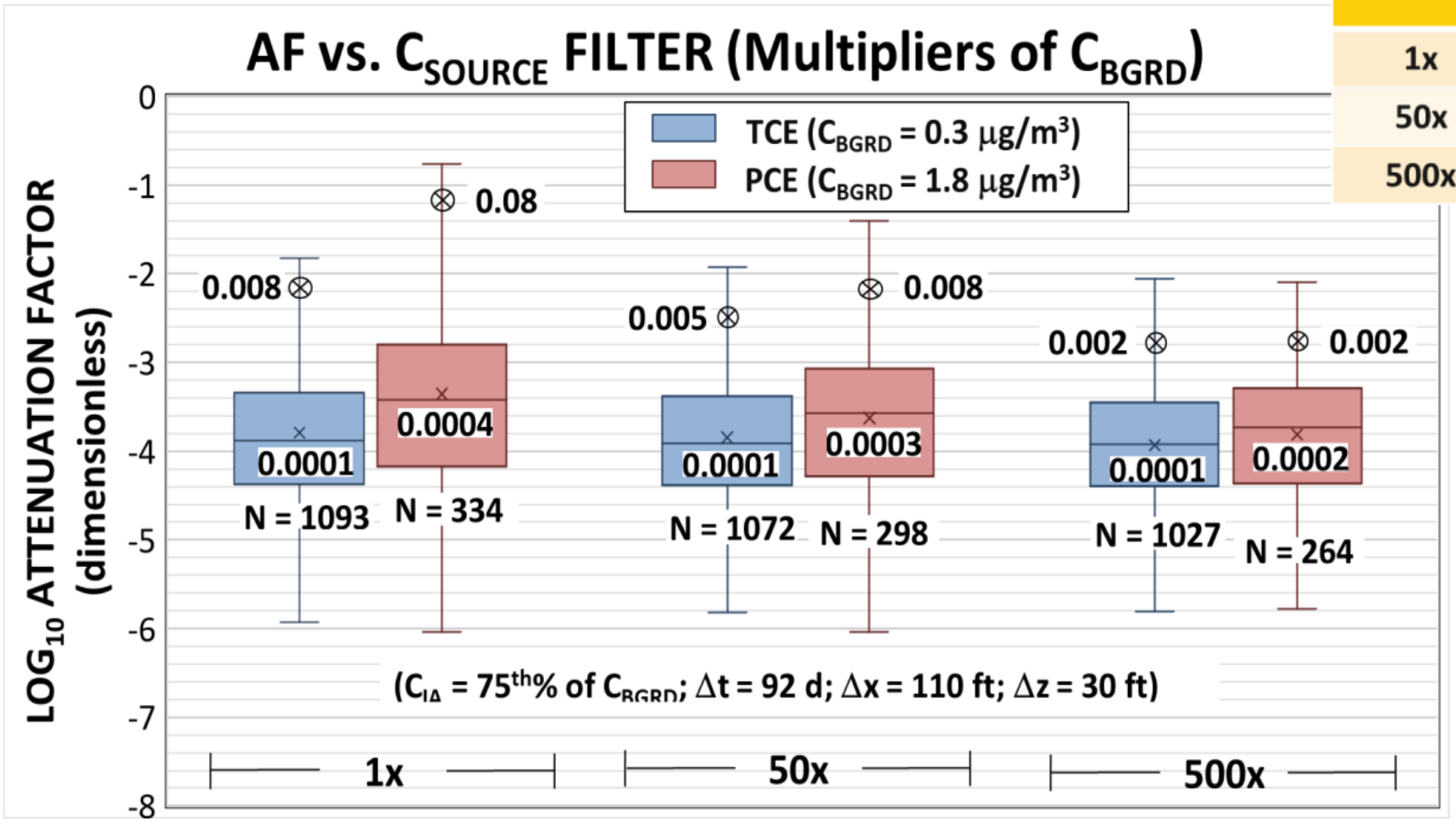
C_{SOURCE}: 500x C_{BGRD} (150 µg/m³)

FINAL DATABASE FOR AF DERIVATION

- only TCE vapor data
- 1027 C_{IA} and C_{SOURCE} data pairs (e.g., AFs)
- 44 sites (7 residential, **37 non-residential**)
- 114 buildings (38 residential, **76 non-residential**)
- **77% soil-gas,** 23% subslab

- C_{SOURCE} filter based on **multiplier of C_{BGRD}** that achieves most log-normally distributed data

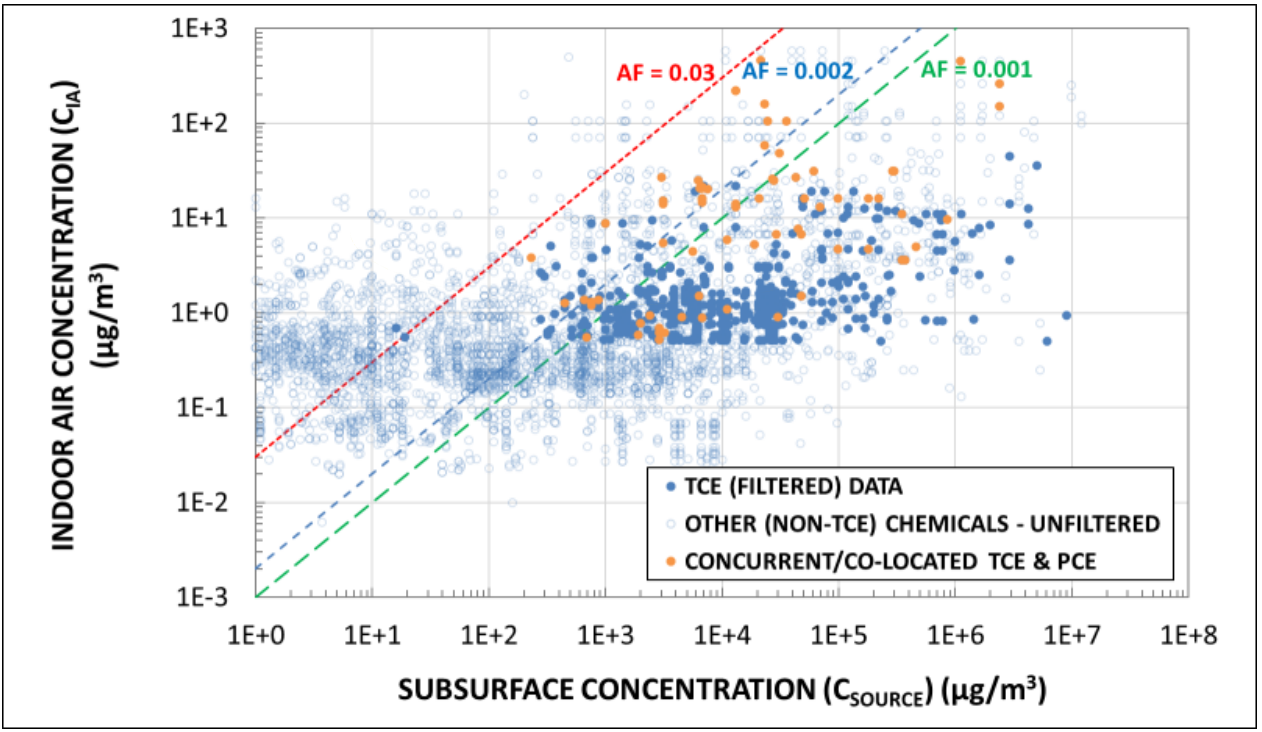
AFs Generally Decrease with Increasing C_{SOURCE} Filtering

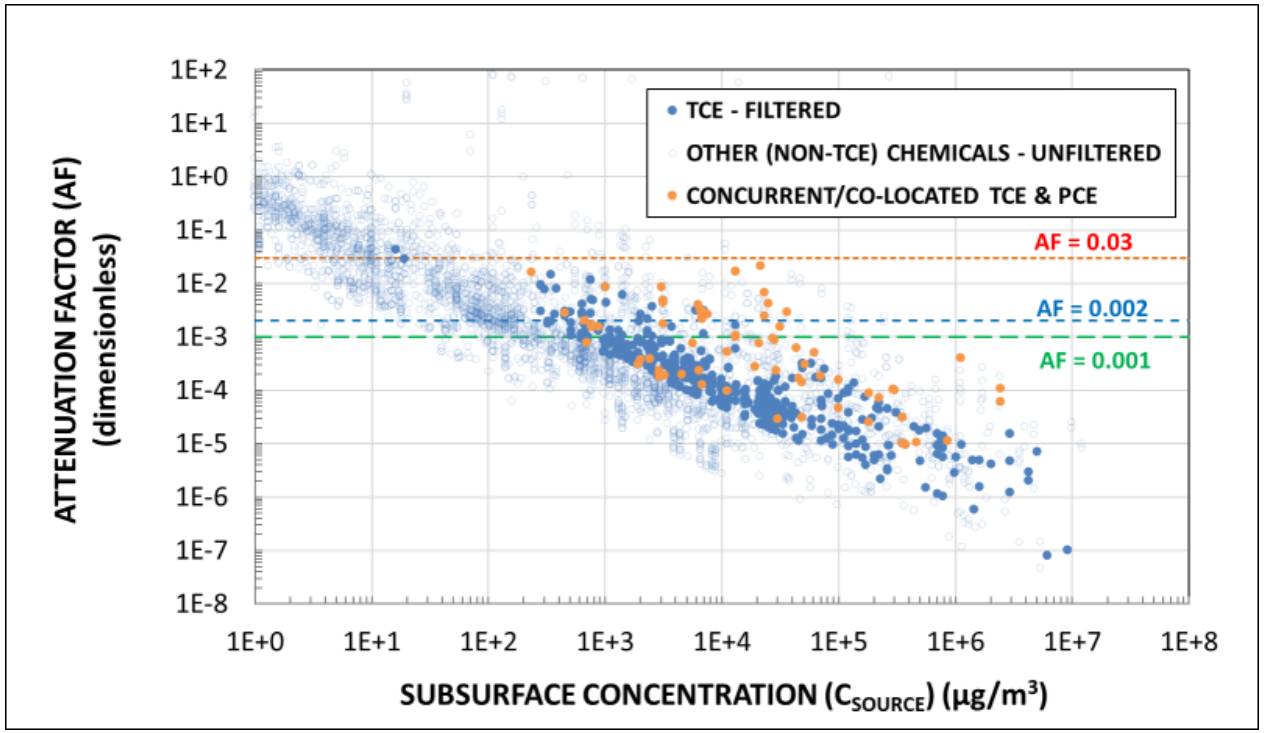


Multiplier	PCE C_{SOURCE} FILTER (µg/m³)	TCE C_{SOURCE} FILTER (µg/m³)
1x	1.8	0.3
50x	90	15
500x	900	150

- 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

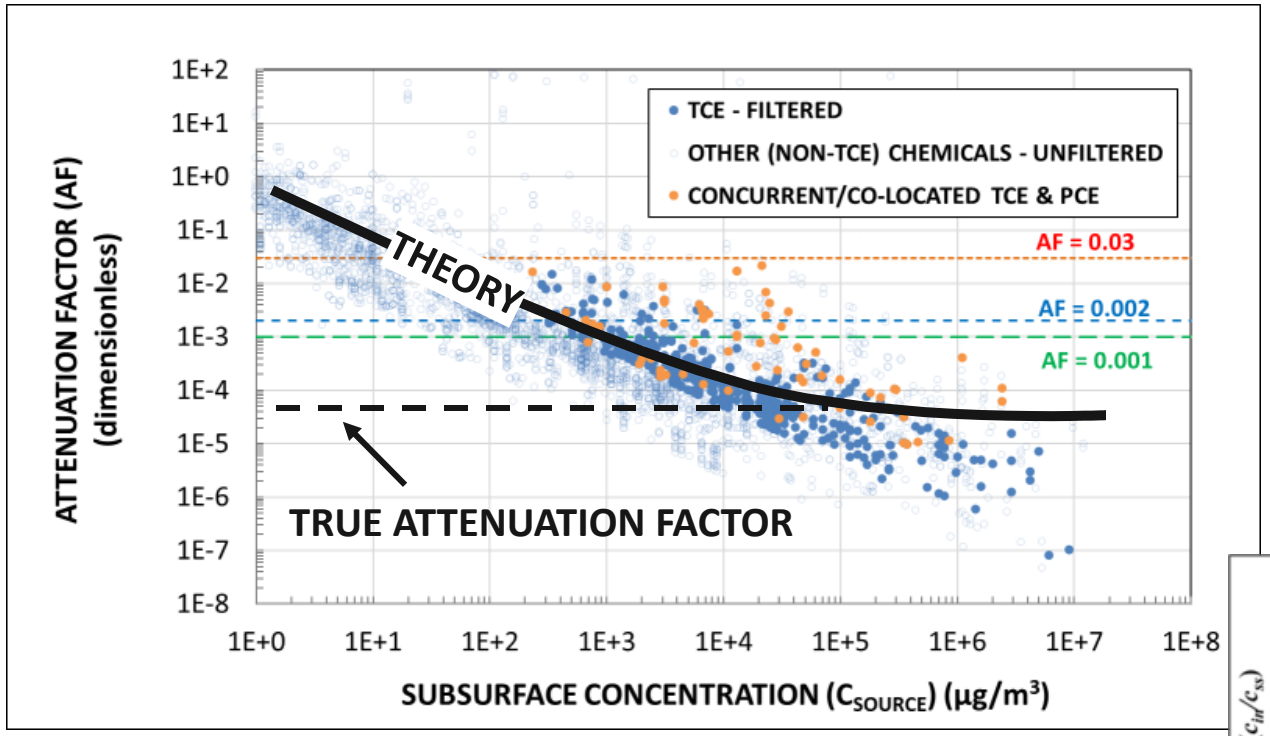
Sensitivity to Source Vapor Concentration (C_{SOURCE})

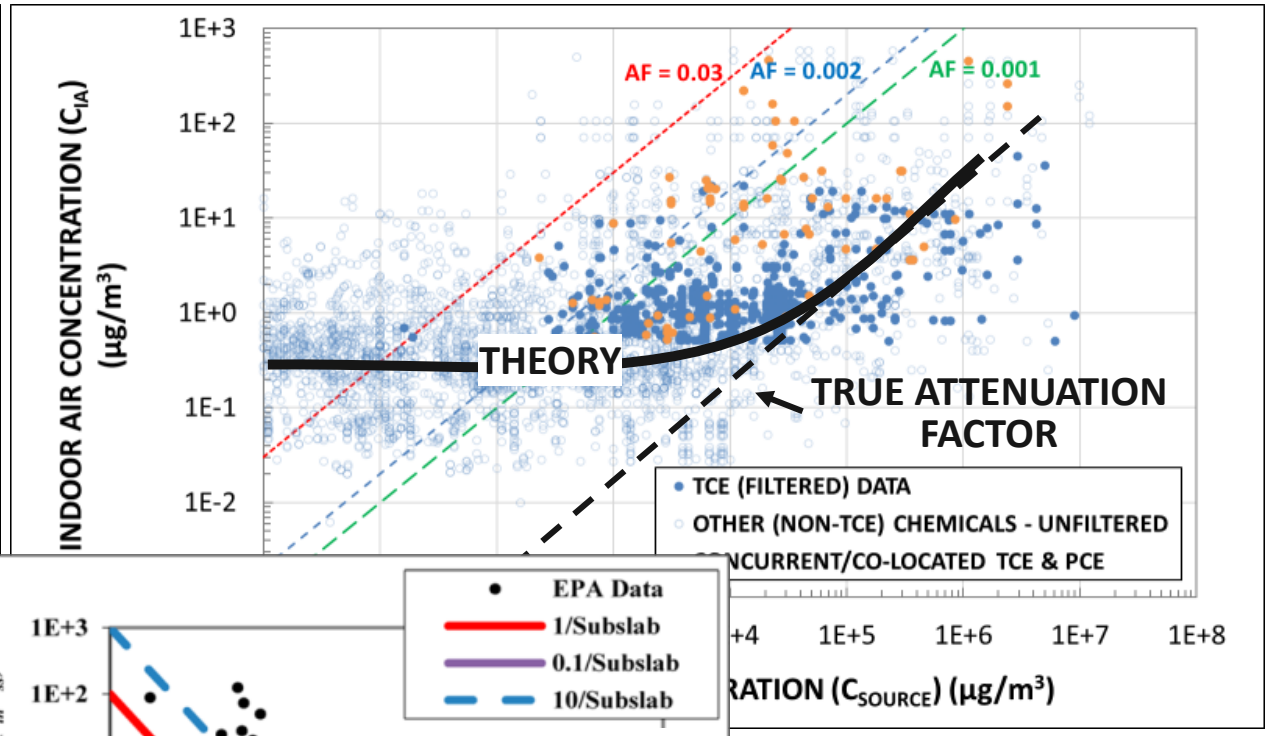




- AFs decrease with increasing C_{SOURCE}, attributed to spatiotemporal variabilities potentially linked to:
  - inability to account for airflow/air exchange or sample where vapors enter buildings
  - background (non-VI sources)
  - preferential pathways
  - slab integrity
- more or “better” (concurrent/co-located)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

Sensitivity to Source Vapor Concentration (C_{SOURCE})

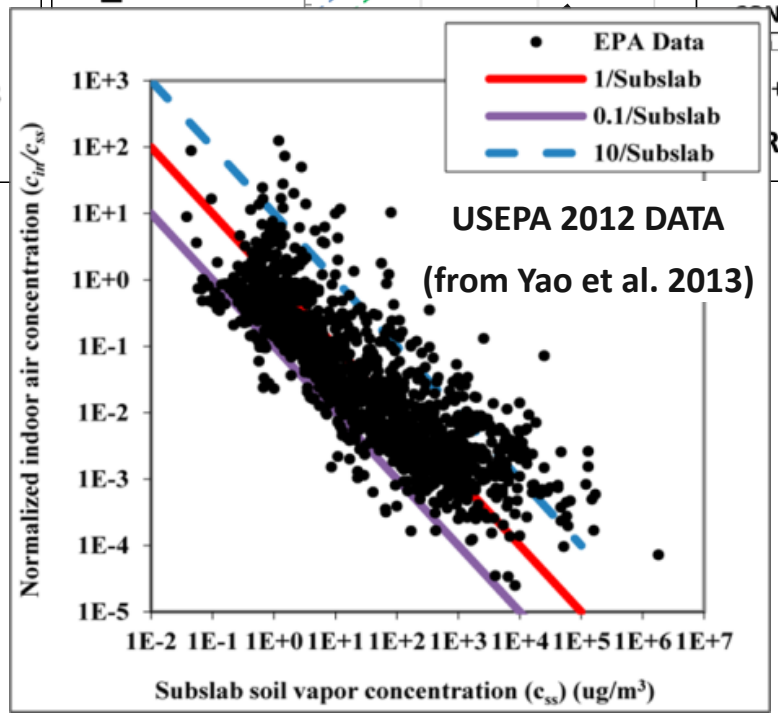




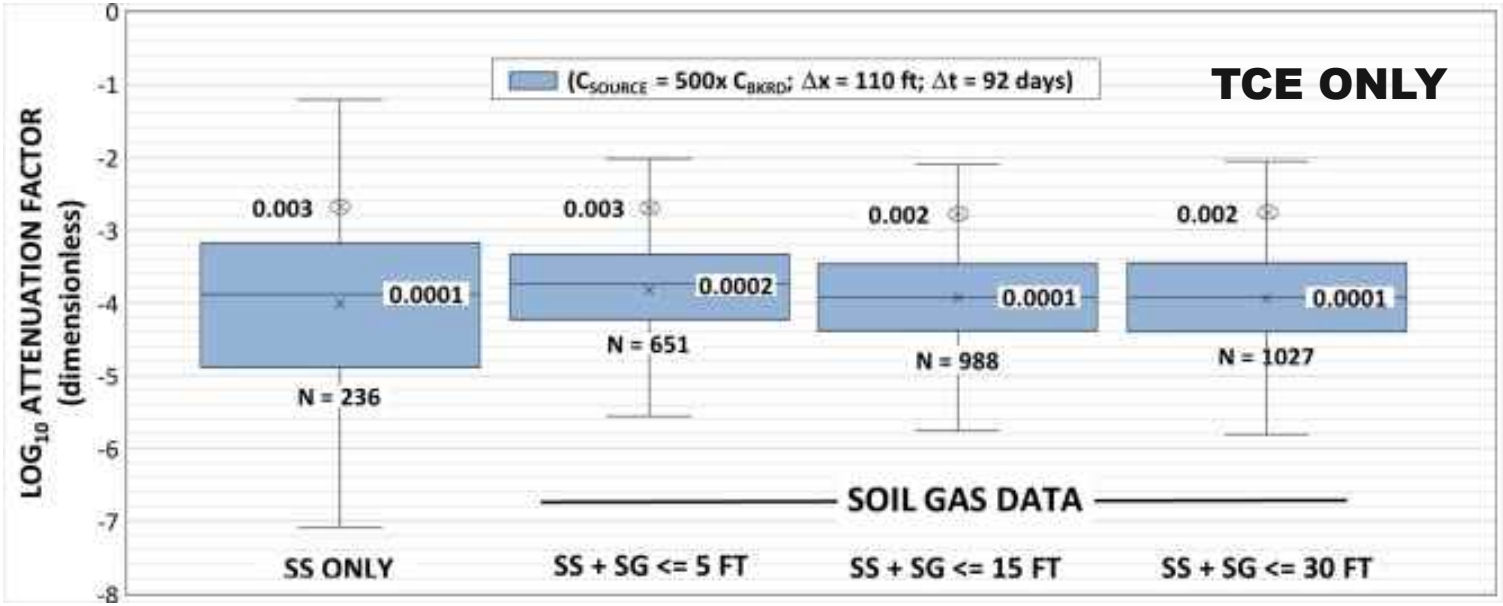
$$AF_{emp} = \frac{C_{IA}}{C_{SSSV}} = AF_{VI} + \frac{C_{Bkgd}}{C_{SSSV}}$$

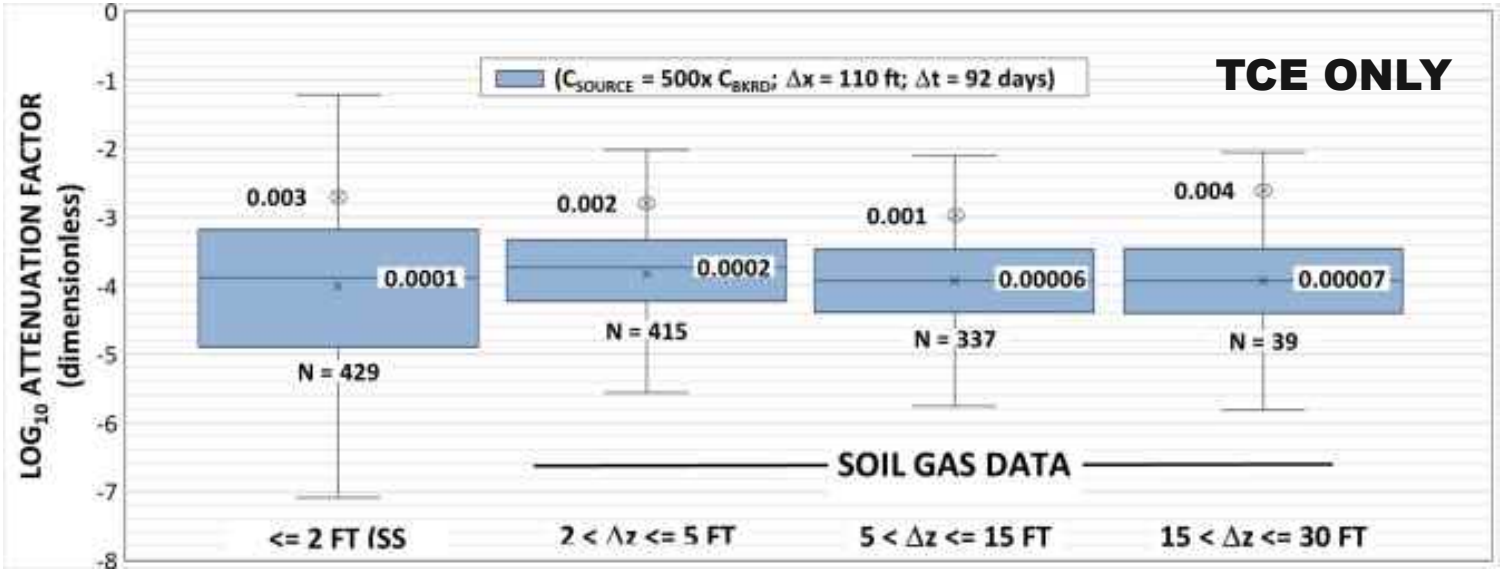
AF_{emp} = measured AF

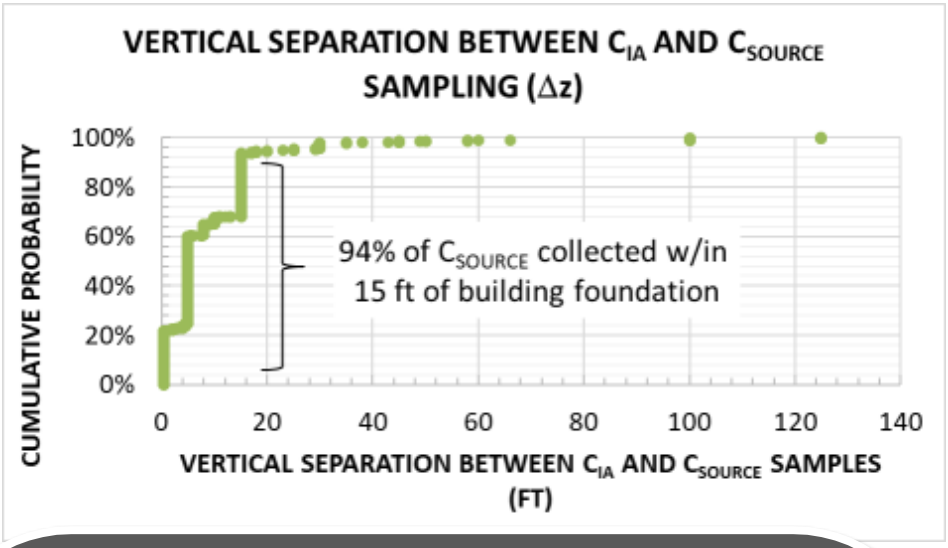
AF_{VI} = actual AF



AF Sensitivity to Δz



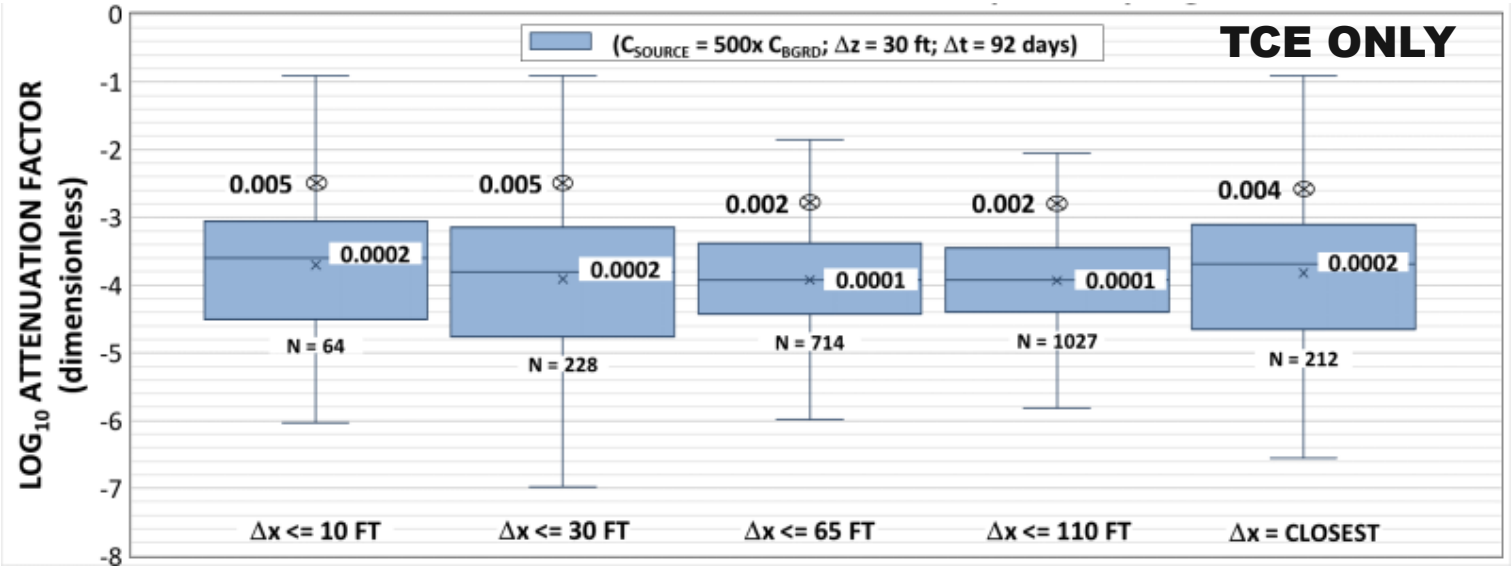


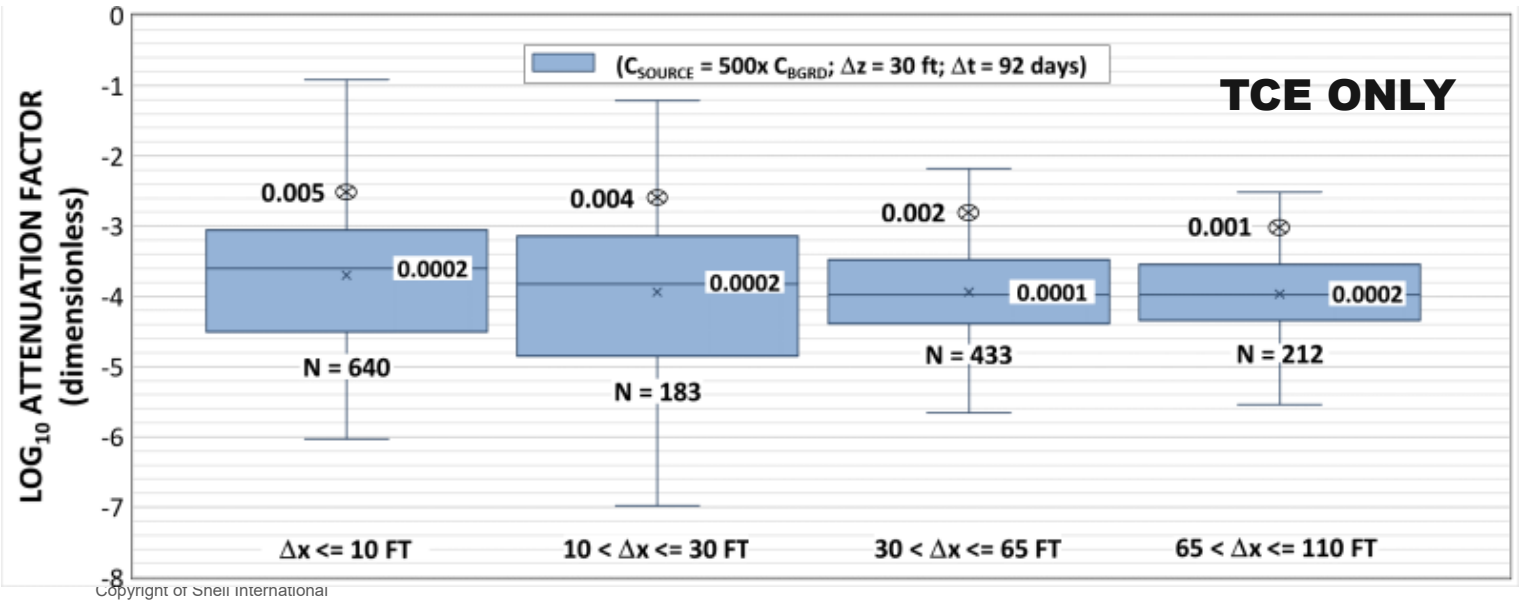


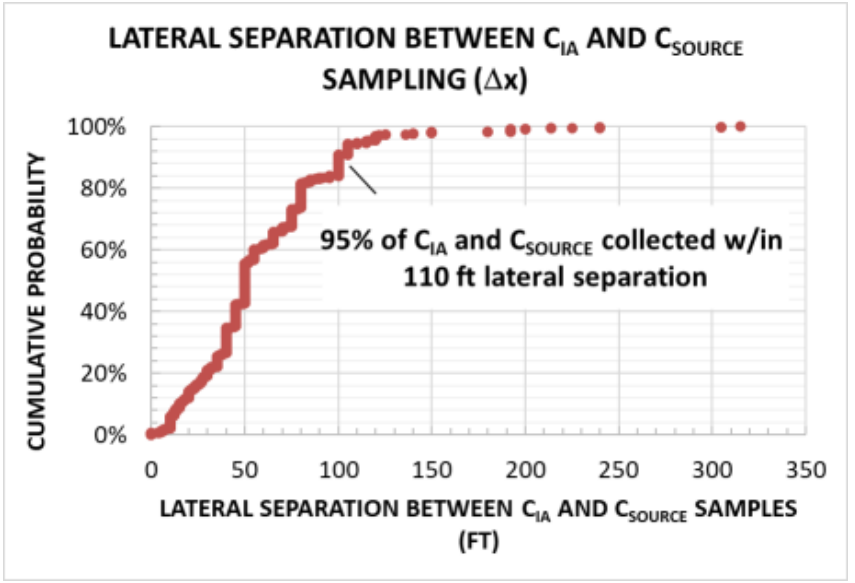
KEY POINT

- AF is relatively unaffected by inclusion of soil-gas data from 15 – 30 ft (small data population)
- median AFs based on soil-gas data decrease slightly with higher Δz (higher C_{SOURCE} concentrations at residential sites w/ GW sources)
- AFs based on soil-gas data are less variable than AFs based on sub-slab data

AFs Decrease Slightly w/ Increasing Δx



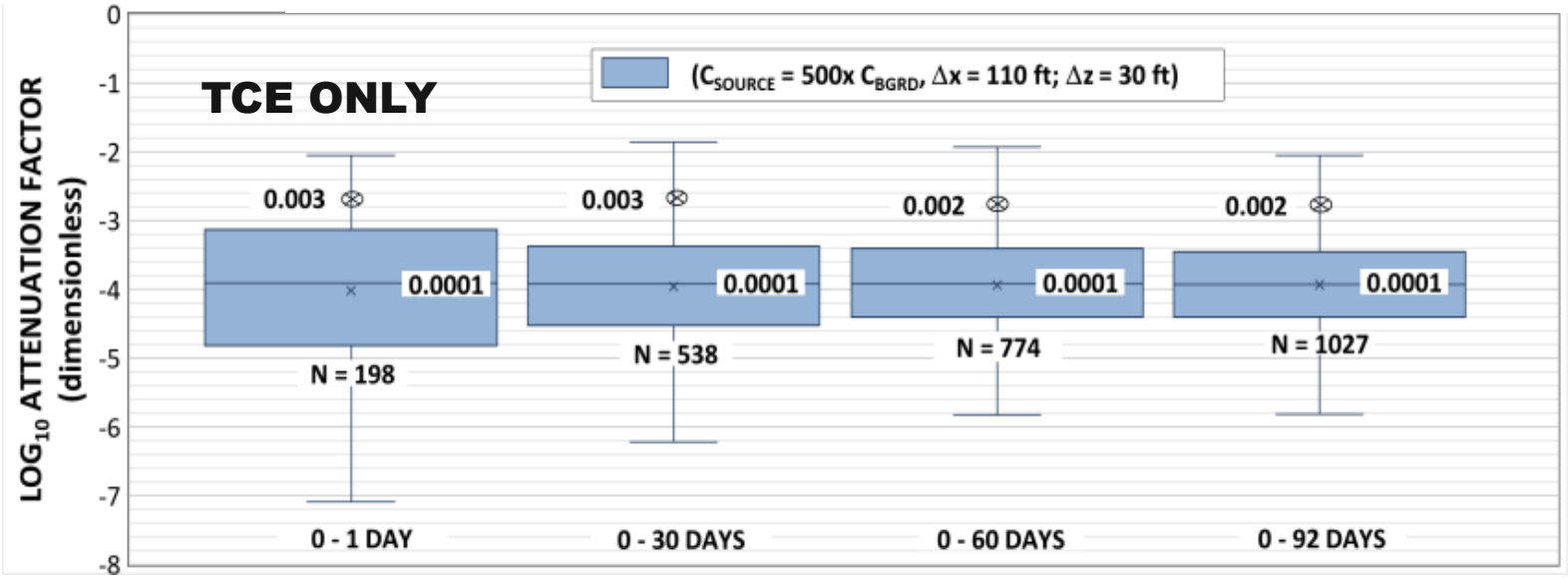


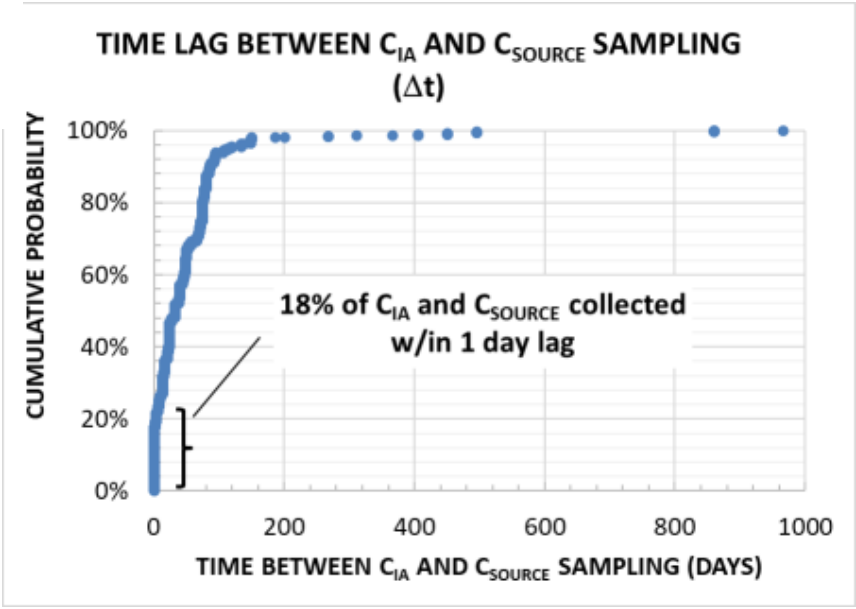


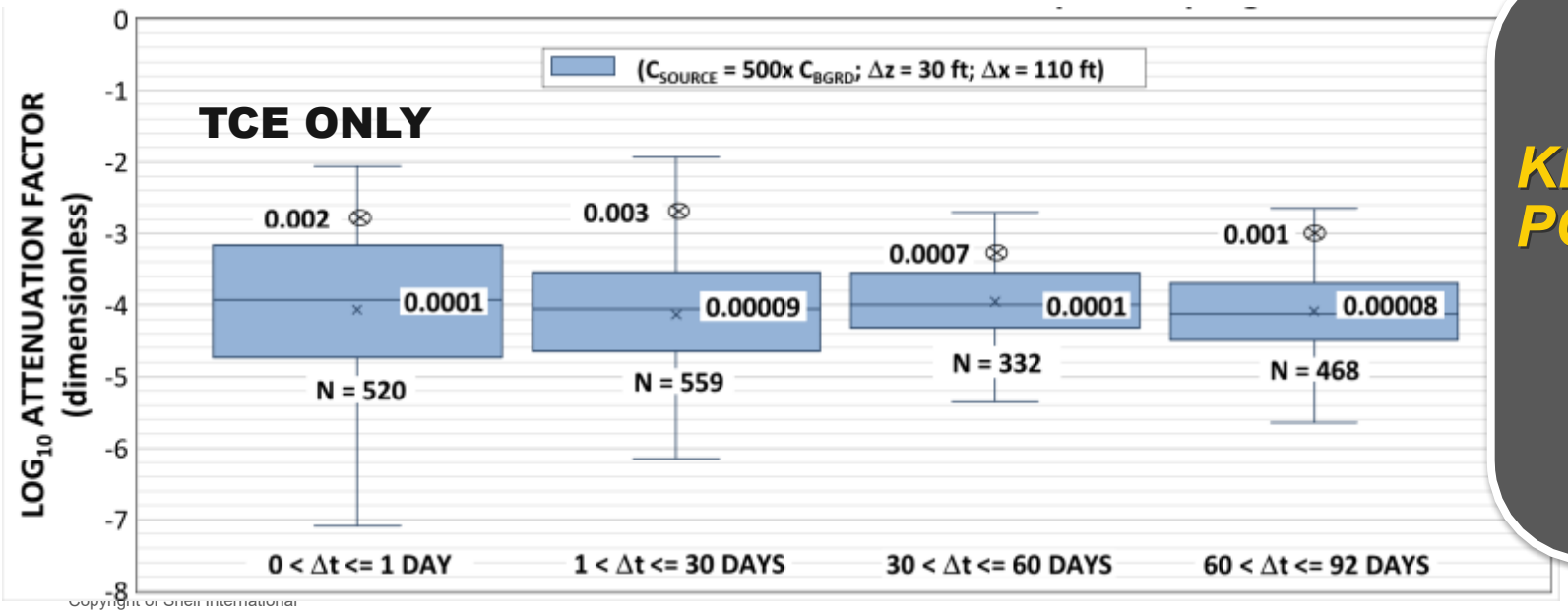
KEY POINT

- AFs decrease by ~2x with Δx > 30 ft; sharp C_{SOURCE} gradients at non-residential sites w/ shallow soil sources
- less variance in AFs for ΔX > 30 ft (higher % of soil-gas data)

AF Sensitivity to Δt



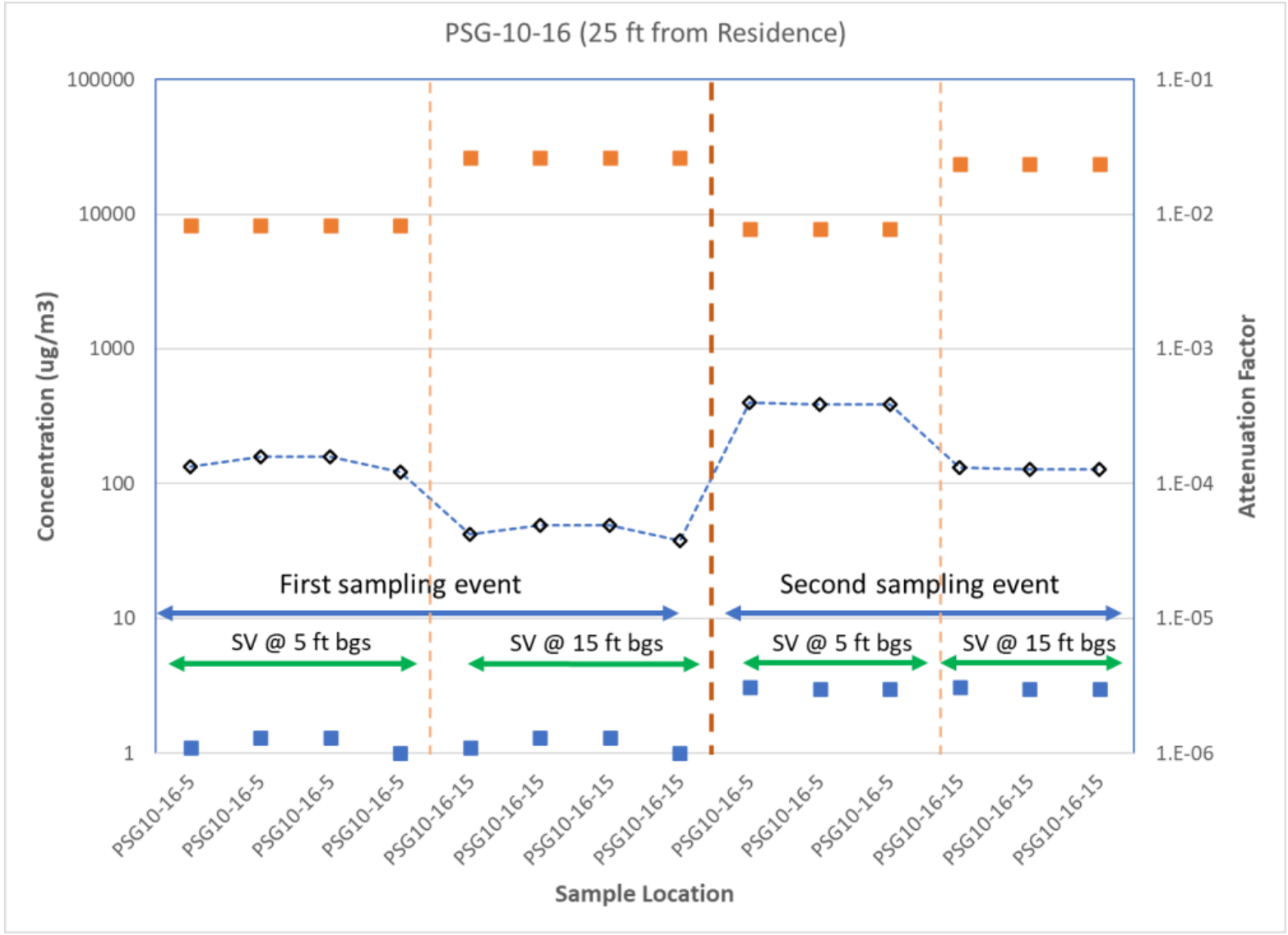




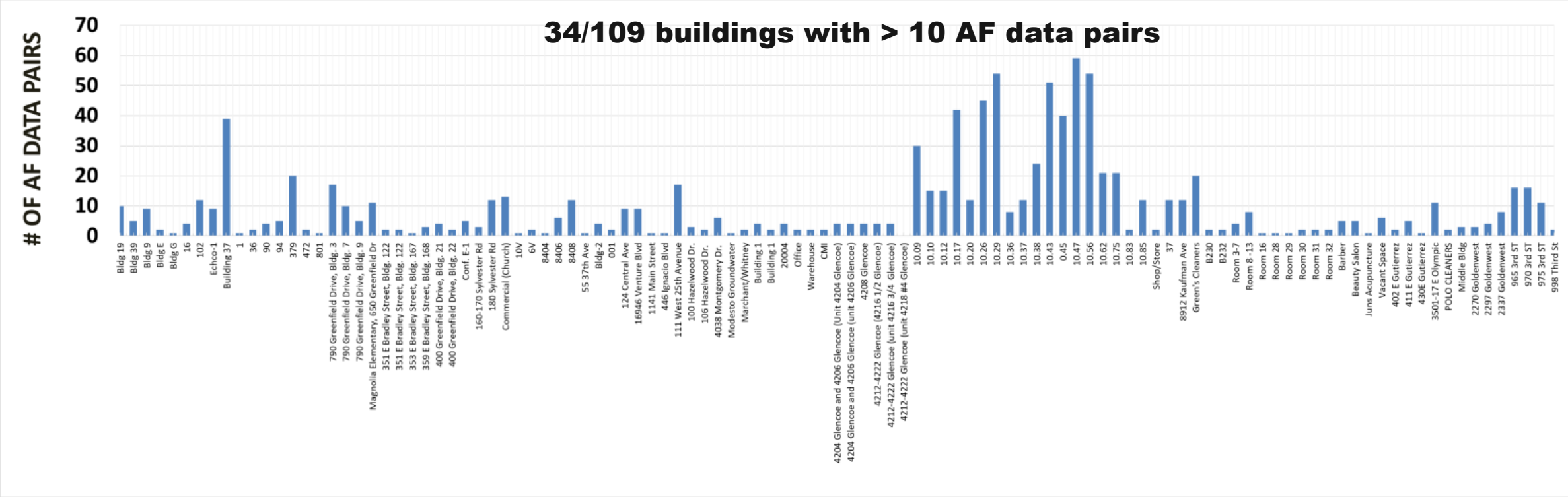
KEY POINT

- AF based on Δt = 1 day similar to AFs derived from data w/ greater Δt
- increased variance in AF w/ smaller Δt
- median and 95th %ile AFs are not generally sensitive to increasing Δt

C_{IA} Data Vary Little Over Time at Individual Residential Buildings – Same Site



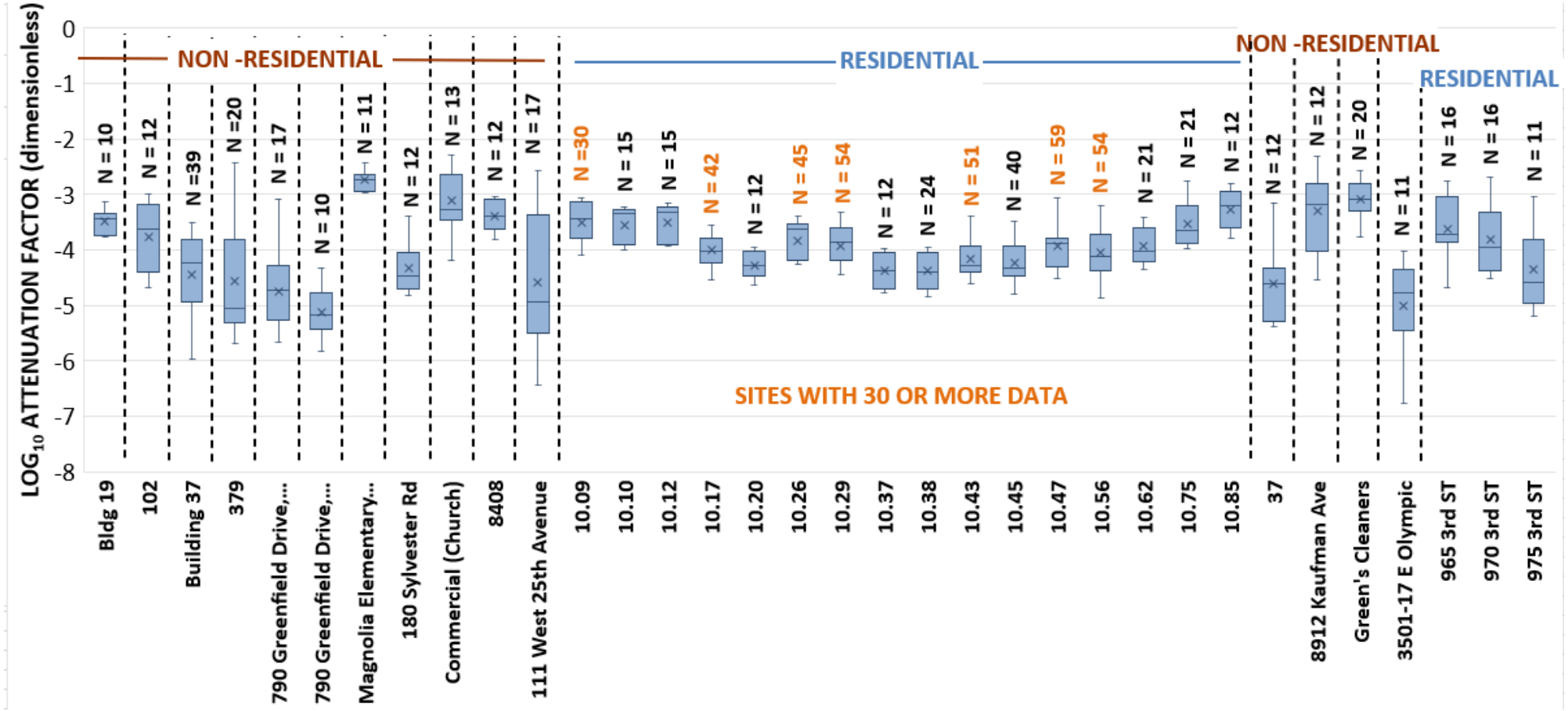
Multiple AF Data Pairs for Certain Buildings



KEY POINT

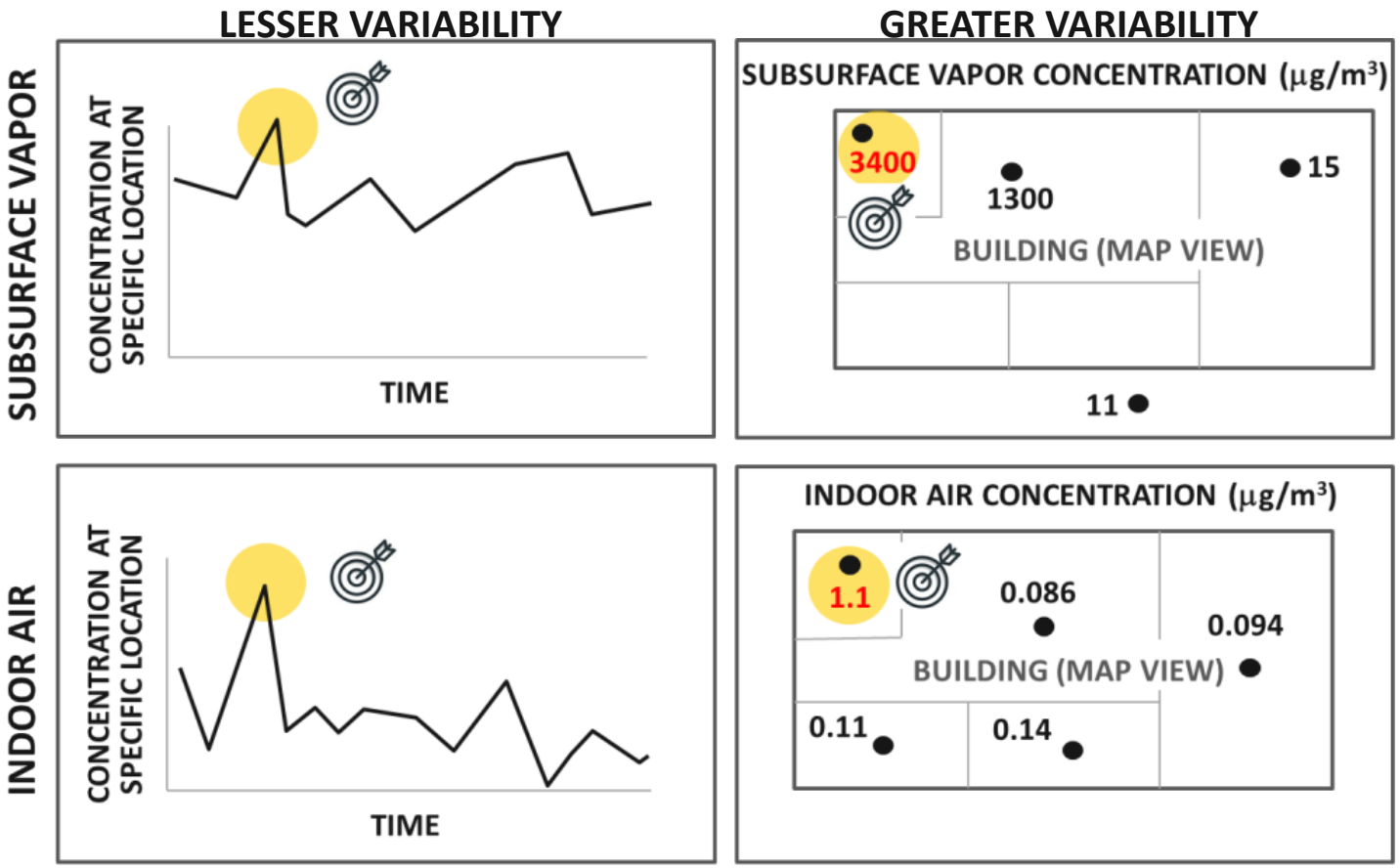
- AFs potentially weighted by certain buildings w/ multiple C_{IA} and C_{SOURCE} data pairs

AF Sensitivity to Individual Buildings/Sites



- AFs can vary by nearly 4 orders of magnitude for certain bldgs.(e.g., 111 West 25th Avenue)
- greater variance in AFs for non-residential vs. residential buildings
- similar variance in AFs for residential buildings at same site even though AFs varied by over an order of magnitude across the site

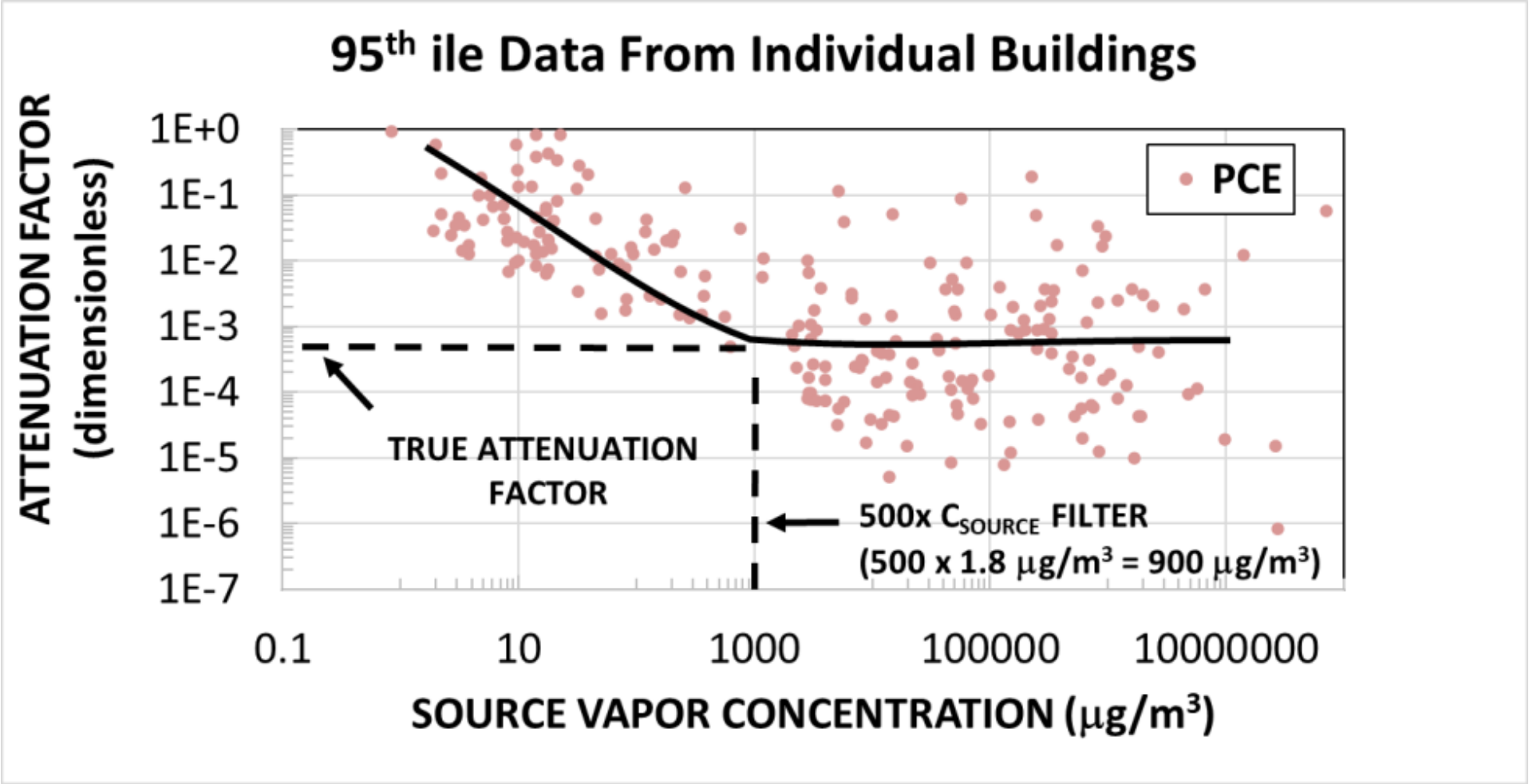
AFs Derived from Building Specific Data



- highest (maximum) C_{SOURCE} and C_{IA}:
  - expected to be co-located and concurrent
  - desirable for VI risk assessment and site screening
- building specific AFs cannot be derived from maximum C_{SOURCE} data because they are paired w/ multiple C_{IA} data and vice versa (i.e., does not address potential data pairing issue)
- building specific AFs can, however, be derived from 95th %ile C_{SOURCE} and C_{IA} data (no C_{SOURCE} and C_{IA} filtering)

KEY POINT **potential to address spatiotemporal variability caused by data pairing and align with aim of site screening by deriving AFs based on 95th %iles of C_{SOURCE} and C_{IA} data for individual buildings**

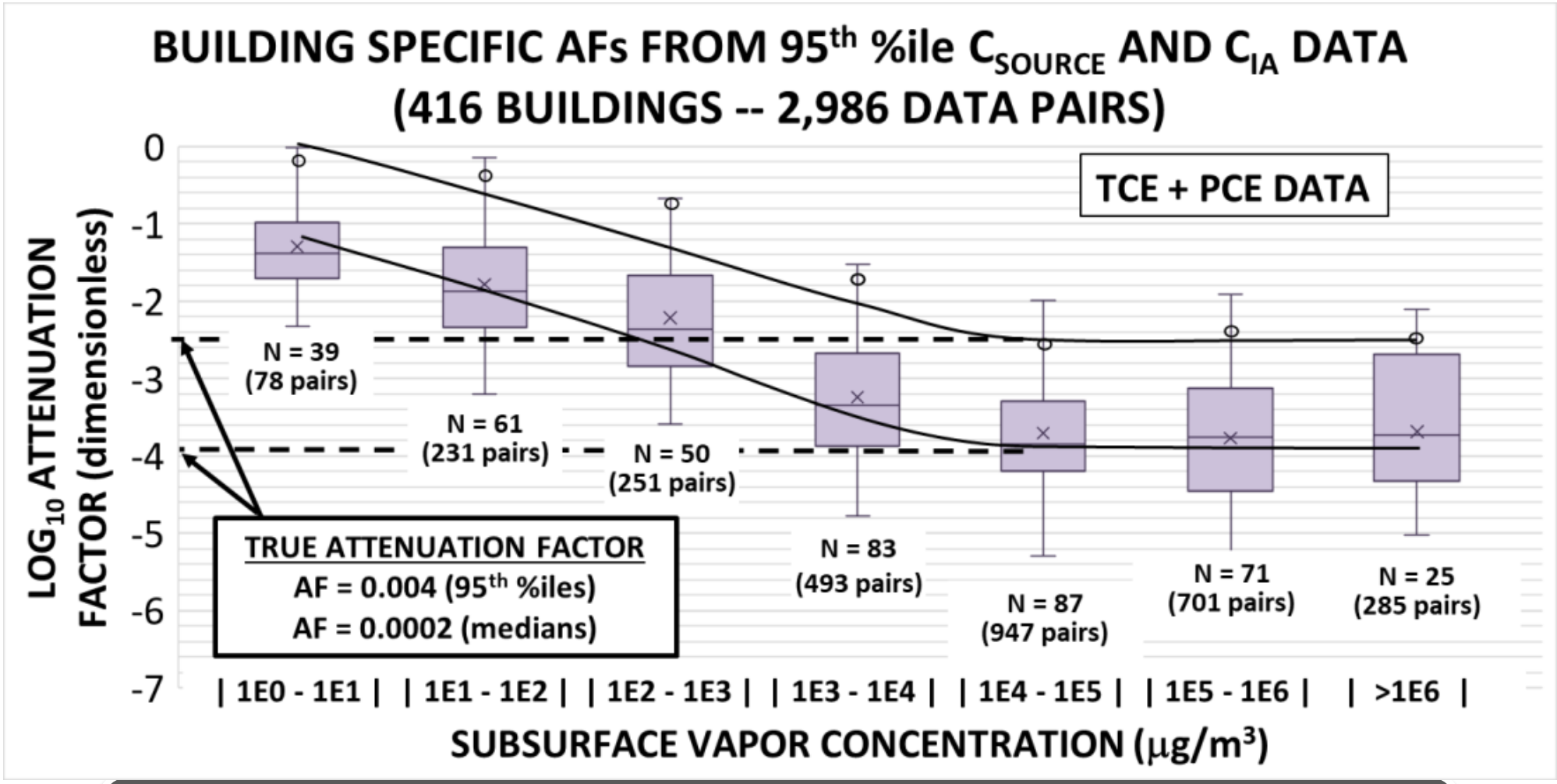
AF Sensitivity to Individual Buildings/Sites



KEY POINT

- **minimizing spatiotemporal variability for specific buildings results in AFs that better align with theory and supports a 500x multiplier for C_{SOURCE} filtering (e.g., PCE)**

AF Sensitivity to Individual Buildings/Sites



KEY POINT

- minimizing spatiotemporal variability for specific buildings results in AFs that match theory and range from 0.0002 to 0.004 depending on level of conservatism

Key Take Aways

- AFs are sensitive to C_{SOURCE} filtering; hence any C_{SOURCE} filtering must be technically defensible
- variables thought to be important for site screening (Δt, Δx, Δz) have little bearing on AF derivation (masked by spatiotemporal variabilities)
- greater variance is observed in AFs for non-residential vs. residential buildings (distribution of vapor source relative to building foundation)
- AF distributions (medians, 95th %iles, variance) are similar for residential buildings at same site even though AFs can vary 1 to 2 order of magnitude depending on where data are collected
- minimizing spatiotemporal variabilities in C_{SOURCE} and C_{IA} for specific buildings (removing background concentration filtering) results in
  - AFs that match theory and support filtering C_{SOURCE} < 500x 75th % of background $C_{IA,}$
  - AFs ranging from 0.0002 to 0.004 depending on degree of conservatism