# PM$_{2.5}$ FRM and FEM Network and Method Update
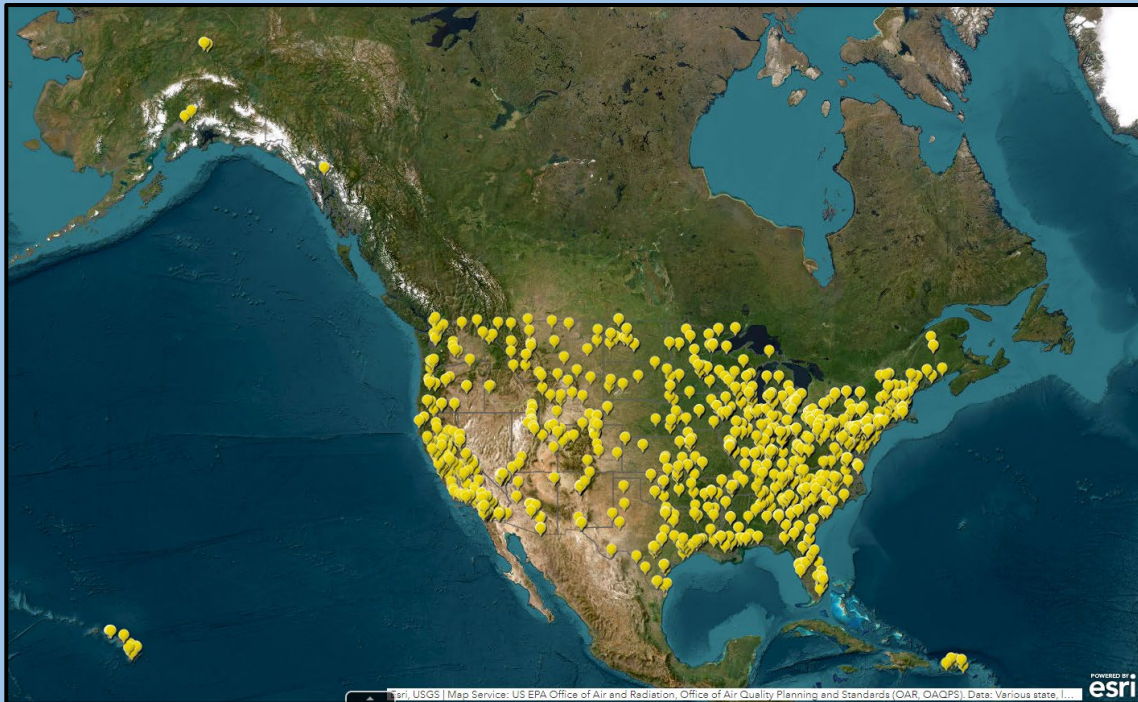
Tim Hanley - U.S. EPA, Office of Air Quality Planning and Standards

National Ambient Air Monitoring Conference, New Orleans LA, August 2024



**Federal Reference Methods (FRMs)**

- Manual filter-based method
- Results typically 2-4 weeks after sampling
- Gravimetric laboratory needed
- 24-hour sampling period

**Federal Equivalent Methods (FEMs)**

- Automated
- Hourly (at least) data available immediately following the end of an hour for near-time reporting of data
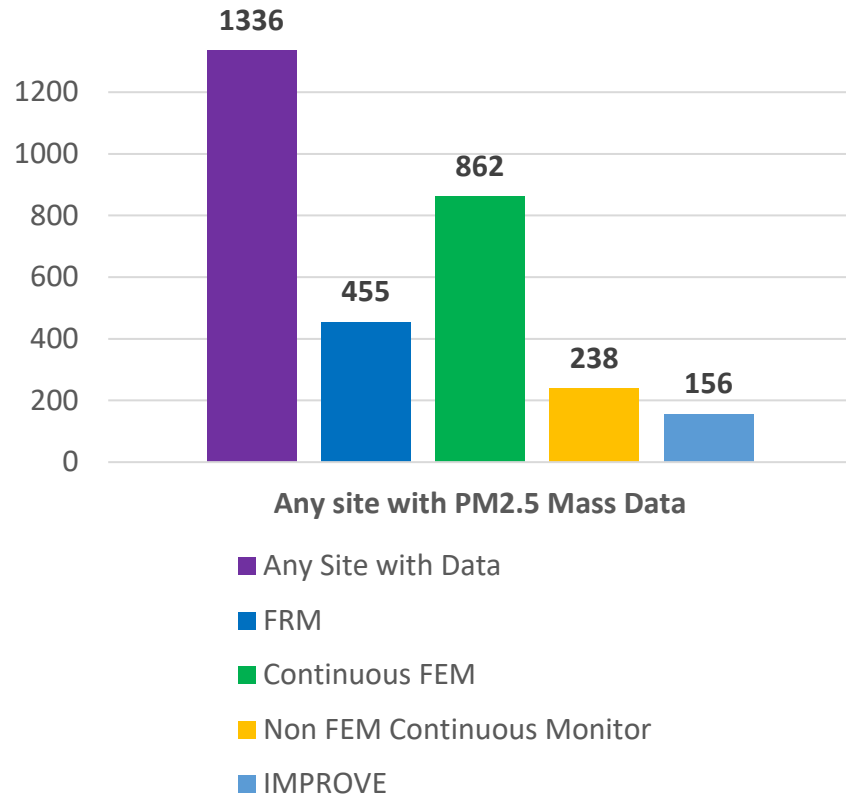
# Highlights of PM$_{2.5}$ Network and Methods Topics in the last few years.
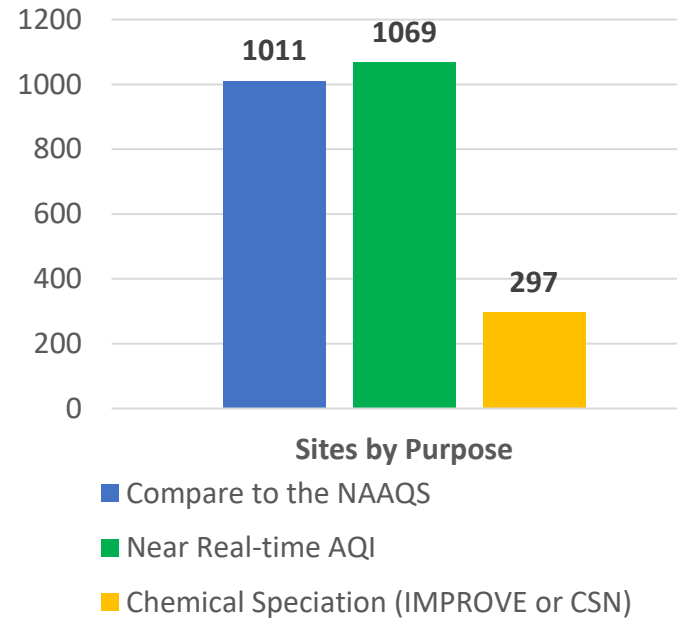
- **<u>Grant Funding</u>** - 2022 – U.S. EPA distributes $22.5M in American Rescue Plan funds to States, locals, and Tribes.
  - Approximately 33% of the $22.5 million is being used for upgrading or supplementing manual PM$_{2.5}$ samplers with continuous PM$_{2.5}$ analyzers across the national network, providing more frequent and higher-time resolution measurements of PM$_{2.5}$ concentrations

- **<u>Teledyne Update:</u>**
  - April 2023 – Teledyne update for T640 and T640x PM FEMs approved by EPA-ORD Reference and Equivalency Program
  - June 2023 – Network Data Alignment update available in firmware release by Teledyne
  - June – December 2023 – All U.S. T640/T640x PM Primary monitors are upgraded in the field with the Network Data Alignment.
  - May 2024 – EPA announces data correction of historical Teledyne T640 and T640x data PM$_{2.5}$ FEM data

- **<u>PM$_{2.5}$ NAAQS</u>** - February 7, 2024, the U.S. EPA strengthened the National Ambient Air Quality Standards (NAAQS) for fine particle pollution (PM$_{2.5}$) by revising the level of the primary (health-based) annual PM$_{2.5}$ standard to 9.0 micrograms per cubic meter (µg/m$^3$ ). EPA retained the primary 24-hour PM$_{2.5}$ standard, with its level of 35 µg/m$^3$
  - To enhance protection of air quality in communities subject to disproportionate air pollution risk, EPA modified the PM$_{2.5}$ monitoring network design criteria to include an environmental justice factor. This factor will account for proximity of populations at increased risk of PM$_{2.5}$-related health effects to air pollution sources of concern.

# Types of PM$_{2.5}$ Monitors or Sites operating across the Country Reporting to AQS
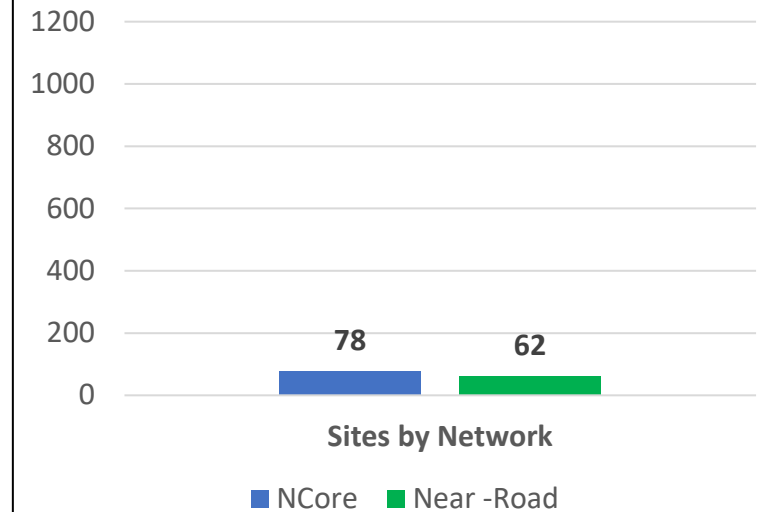
## Number of Sites with a PM$_{2.5}$ Monitor or Sampler

Any site with PM2.5 Mass Data

- Any Site with Data: 1336
- FRM: 455
- Continuous FEM: 862
- Non FEM Continuous Monitor: 238
- IMPROVE: 156

## Number of PM$_{2.5}$ Sites by Major Monitoring Objective

Sites by Purpose

- Compare to the NAAQS: 1011
- Near Real-time AQI: 1069
- Chemical Speciation (IMPROVE or CSN): 297

## Multi-pollutant Networks with PM$_{2.5}$ NAAQS comparable measurements

Sites by Network

- NCore: 78
- Near -Road: 62



EPA

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# Contrasting reporting of PM$_{2.5}$ Federal Reference Methods (FRMs) and continuous Federal Equivalent Methods (FEMs) to AQS by Year and Site



**Number of PM$_{2.5}$ Sites reported to AQS by Year and Method Type (i.e., FRM or continuous FEM)**

*Addition of ARP direct award funds expected to accelerate migration to continuous FEMs*

Frist continuous PM2.5 monitor designated as FEM (3/2008)

Legend: ─── FRMs (and any filter-based FEM, i.e., dichot)  ─── Continuous FEMs  ▪▪▪ Total number of sites
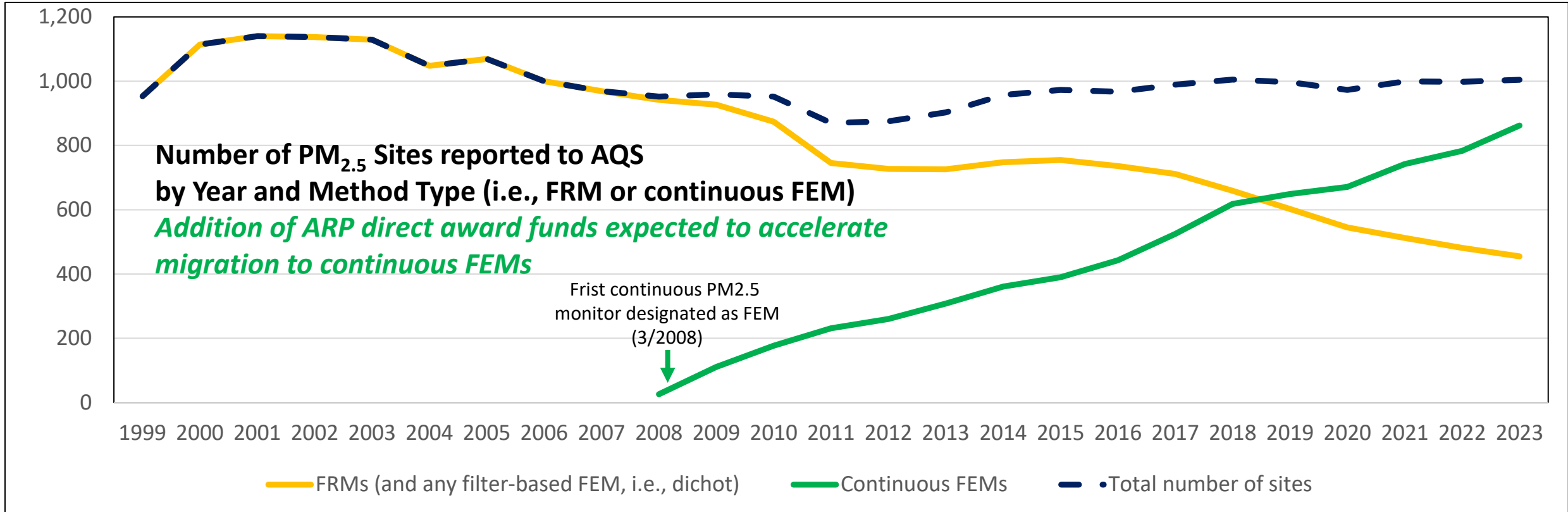
| Description or Metric | Year(s) | FRMs | Continuous FEMs | Notes |
|---|---|---|---|---|
| Total operating sites with an FRM or FEM | 2023 | 455 | 862 | Total overall number of sites including collocation = 1,011 |
| Total sample days reported | | 63,204 | 301,071 | 39,315 collocated days |
| Required sample frequency | - | Typically - 1:3 | Daily | Site can be required to go to daily if near the 24-hour NAAQS; sites can go to 1:6 under certain provisions |

# PM$_{2.5}$ NAAQS Sites with count of Data Days for 2023
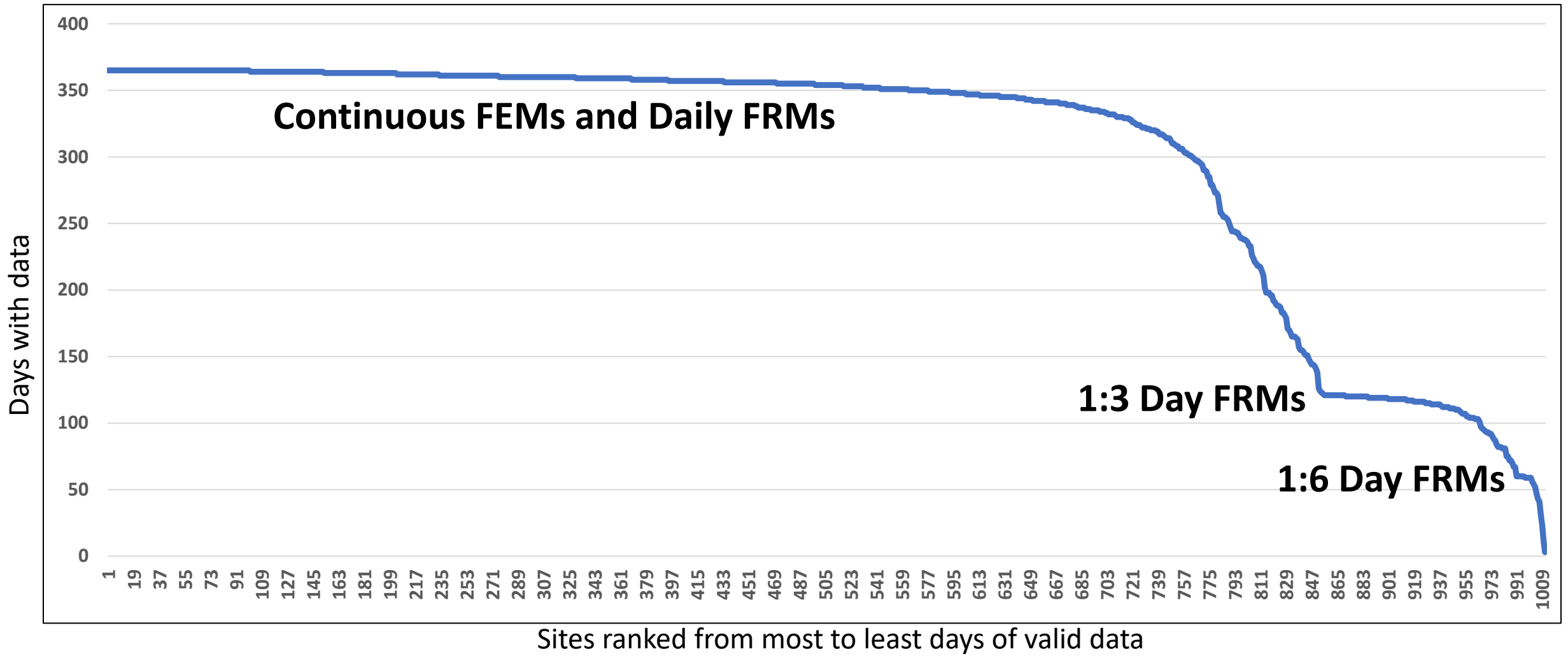
# Three Types of PM$_{2.5}$ Data are produced using Federal Reference Methods (FRMs) and Federal Equivalent Methods (FEMs)

Commonly used
Federal Reference Methods (FRMs)

**BGI PM$_{2.5}$ FRM Single Channel Sampler**

**Met One PM$_{2.5}$ FRM E-SEQ Sequential Sampler**

**Thermo PM$_{2.5}$ FRM Sequential Sampler**



**Primary Monitors produce data intended to be compared to the National Ambient Air Quality Standards (NAAQS) and other data uses. Primary monitors can be either FRMs or continuous FEMs.**

**Collocated Samplers and Monitors produce data used in Quality Assurance and Quality Control (QA/QC) calculations**
- e.g., Collocated Precision is used to determine if the precision Measurement Quality Objective (MQO) is met by using methods with the same make and model

**Performance Evaluation Program (PEP) FRMs produce data to independently assess if Primary monitors are meeting the bias MQOs**
- PEP FRM|State/Local/Tribal Primary FRM or FEM
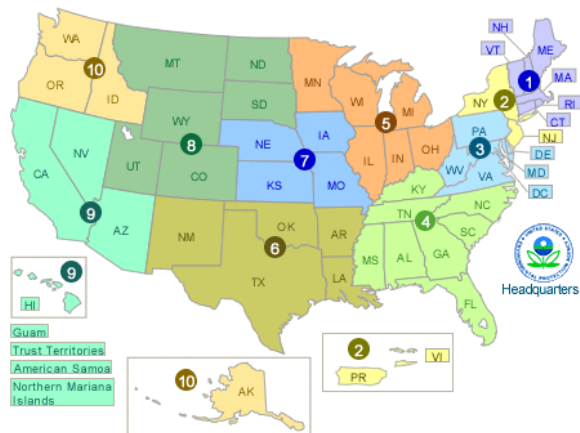
Commonly used
Federal Equivalent Methods (FEMs)

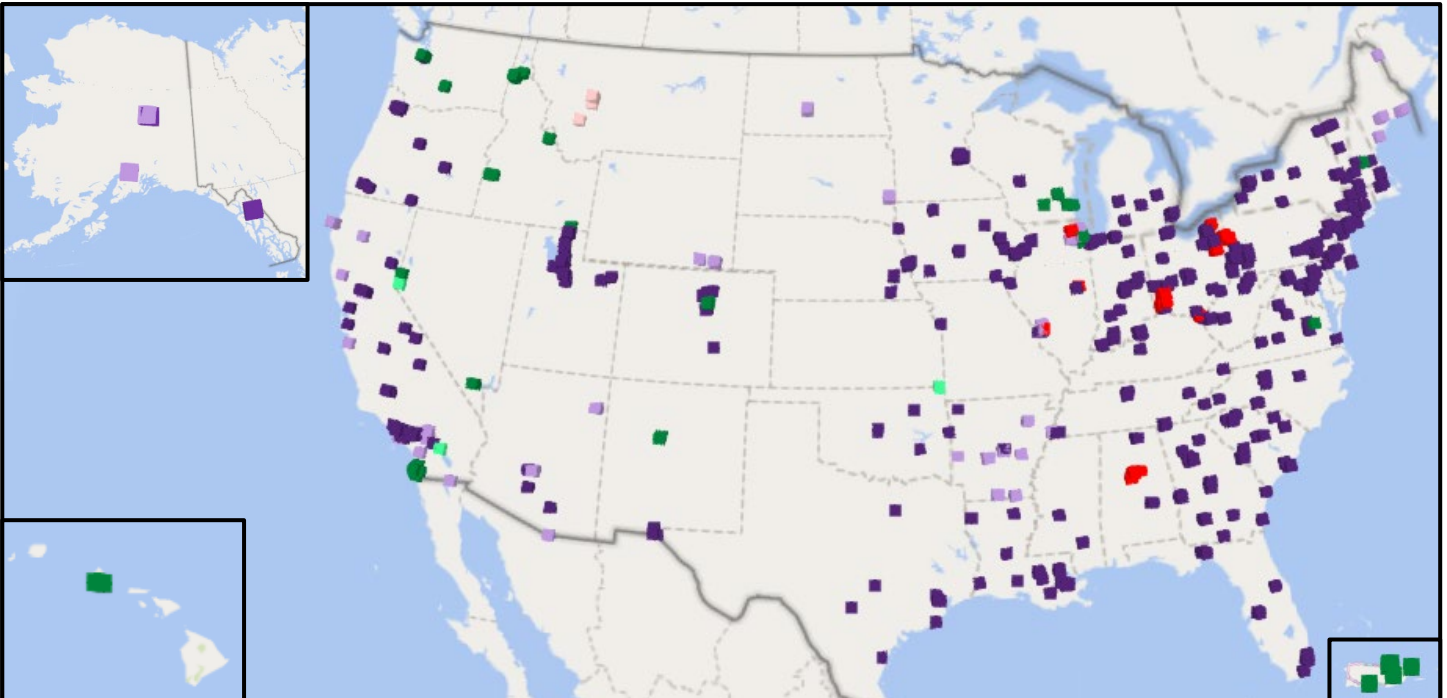**Met One BAM 1020 FEM**

**Met One BAM 1022 FEM**

**Teledyne-API T640/T640x FEM**



**PEP FRM Data**
- Largely run out of each EPA Regional office Lab
- Several hundred data points per year across the country
- FRMs are temporarily set up to run on the same period as the State, Local, or Tribal (SLT) primary monitor

**FRMs**

- BGI PQ200 w/VSCC
- BGI PQ200 w/WINS
- Met One E-FRM w/VSCC
- Met One E-SEQ-FRM w/VSCC
- R & P 2000 w/VSCC
- R & P 2000 w/WINS
- R & P 2025 w/VSCC

**Network of PM$_{2.5}$ FRMs**

- Primary Samplers
- FRMs at National Core Network (NCore)
- Collocated QA FRMs
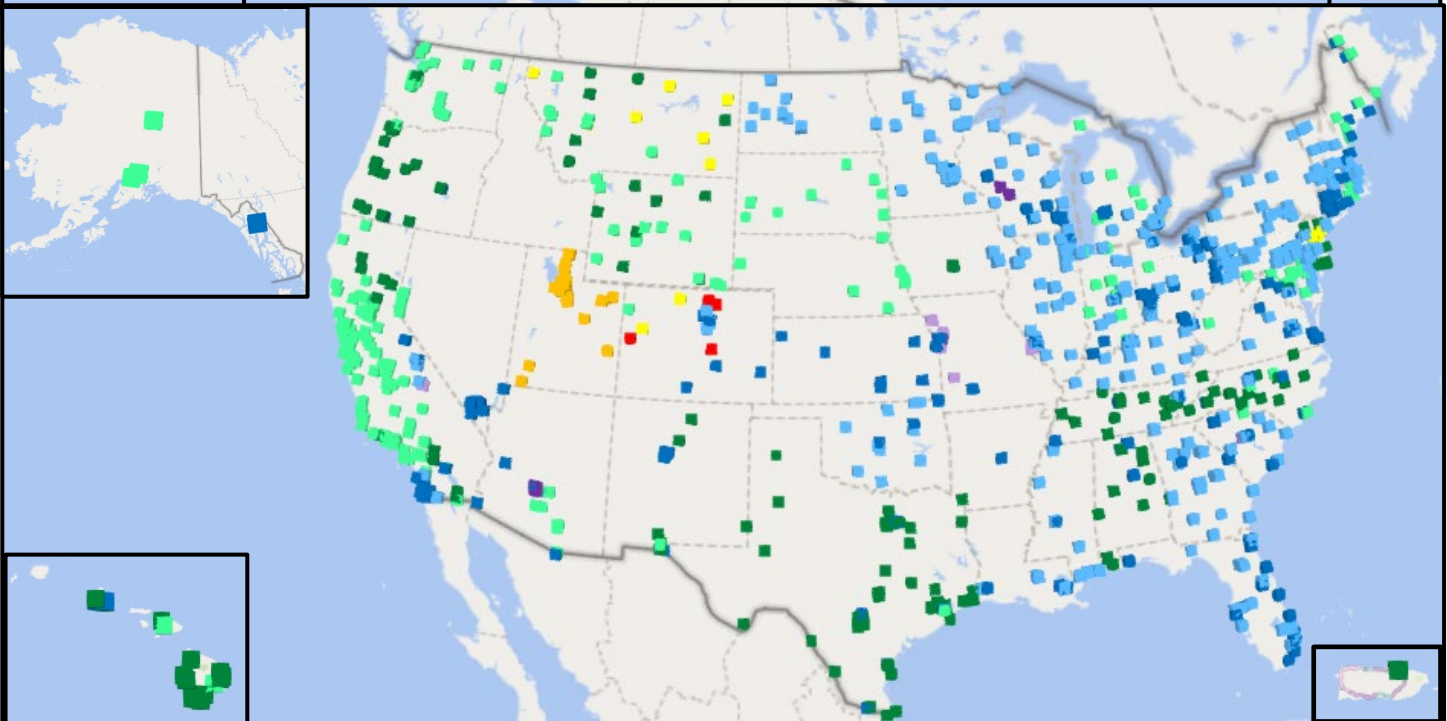
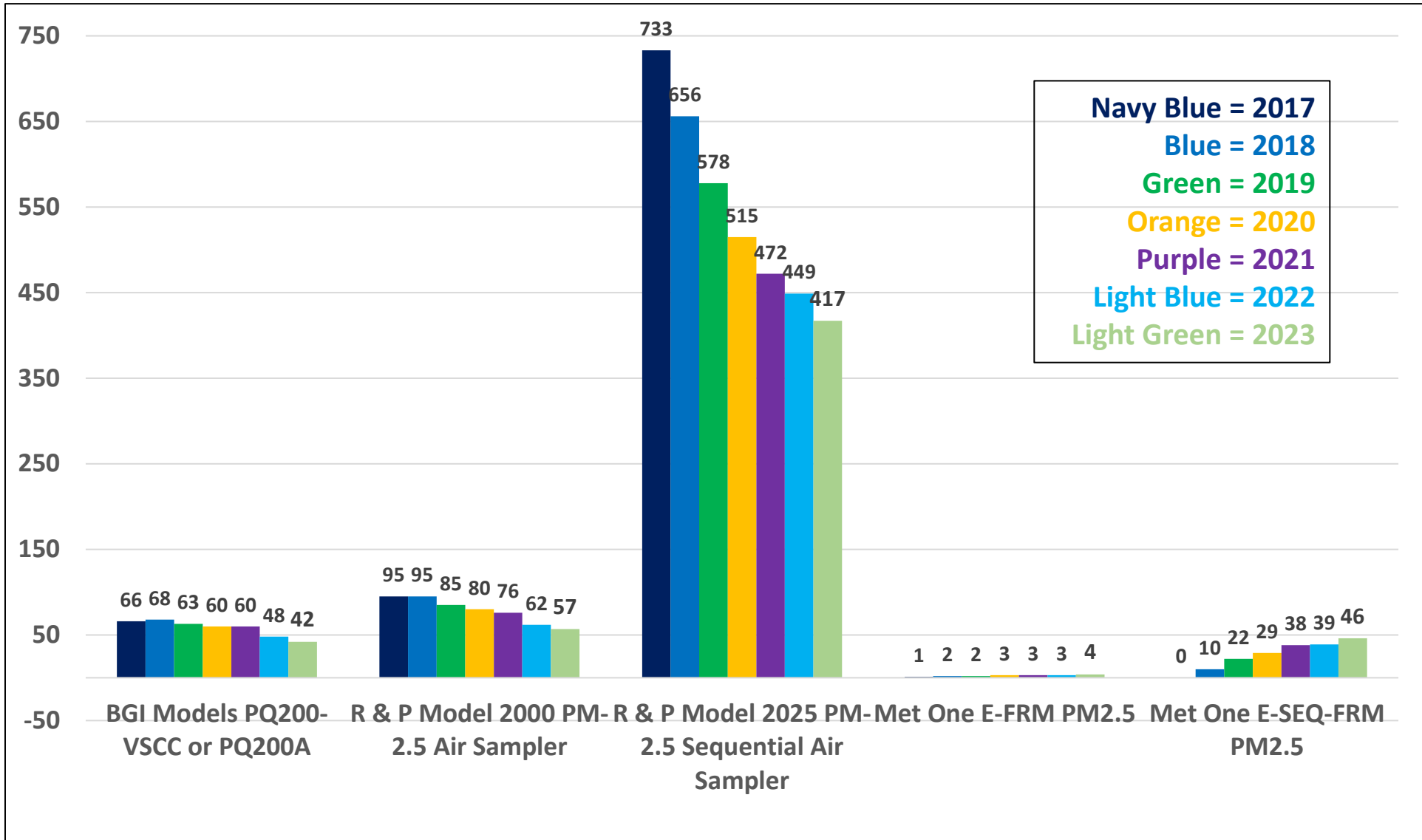**FEMs**

- GRIMM EDM 180
- Met One BAM-1020
- Met One BAM-1022
- Teledyne T640
- Teledyne T640X
- Thermo TEOM 1400 FDMS or 1405 8500C
- Thermo 1405-F FDMS
- Thermo 5014i - Beta Attenuation
- Thermo 5030 SHARP- Beta Attenuation
- Thermo TEOM 1405-DF Dichot FDMS

**Network of PM$_{2.5}$ Continuous FEMs**

- Primary Samplers
- Air Quality Index (AQI) monitors
- Collocated FEMs

PM$_{2.5}$ FRMs Reporting to EPA's Air Quality System (AQS)
- Comparing last several years. *(any method reporting at a site in a year)*

Navy Blue = 2017
Blue = 2018
Green = 2019
Orange = 2020
Purple = 2021
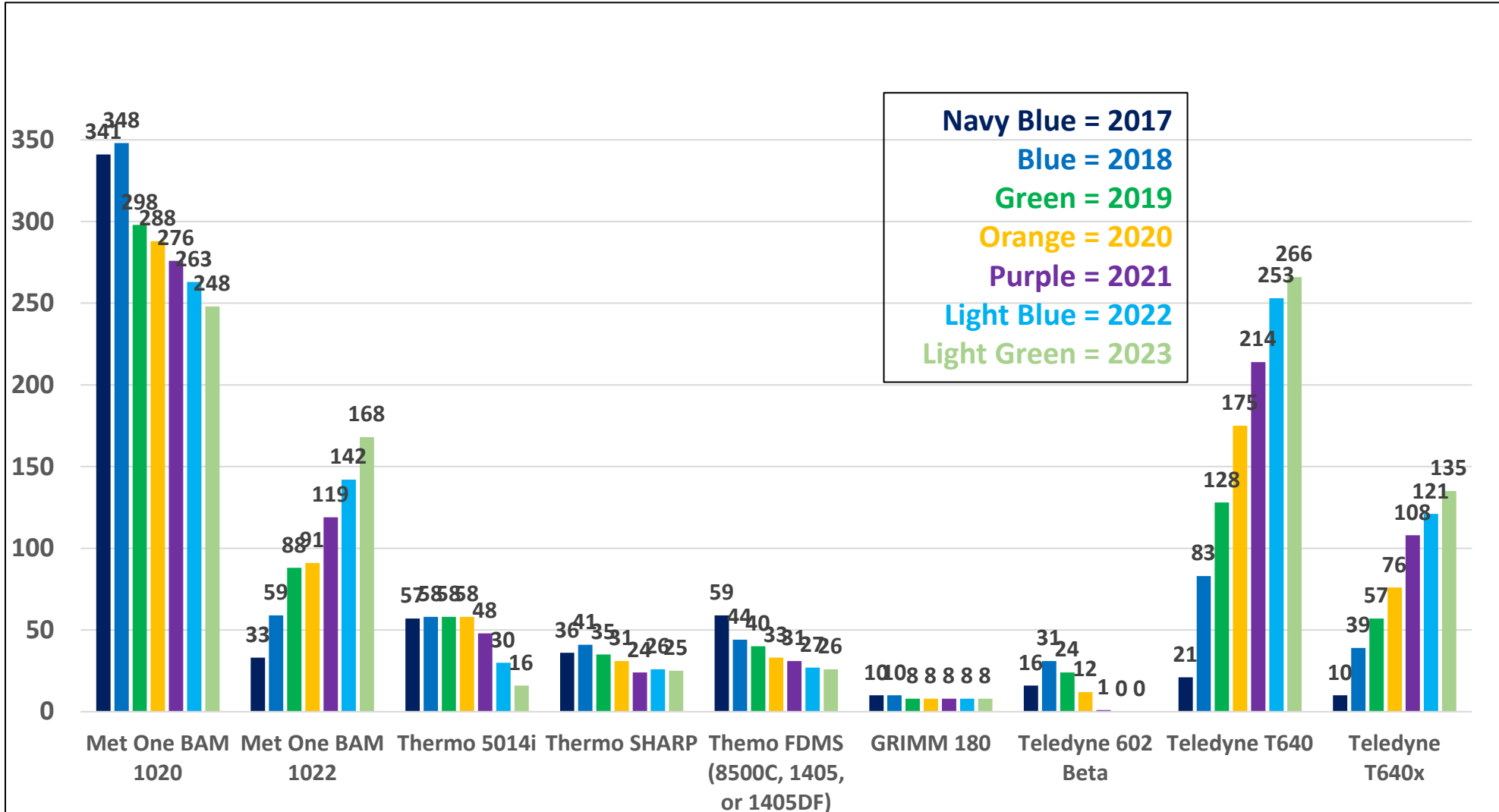Light Blue = 2022
Light Green = 2023

For 2023, three manufactures have FRMs in the national network, with two companies offering sequential FRMs and all three offering single day FRMs:
- Sequential day FRM instruments:
  - Thermo 2025
  - Met One E-SEQ
- Single day FRM instruments:
  - BGI PQ200
  - Thermo 2000
  - Met One E-FRM

# PM$_{2.5}$ Continuous FEMs Reporting to AQS parameter code 88101 - Comparing last several years. *(any method reporting at a site in a year)*



Legend:
- **Navy Blue = 2017**
- **Blue = 2018**
- **Green = 2019**
- **Orange = 2020**
- **Purple = 2021**
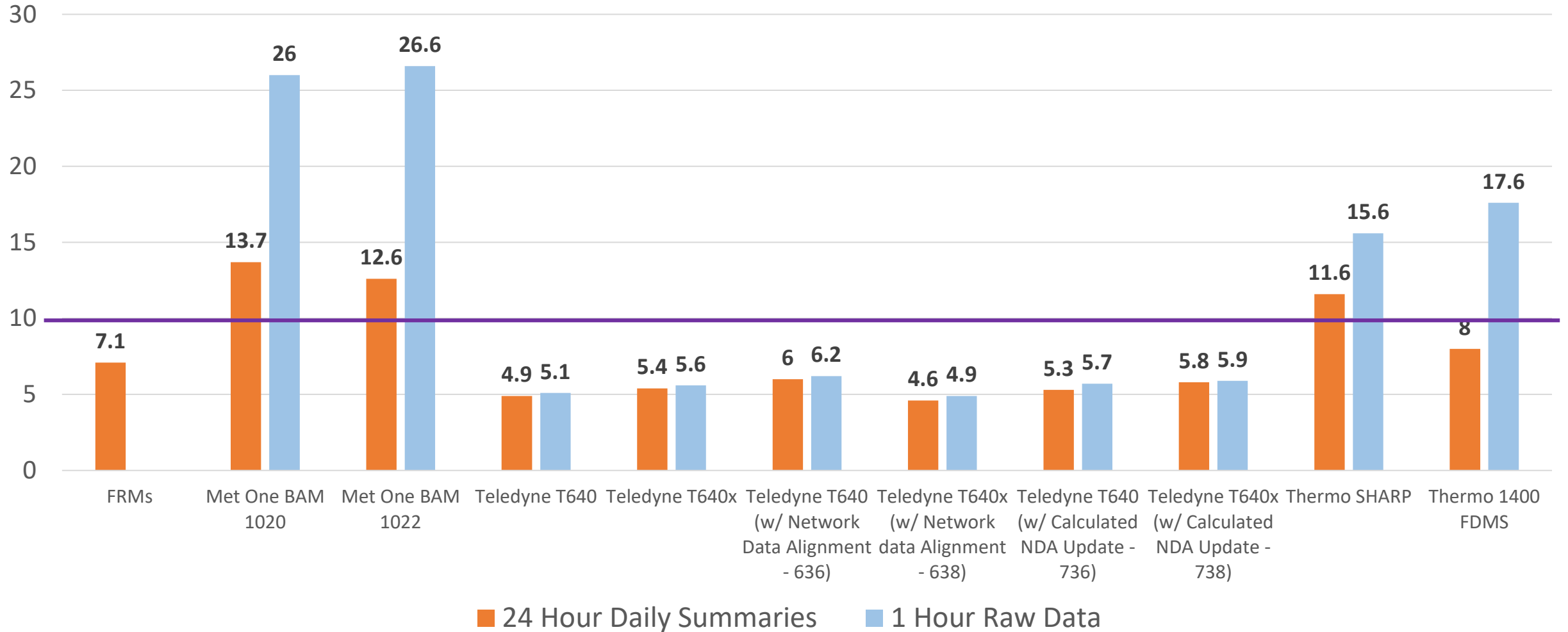- **Light Blue = 2022**
- **Light Green = 2023**

**For 2023, two Companies with four models dominate the market (total of 92%):**
- **Met One:**
  - **BAM 1020 – 28%**
  - **BAM 1022 – 19%**
- **Teledyne:**
  - **T640 – 30%**
  - **T640x – 15%**

2023 Collocated Precision
PM$_{2.5}$ FRM and Continuous FEMs with Collocated Data
*(updated on 8/1/24; daily (24-hour) and raw (hourly) data used in Precision Assessments)*

*Data assessed with Appendix A equations as of May 1, 2024*

# What is the PM$_{2.5}$ continuous FEM data quality for 2021 - 2023?

*(updated 8/9/2024)*

**EPA's Performance Evaluation Program (PEP) Audits provide PM$_{2.5}$ Method Specific Bias (most widely used continuous FEMs provided)**
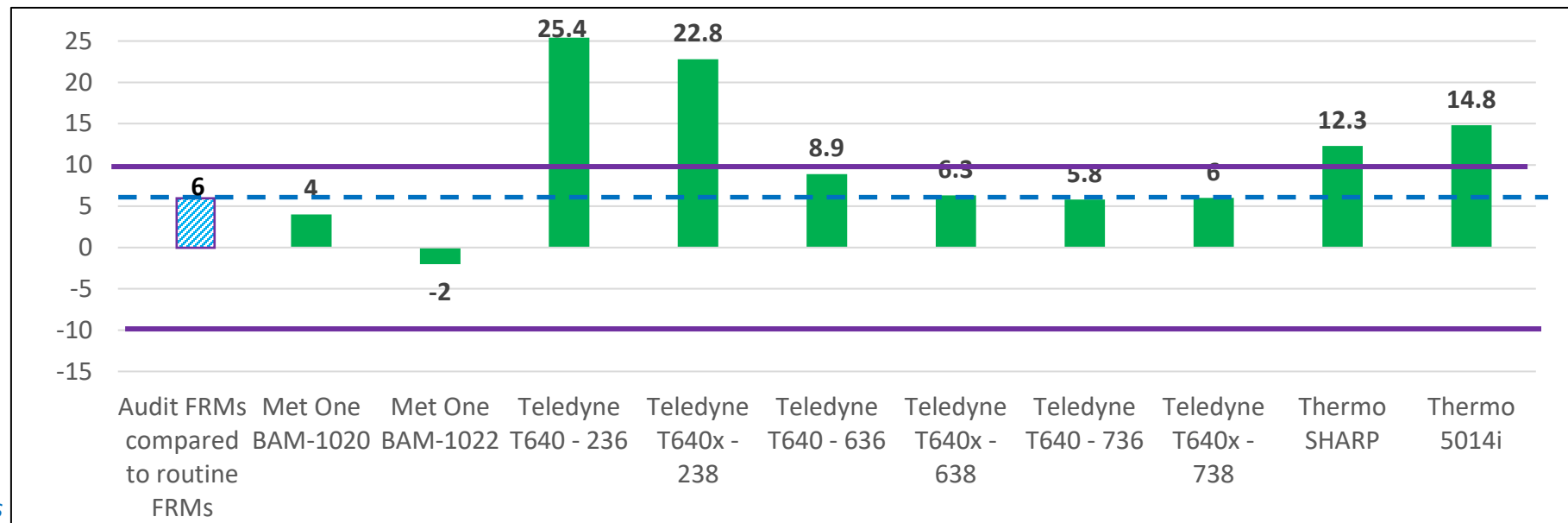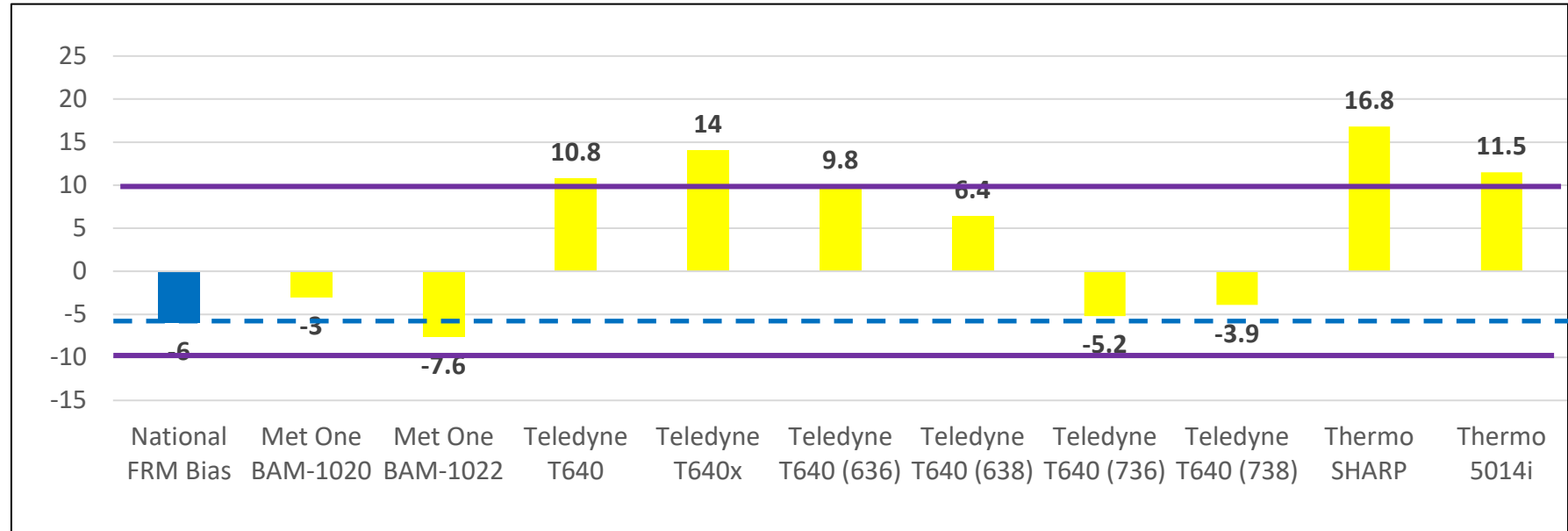*Tens to hundreds of datapoints per method across the country*
[Using App A PEP equations in place as of May 1, 2024; >=3.0 ugm3; pulling in all collocated data; for 736 and 738 using cases with collocated T]

T640 (236) = conventional PM2.5 FEM
T640x (238) = conventional PM2.5/PM10/PM10-2.5 FEM
T640 (636) = Field upgrade to Network Data Alignment PM2.5 FEM
T640x (638) = Field upgrade to Network Data Alignment PM2.5/PM10/PM10-2.5 FEM
T640 (736) = AQS Calculated Network Data Alignment PM2.5 FEM
T640x (738) = AQS Calculated Network Data Alignment PM2.5/PM10/PM10-2.5 FEM

**SLT collocation for FRM to FEM bias (most widely used continuous FEMs provided)**
*Hundreds to thousands of datapoints per method across the country*

*Note: Blue dashed line represents SLT FRM mean bias*

**Top chart (PEP Audits):**

| Method | Bias |
|---|---|
| National FRM Bias | -6 |
| Met One BAM-1020 | -3 |
| Met One BAM-1022 | -7.6 |
| Teledyne T640 | 10.8 |
| Teledyne T640x | 14 |
| Teledyne T640 (636) | 9.8 |
| Teledyne T640 (638) | 6.4 |
| Teledyne T640 (736) | -5.2 |
| Teledyne T640 (738) | -3.9 |
| Thermo SHARP | 16.8 |
| Thermo 5014i | 11.5 |

**Bottom chart (SLT collocation):**

| Method | Bias |
|---|---|
| Audit FRMs compared to routine FRMs | 6 |
| Met One BAM-1020 | 4 |
| Met One BAM-1022 | -2 |
| Teledyne T640 - 236 | 25.4 |
| Teledyne T640x - 238 | 22.8 |
| Teledyne T640 - 636 | 8.9 |
| Teledyne T640x - 638 | 6.3 |
| Teledyne T640 - 736 | 5.8 |
| Teledyne T640x - 738 | 6 |
| Thermo SHARP | 12.3 |
| Thermo 5014i | 14.8 |

# Summarizing PM$_{2.5}$ Federal Reference Method (FRM) and most widely used continuous Federal Equivalent Methods (FEMs) Data Quality (2021 – 2023)

| Method | Notes | Collocated Precision (2023 only) (values >=3 µg/m³) (%) | Bias to PEP audits (values >=3 µg/m³) (%) | Bias to SLT FRM (values >=3 µg/m³) (%) |
|---|---|---|---|---|
| FRMs | All FRM's included, even if not primary | 7.1 | -6.0 | - |
| BAM 1020 | | 13.7 | -3.0 | 4.0 |
| BAM 1022 | | 12.6 | -7.6 | -2.0 |
| Teledyne T640 (236) (conventional method) | Data is all of 2021 and 2022 with mostly the first half of 2023 | 4.9 | 10.8 | 25.4 |
| Teledyne T640x (238) (conventional method) | | 5.4 | 14.0 | 22.8 |
| Teledyne T640 (636) (w/ Network Data Alignment) | Most monitors were updated in Summer to Fall 2023; therefore, this data is largely the second half of 2023 | 6.0 | 9.8 | 8.9 |
| Teledyne T640x (638) (w/ Network Data Alignment) | | 4.6 | 6.4 | 6.3 |
| Teledyne T640 (736) (recalculated data) | These are the data recalculated in AQS for those cases where a valid collocated Outdoor Temperature was available | 5.3 | -5.2 | 5.8 |
| Teledyne T640x (738) (recalculated data) | | 5.8 | -3.9 | 6.0 |
| Thermo SHARP | | 11.6 | 16.8 | 12.3 |
| Thermo 5014i | | NA | 11.5 | 14.8 |

Note: The goal for acceptable measurement uncertainty is defined for precision as an upper 90 percent confidence limit for the coefficient of variation (CV) of 10 percent and ±10 percent for total bias. These goals are applied across a PQAO.

**Editorial – We have the most confidence in FEM methods where the bias is in control for both the PEP audits and collocated SLT run FRMs**

# Summary of $PM_{2.5}$ continuous FEMs and FRMs status and data quality

- Use of $PM_{2.5}$ continuous FEMs is dominated by two companies with a total of four methods (86% of the operating network):
  - Met One BAM 1020 and BAM 1022
  - Teledyne API T640 and T640x
- EPA has implemented a data correction to historical $PM_{2.5}$ data from Teledyne T640 and T640x monitors in the AQS database. Both original and updated data will remain available.
  - All downstream reports and assessments should be updated
- Recommend monitoring agencies assess their FRM and continuous FEM data quality and for cases where they may have one of more sites with outliers (relative to data in other agencies) pursue additional support and training as needed.
- Please pursue training at all levels available (e.g., instrument companies, workshops, and conferences…)

# Questions and Discussion

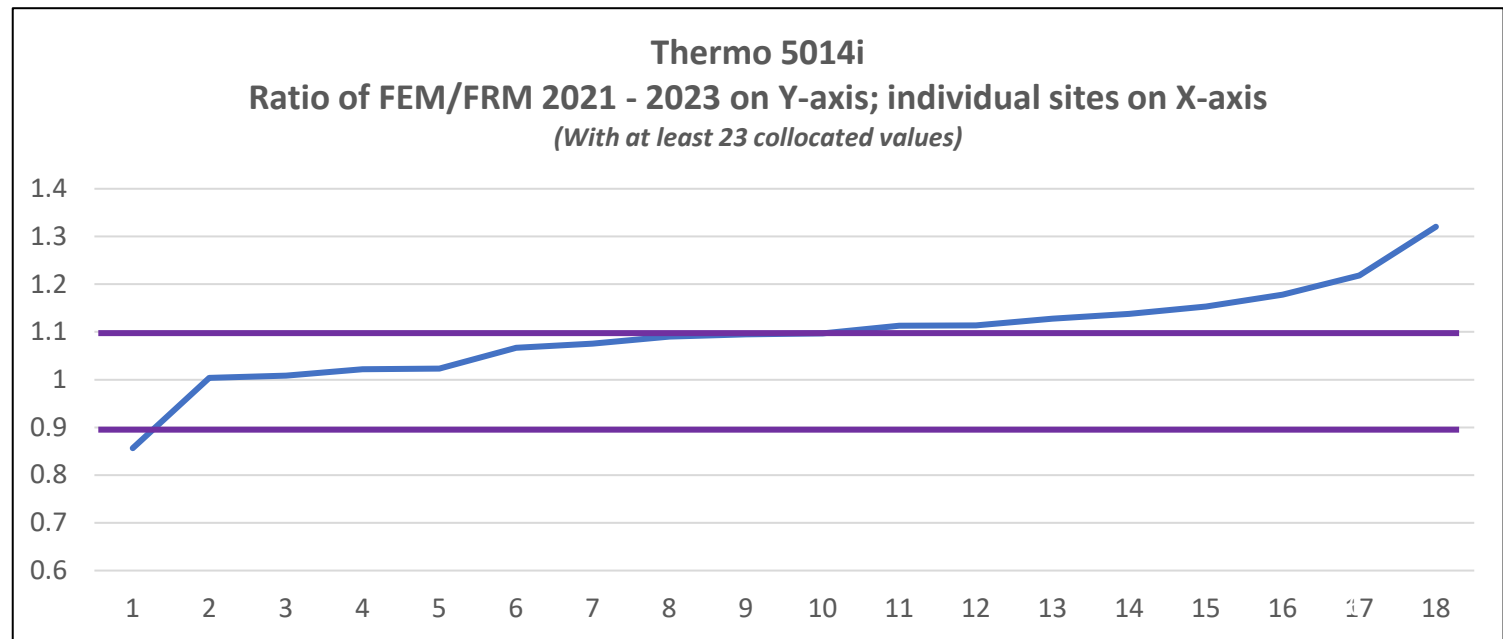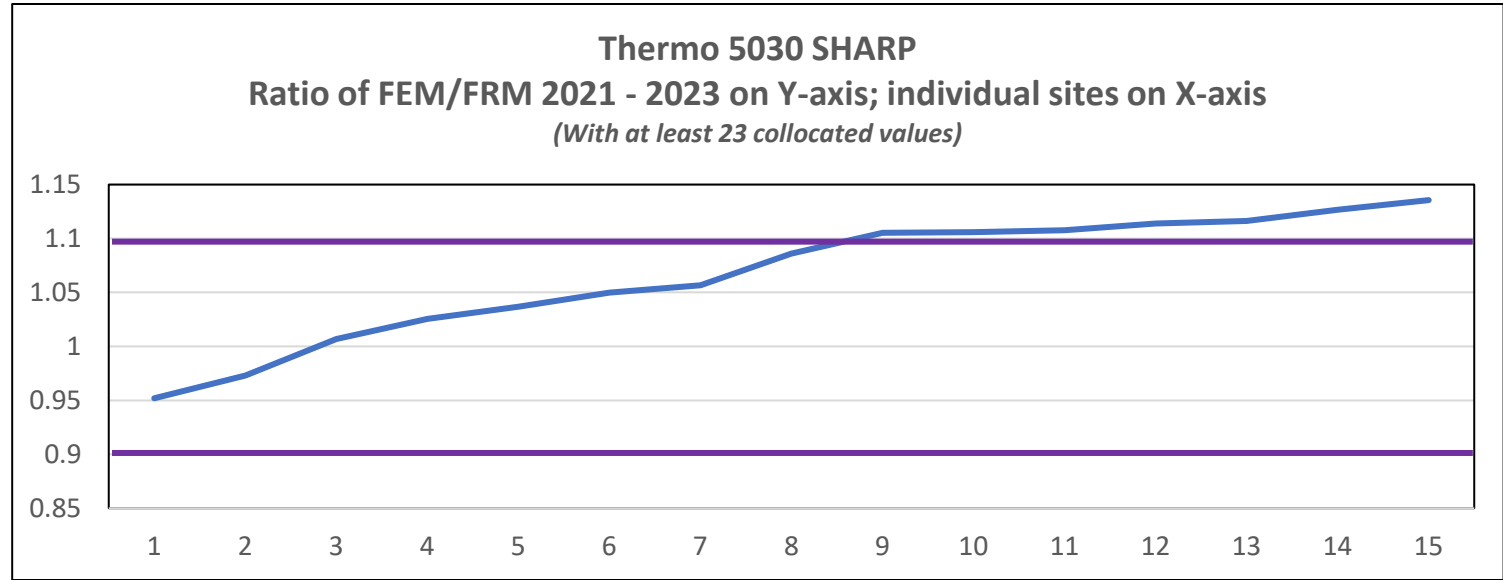# Additional Slides

# Key notes on Thermo BAM FEMs

- ## 5030 SHARP
  - 13 of 15 collocated sites are in Utah
  - Ratio within +/-0.1 of 1.0 for a little over half the sites
  - Method combines light-scattering nephelometry with beta attenuation technology
    - Allows for high time resolution data (e.g., 1-minute data)

- ## 5014i
  - Ratio within +/-0.1 of 1.0 for half of the sites
  - Does not have an integrated nephelometer

- Using all concentrations (i.e., includes data below 3 ug/m3)
- Mean of FEM/mean of FRM presented as a ratio
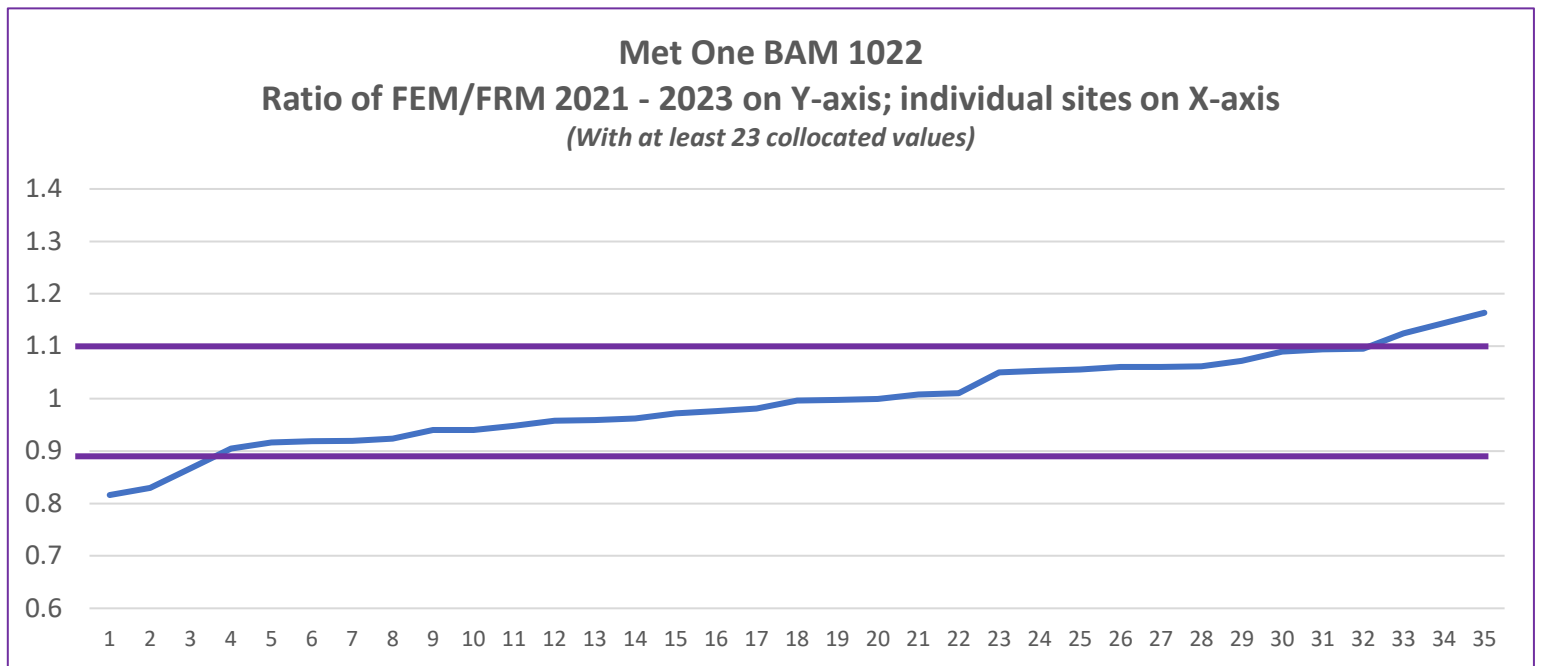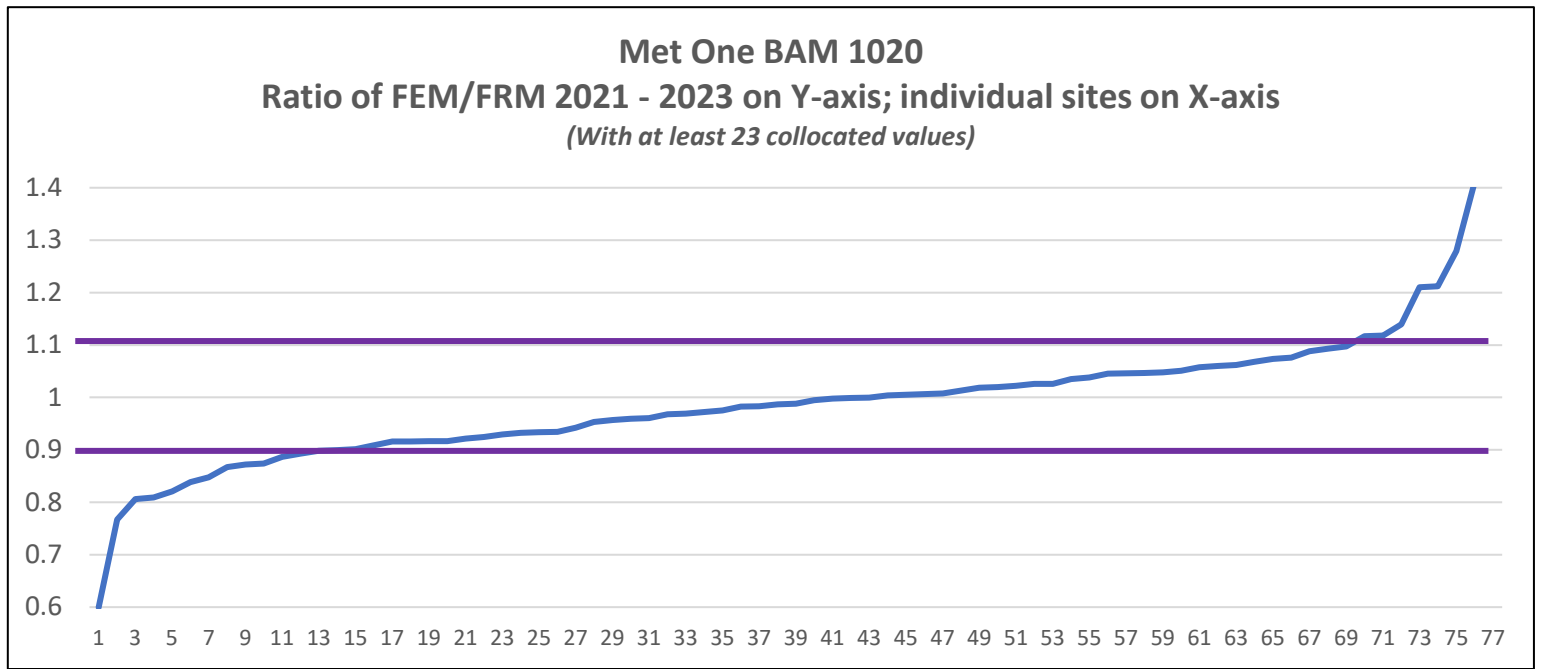- Data from 2021 – 2023
- N of >= 23 data pairs

**Thermo 5030 SHARP**
**Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis**
*(With at least 23 collocated values)*



**Thermo 5014i**
**Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis**
*(With at least 23 collocated values)*

# Key notes on Met One BAM FEMs

- ## BAM 1020
  - Ratio within +/-0.1 of 1.0 for 57 of 77 sites
  - Can be run inside a walk-in shelter or outside in a small shelter.

- ## BAM 1022
  - Ratio within +/-0.1 of 1.0 for 29 or 35 sites
  - Operates outside
  - Runs nearly a complete hour (58 minutes)

- Using all concentrations (i.e., includes data below 3 ug/m3)
- Mean of FEM/mean of FRM presented as a ratio
- Data from 2021 – 2023
- N of >= 23 data pairs



**Met One BAM 1020**
Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis
*(With at least 23 collocated values)*



**Met One BAM 1022**
Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis
*(With at least 23 collocated values)*

# Key notes on Teledyne T640 and T640x FEMs

Blue line is reported T640 or T640x

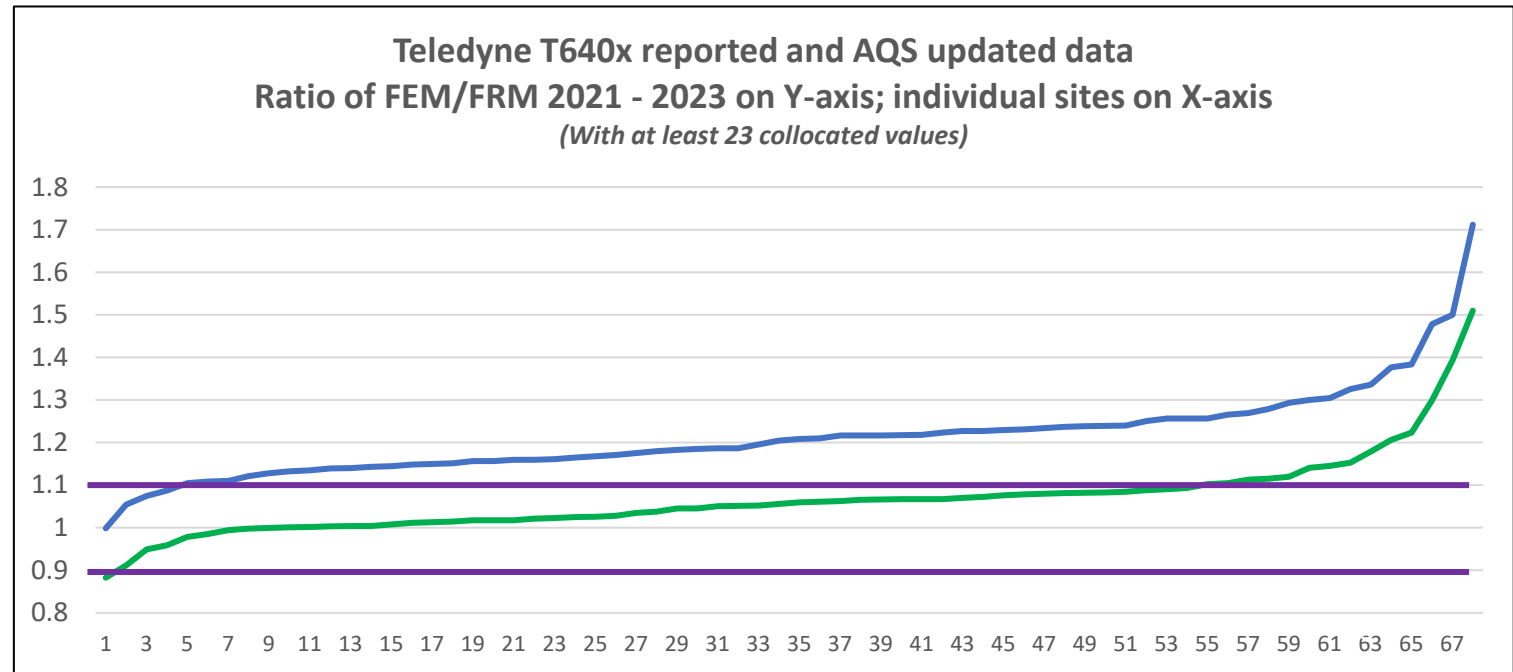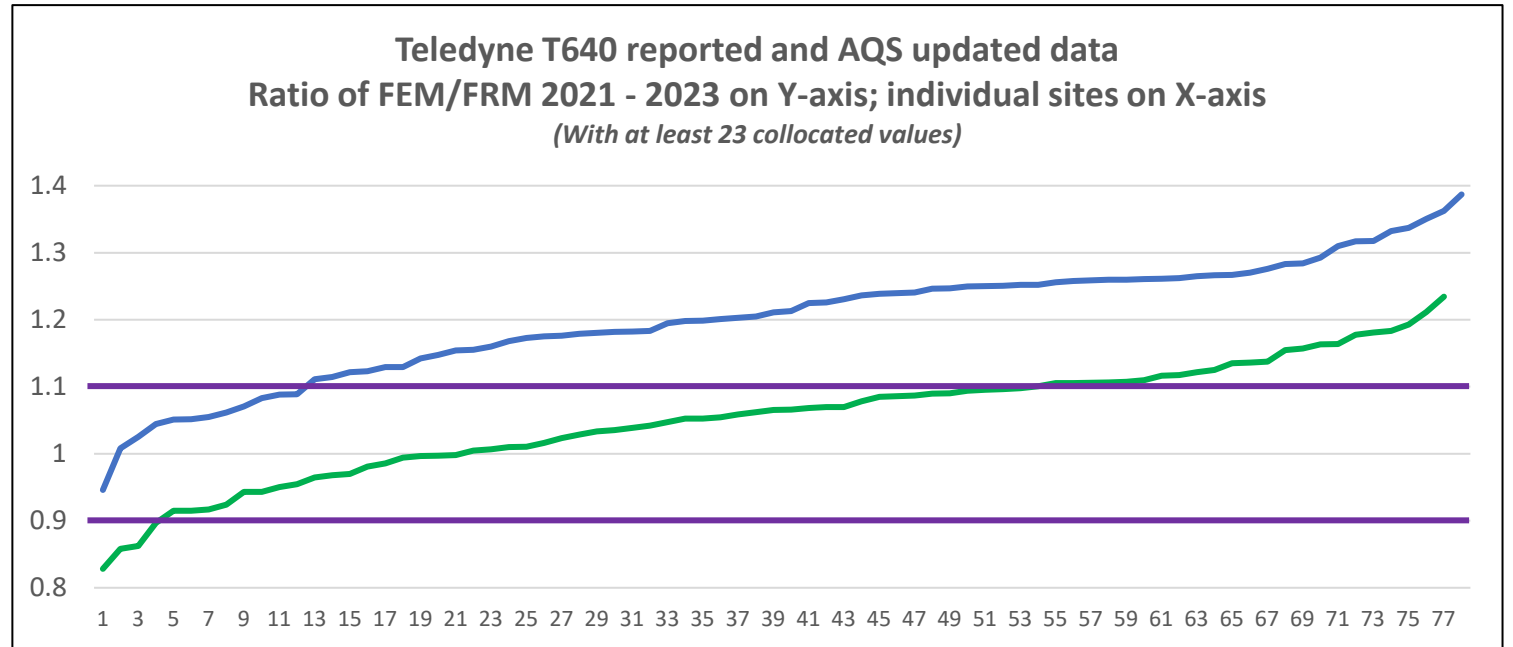Green line is AQS updated data

- ## T640
  - Ratio within +/-0.1 of 1.0 for 51 of 77 sites
  - FEM for PM2.5; data available for PM10 to report non-reg uses (e.g., AQI)

- ## T640x
  - Ratio within +/-0.1 of 1.0 for 55 of 68 sites
  - Includes FEM for PM2.5, PM10, and PM10-2.5

- Using all concentrations (i.e., includes data below 3 ug/m3)
- Mean of FEM/mean of FRM presented as a ratio
- Data from 2021 – 2023
- N of >= 23 data pairs
- Must have a collocated Temp for inclusion in this assessment



**Teledyne T640 reported and AQS updated data**
**Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis**
*(With at least 23 collocated values)*



**Teledyne T640x reported and AQS updated data**
**Ratio of FEM/FRM 2021 - 2023 on Y-axis; individual sites on X-axis**
*(With at least 23 collocated values)*

**T640 - Monthly ratios (FEM/FRM) of data reported to AQS, AQS updated, and Field Updated monitors 2021 - 2023**

— T640 — T640 (AQS Updated) — T640 (Field Updated)

**T640X - Monthly ratios (FEM/FRM) of data reported to AQS, AQS updated, and Field Updated monitors 2021 - 2023**
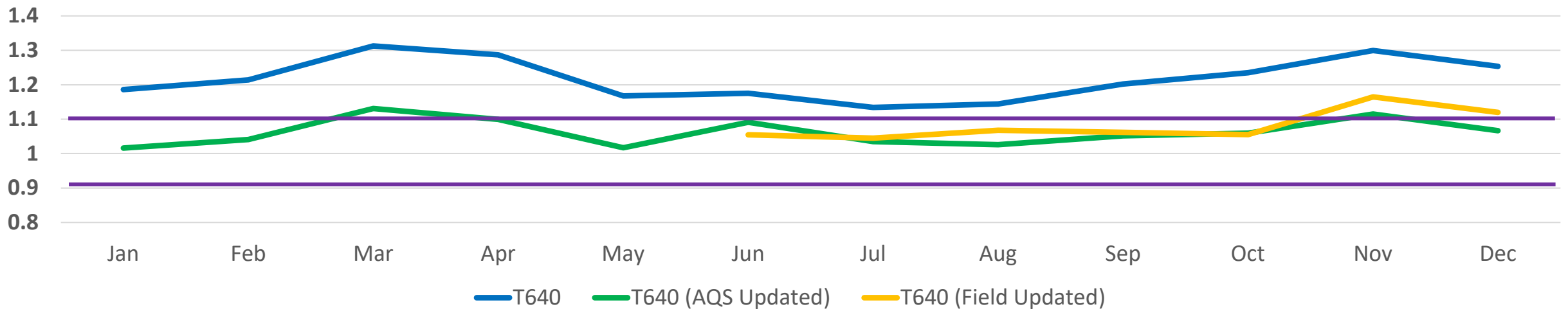
— T640X — T640X (AQS Updated) — T640X (Field Updated)
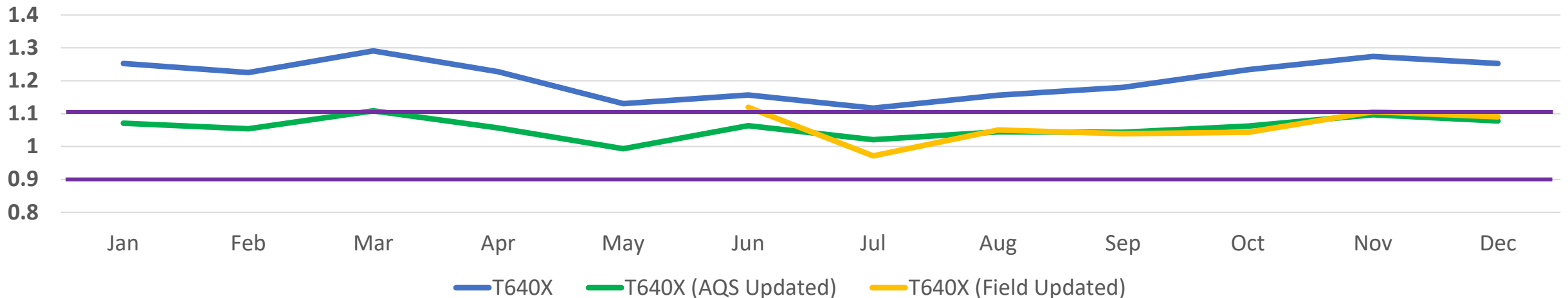
# Assess data



1. Determine if your FRM data are acceptable (meet MQO's) and look like other agencies or are an outlier?

   - PM$_{2.5}$ FRM Data Quality Dashboard
     - From AMTIC at: https://sti-r-shiny.shinyapps.io/QVA_Dashboard/ or
     - https://www.epa.gov/amtic/amtic-ambient-air-monitoring-assessments

2. Consider the concentrations being experienced at your sites.

3. Compare your collocated site of interest to other similar paired sites in your network and networks around you.

4. Network wide comparability r-shiny tool coming soon.

   - Includes option to evaluate continuous FEMs against reconstructed mass