Fine Particulate Matter ($PM_{2.5}$) Trends and Sources in the Texas-Louisiana Gulf Coast Region

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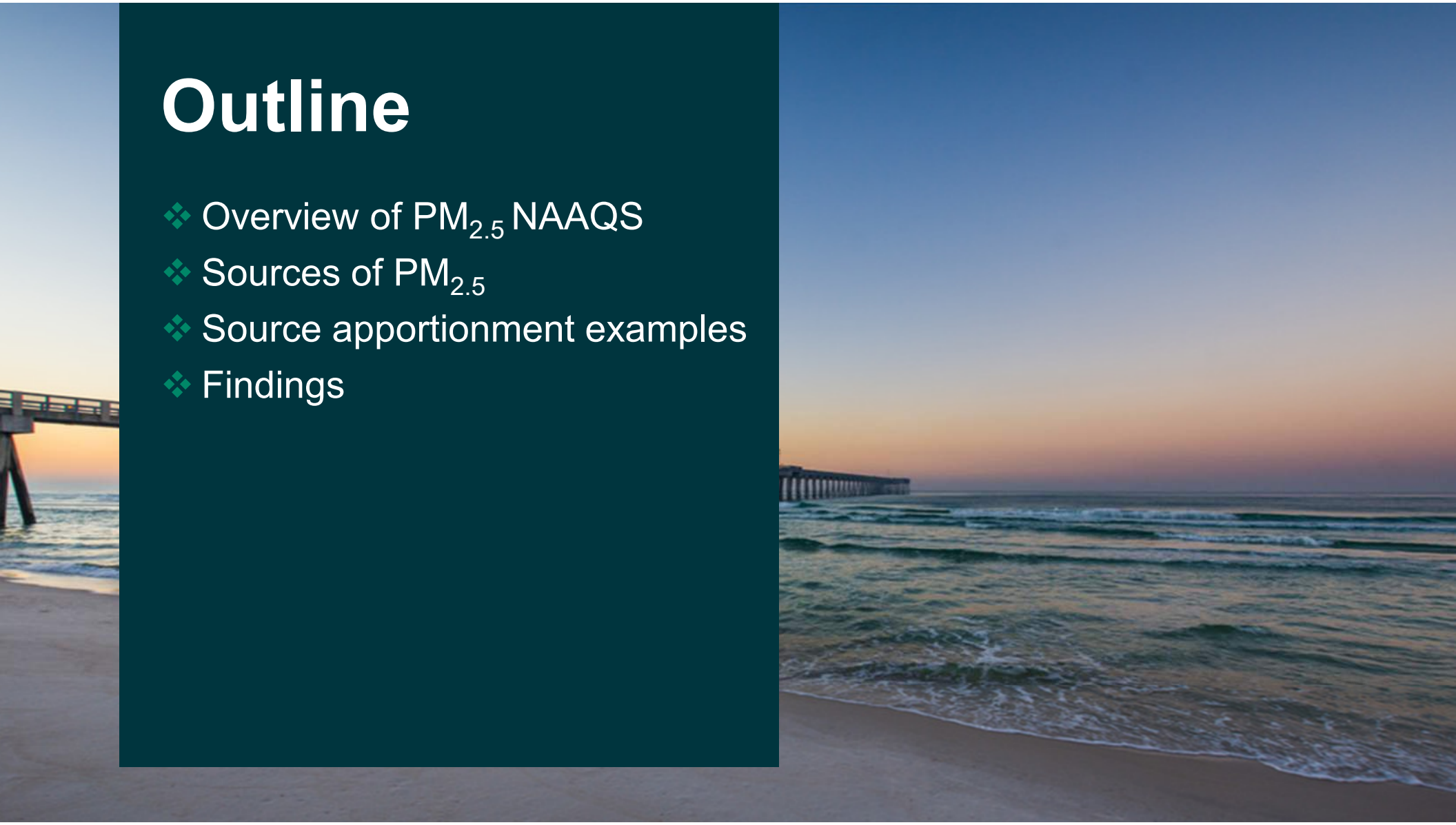
Outline

- Overview of $PM_{2.5}$ NAAQS
- Sources of $PM_{2.5}$
- Source apportionment examples
- Findings



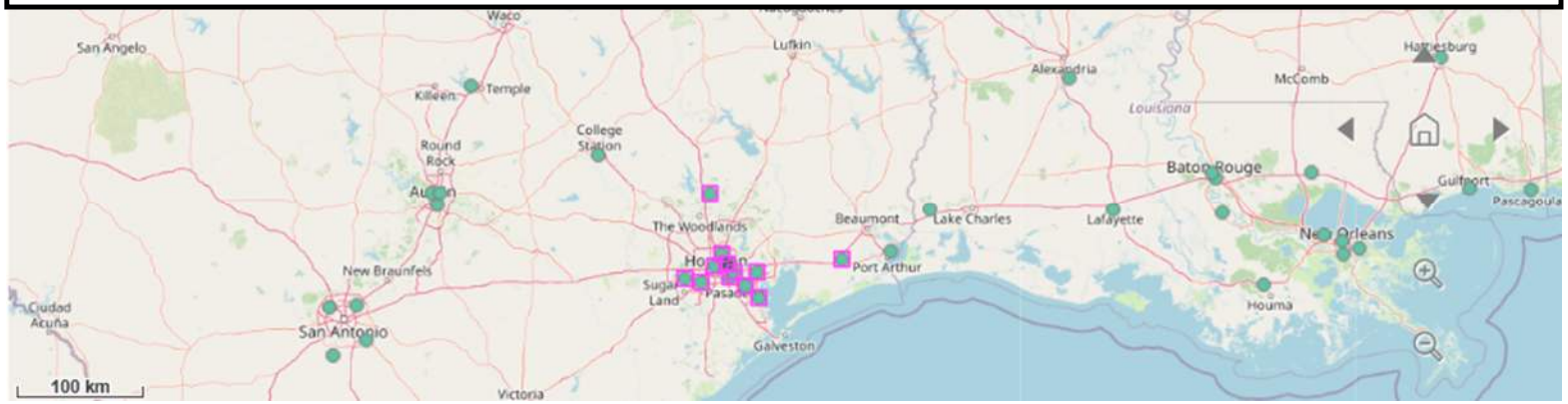
Overview of $PM_{2.5}$

Description

- Fine particulate matter with a diameter of 2.5 micrometers or smaller
- EPA NAAQS
  - **Primary – 9 µg/m³** (3-year average of annual mean)
  - **Secondary – 15 µg/m³** (3-year average of annual mean)
  - **Primary and Secondary – 35 µg/m³** (98th percentile of 24-hour concentrations averaged over 3 years)
  - Primary standard was lowered on February 7, 2024 from 12 to 9 µg/m³
- Concerns of many regions along the Gulf falling into nonattainment classification

The 2024 Annual Design Value in the Texas Gulf Coast Region (HGB)

AQS Site ID	Local Site Name	Street Address	Latitu...	Longi...	2024 Design Value
48-201-1050	Seabrook Friendship Park	4522 Park Rd	29.5...	-95.0...	8.3
48-245-0022	Hamshire	12552 Second St	29.8...	-94.3...	8.3
48-201-0066	Houston Westhollow	3333 1/2 Hwy 6 South	29.72...	-95.6...	8.9
48-201-1039	Houston Deer Park #2	4514 1/2 Durant Street	29.6...	-95.1...	9.2
48-201-1034	Houston East	1262 1/2 Mae Drive	29.76...	-95.2...	10.3
48-201-0055	Houston Bayland Park	6400 Bissonnet Street	29.6...	-95.4...	10.4
48-201-0024	Houston Aldine	4510 1/2 Aldine Mail Rd	29.9...	-95.3...	10.5
48-201-0058	Baytown	7210 1/2 Bayway Drive	29.77...	-95.0...	10.6
48-339-0078	Conroe Relocated	9472A Hwy 1484	30.3...	-95.4...	10.7
48-201-1035	Clinton	9525 1/2 Clinton Dr	29.73...	-95.2...	10.8
48-201-1052	Houston North Loop	822 North Loop	29.8...	-95.3...	11.9
48-201-0046	Houston North Wayside	7330 1/2 North Wayside	29.8...	-95.2...	12.7



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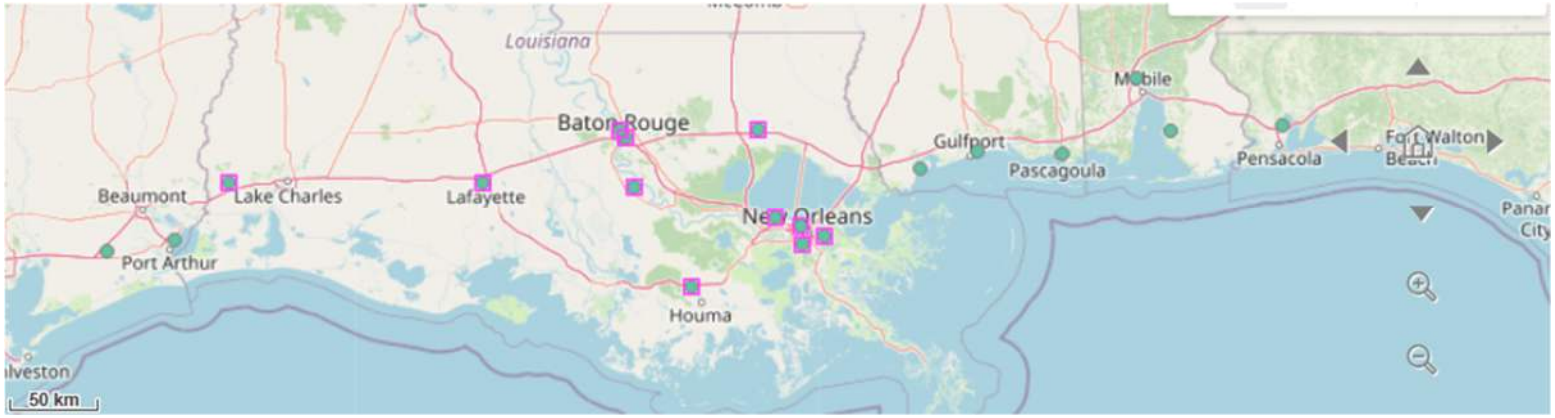
Most of the monitors exceed the 2024 NAAQS of 9.0 µg/m^3.

The 2024 Annual Design Value in the Louisiana Gulf Coast Region

AQS Site ID	Local Site Name	Street Address	Latitu...	Longi...	2024 Design Value
22-071-0021	I-610	I610 at West End Blvd.	29.9...	-90.1...	7.7
22-051-2001	Marrero	328 Marrero Road	29.9...	-90.1...	7.8
22-051-1001	Kenner	100 West Temple Pl	30.0...	-90.2...	7.9
22-055-0007	Lafayette / USGS	700 Cajundome Boulevard	30.2...	-92.0...	8.1
22-105-0001	Hammond	21549 Old Covington Hwy	30.5...	-90.3...	8.2
22-047-0005	Geismar	55445 Point Clair Road (275 yards SW of the end of Betty Martin Ext.)	30.2...	-91.1...	8.3
22-109-0001	Houma	4047 West Park Ave. at Hwy 24	29.6...	-90.7...	8.3
22-087-0007	Chalmette Vista	24 E. CHALMETTE CIRCLE	29.9...	-89.9...	8.4
22-033-0009	Capitol	1061-A Leesville Ave	30.4...	-91.1...	9.0
22-121-0001	Port Allen	1005 Northwest Drive, Port Allen	30.5...	-91.2...	9.1



Two monitors are near or exceed the 2024 NAAQS of 9.0 µg/m^3.

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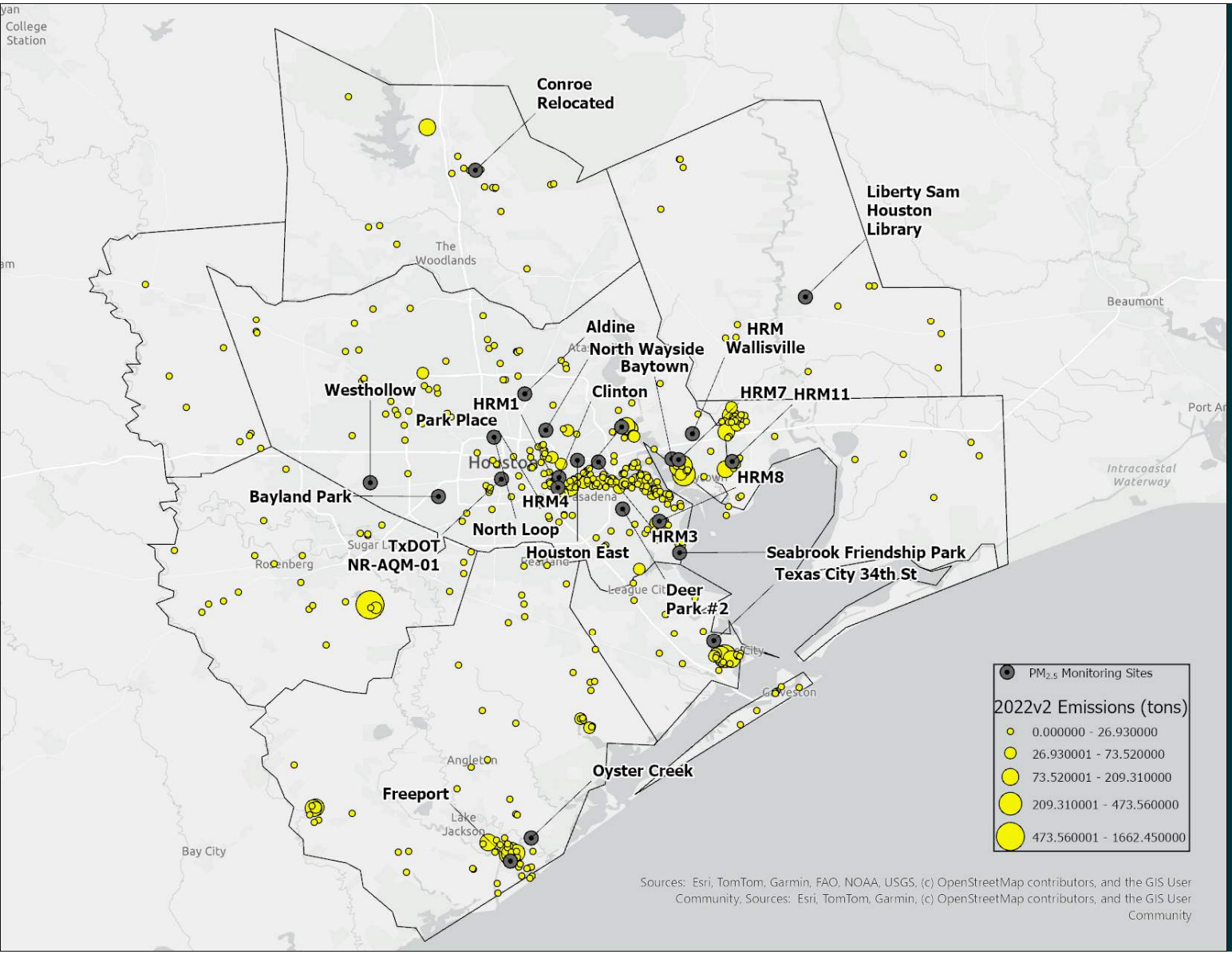
Sources of $PM_{2.5}$
Biomass Burning / Fires
Dust
Sea Salt
Secondary Organic Aerosols
Road Traffic
Industrial

Project Focus

$PM_{2.5}$ Analysis and modeling project in collaboration with the Houston-Galveston Area Council.

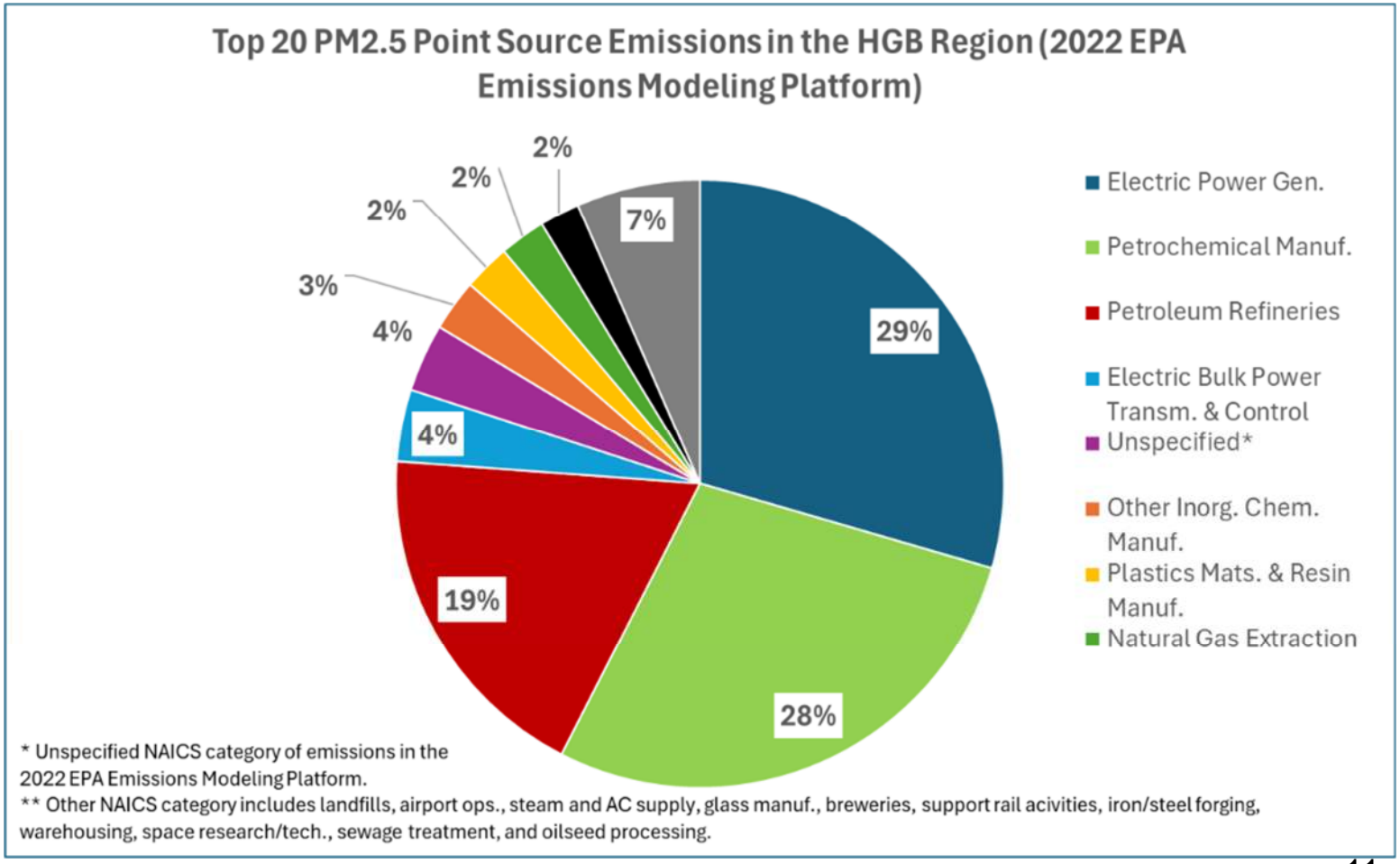
Industrial Point Emissions in the HGB region in 2022

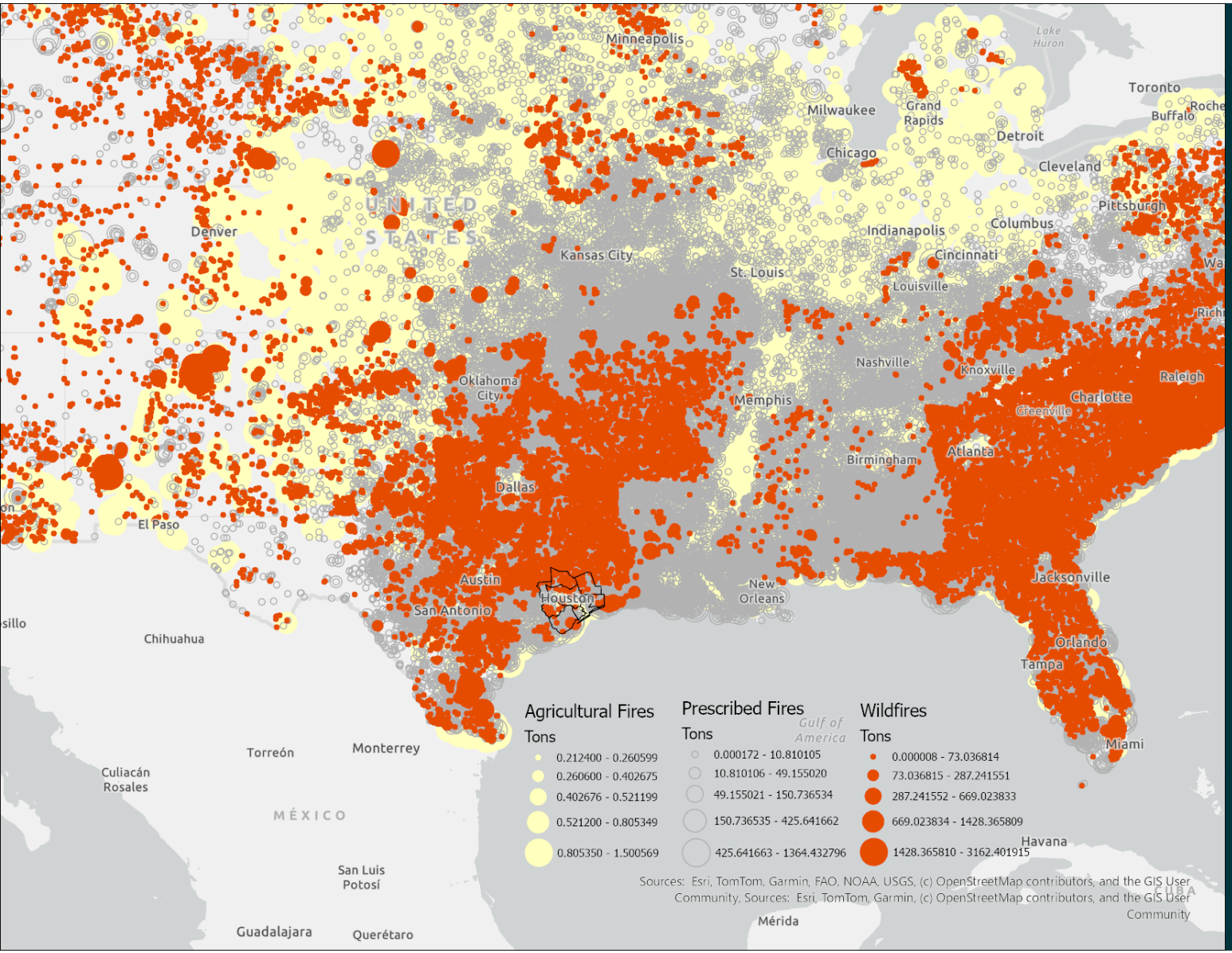


Major Point Source Emissions in the HGB Region in 2022

Rank	NAICS Description	Emissions (tons)	Rank	NAICS Description	Emissions (tons)
1	Electric Power Generation	2,502.47	11	Airport Operations	103.99
2	Petrochemical Manufacturing	2,380.24	12	Steam & AC Supply	73.57
3	Petroleum Refineries	1,581.38	13	Glass Container Manufacturing	53.89
4	Electric Bulk Power Transm. & Control	326.77	14	Breweries	51.62
5	Unspecified	305.96	15	Support Activities for Rail Transportation	35.81
6	Other Inorganic Chemical Manufacturing	232.26	16	Space Research & Technology	32.61
7	Plastics Material & Resin Manufacturing	210.83	17	General Warehousing & Storage	26.14
8	Natural Gas Extraction	208.24	18	Iron & Steel Forging	23.24
9	Industrial Gas Manufacturing	180.75	19	Soybean & Other Oilseed Processing	17.78
10	Solid Waste Landfill	122.18	20	Sewage Treatment Facilities	17.67

Major Point Source Emissions in HGB Region 2022 (Continued)





Large-Scale Fire Emissions in 2022

- Wildfires
- Agricultural Fires
- Prescribed Fires

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Source Apportionment in the Houston-Galveston-Brazoria Region (HGB)

Data: Jan-Dec 2022-2024, 23 monitoring sites

Approach: Positive Matrix Factorization (PMF) Receptor Model

- Mass balance equation between measured species/sites concentrations and source profiles:

Amount of mass contributed by each factor to each sample (factor contributions)

Number of factors

Species profile for each source (factor profiles)

Residual for each sample/species

$$x_{ij} = \sum_{k=1}^{p} g_{ik} f_{kj} + e_{ij}$$

Data matrix

- Minimizing the objective function Q (Q_{true} *and* Q_{robust}):

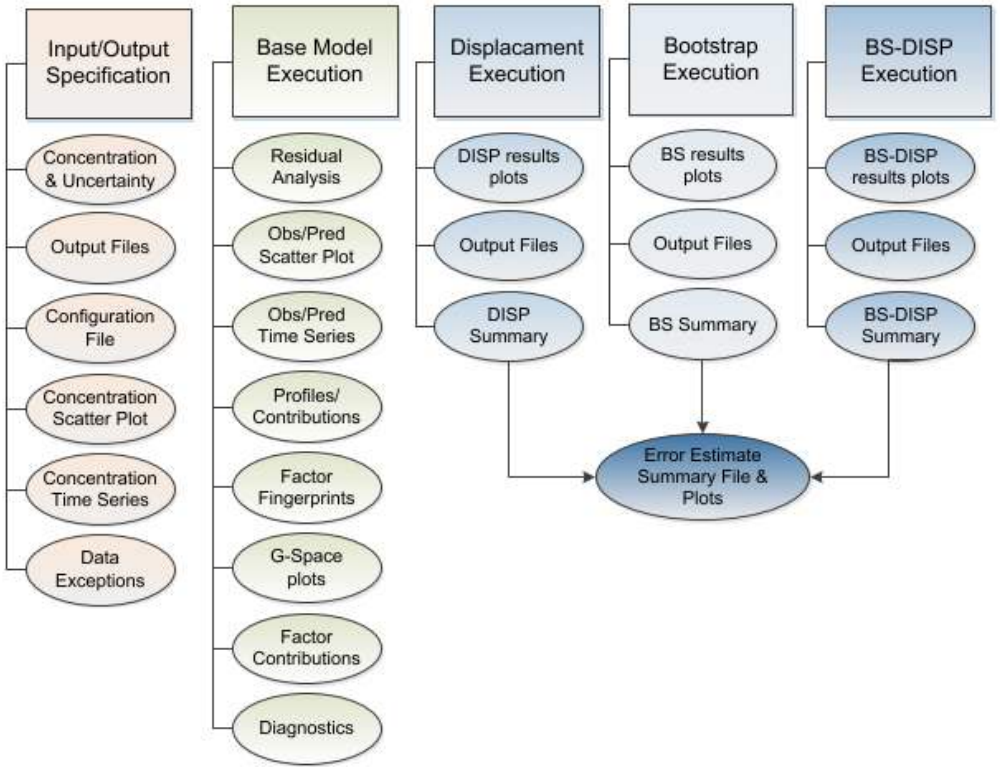
Goodness-of-fit including all points

$$Q = \sum_{i=1}^{n} \sum_{j=1}^{m} \left[\frac{x_{ij} - \sum_{k=1}^{p} g_{ik} f_{kj}}{u_{ij}} \right]^2$$

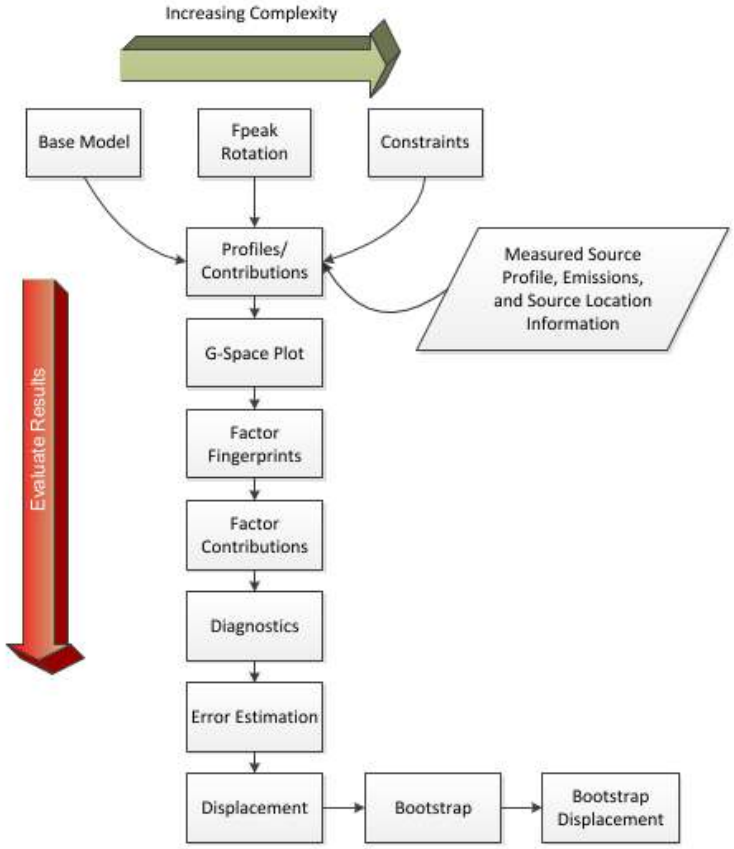
Goodness-of-fit excluding points with uncertainty-scaled residuals > 4

Approach: Flow Charts for PMF Operations and Results Evaluation

PMF Operations



PMF Results Evaluation Process



(Figures taken from EPA PMF 5.0 User Guide)

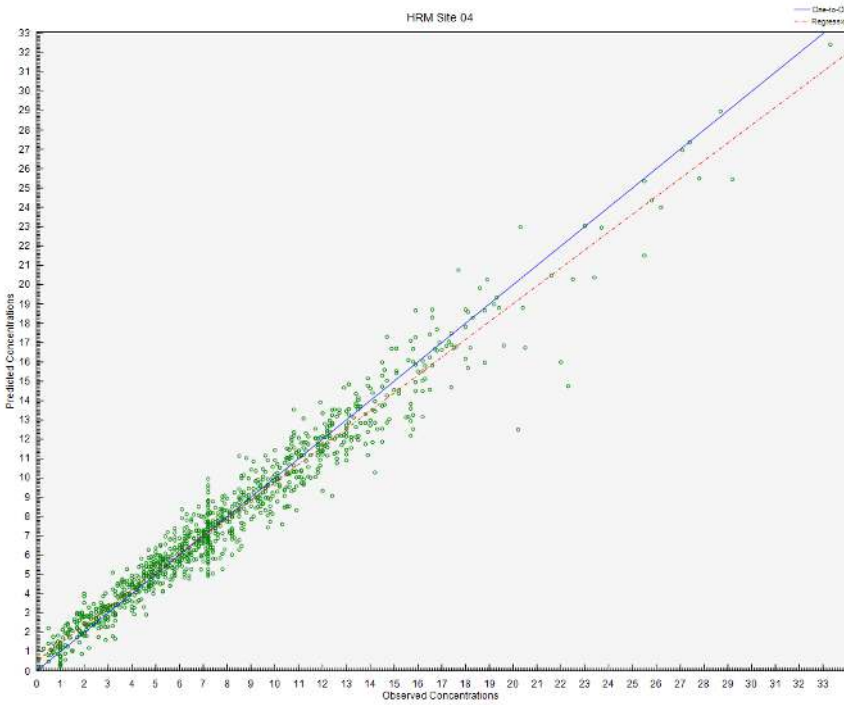
Goal and objectives

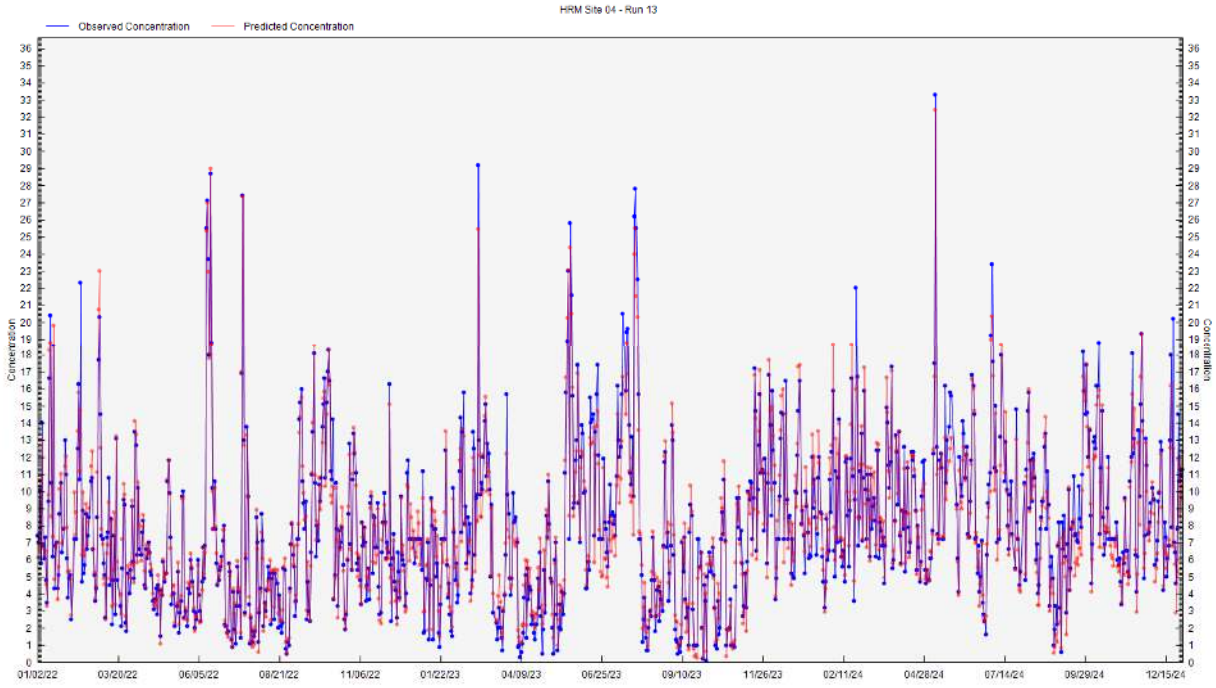
- Goal:
  - Characterize sources of $PM_{2.5}$ and their importance in the HGB region;
    - Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery & Weller counties
- Objectives:
  - Collect 1-h and 24-h average concentration measurements from FEM (BAM) and FRM (TEOM) monitors in the HGB region (~23 sites) for continuous $PM_{2.5}$ mass concentrations.
  - Process 24-h average data inputs for PMF runs
  - Run PMF models for various scenarios
  - Determine PMF factors and specific source contributions

Measurements of $PM_{2.5}$ in the HGB Region (2019-2024)

No.	Site Name	Site Location		Validated Data Availability (2019-2024)		Proposed term for source apportionment analysis		Data Resolution	Type of Monitor
		Latitude	Longitude	Start Date	End Date	PM2.5 Total Mass	PM2.5 Speciated Mass		
1	Houston Deer Park # 2	29.6700343	-95.1285059	2019	2024	2022-2024	2019-2024	Daily/Hourly	FRM^{R}, Speciated ^{NR}
2	Clinton	29.7337367	-95.2576045	2019	2024	2022-2024	2021-2024	Daily	FRM^{R}, TEOM^{NR,} , Speciated ^{NR}
3	Freeport South Avenue I	28.9644069	-95.3549703	2023	2024	2022-2024	2023-2024	Daily	FRM^{R}, Speciated ^{NR}
4	Houston North Wayside	29.8285159	-95.2839556	2021	2024	2022-2024	2022-2023	Daily/Hourly	BAM^{R}, Speciated ^{NR}
5	Houston North Loop	29.8143865	-95.3878169	2021	2024	2022-2024	-	Daily/Hourly	FRM^{R}, BAM^{R}
6	Houston Aldine	29.9010299	-95.3261467	2019	2024	2022-2024	2019	Daily/Hourly	FRM^{R}, BAM^{R}
7	Conroe Relocated	30.3503550	-95.4251242	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}, TEOM^{NR}
8	Houston Westhollow	29.7233161	-95.6359248	2021	2024	2022-2024	-	Daily/Hourly	BAM^{R}
9	Houston Bayland Park	29.6957433	-95.4992418	2022	2024	2022-2024	-	Daily/Hourly	BAM^{R}
10	Park Place	29.6862893	-95.2947227	2019	2020	-	-	Hourly	TEOM^{NR}
11	Houston East	29.7680329	-95.2205736	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}
12	Baytown	29.7706890	-95.0312263	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}
13	Seabrook Friendship Park	29.5830619	-95.0155477	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}, TEOM^{NR}
14	Galveston 99th Street	29.2544674	-94.8612829	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}
15	Oyster Creek	29.0105560	-95.3133330	2019	2024	2022-2024	-	Daily/Hourly	BAM^{R}, Speciated ^{NR}
16	Liberty Sam Houston Library	30.0966000	-94.7634000	2022	2024	2022-2024	-	Daily	TEOM^{NR}
17	HRM 1 Central Street	29.7134500	-95.2598000	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
18	HRM 3 Hayden Rd	29.7647823	-95.1783736	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
19	HRM 4 Sheldon Rd	29.8347220	-95.1319440	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
20	HRM 7 Baytown West	29.7692640	-95.0175090	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
21	HRM 8 La Porte	29.6461110	-95.0563890	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
22	HRM 11 Baytown East	29.7658330	-94.9102780	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
23	HRM Wallisville	29.8213890	-94.9900000	2019	2024	2022-2024	-	Daily/Hourly	BAM^{NR}
24	Texas City 34th Street	29.4057000	-94.9471200	2019	2024	2022-2024	-	Daily/Hourly	FRM^{NR}, BAM^{NR}
25	NR-AQM-01 (TxDOT)	29.7305540	-95.3728730	2023	2024	2023-2024	-	Daily/Hourly	BAM^{NR}

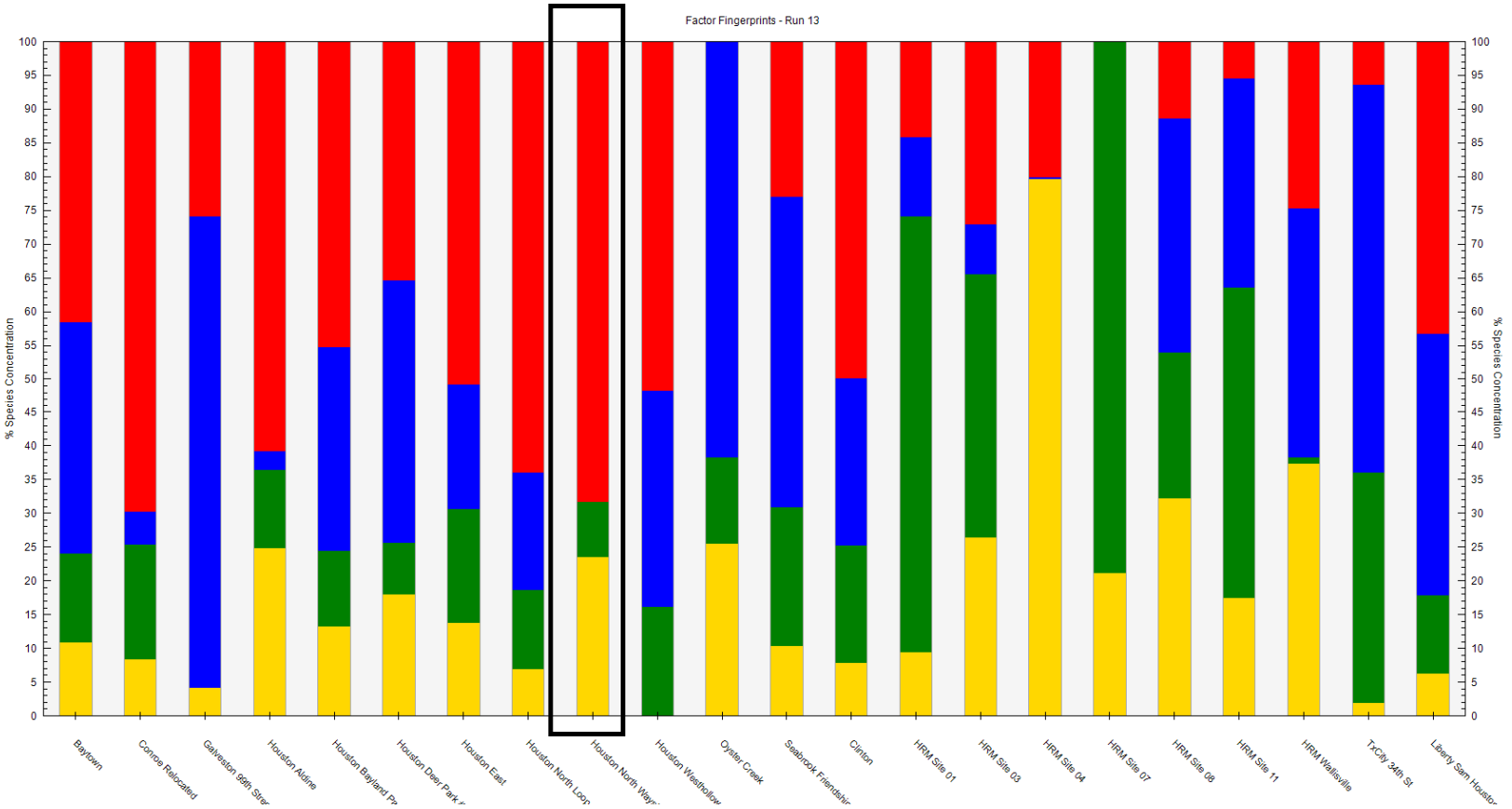
PMF Base Model Results: Best predicted site concentration





$PM_{2.5}$ concentrations slightly underpredicted, but the model agreed very well with the measurements (R^2 = 0.95)

PMF Base Model Results: Factor fingerprints (% of species concentration)



Factor 1: Local / Urban Core

Factor 2: Marine / Gulf Coast

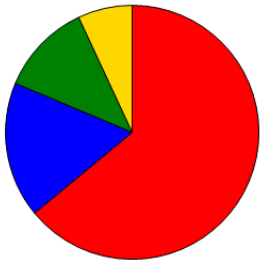
Factor 3: Industrial

Factor 4: Mixed Urban / Local / Industrial

In this approach: species = sites

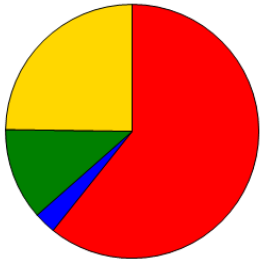
PMF Base Model Results: Factor contributions

Houston North Loop - Run 13



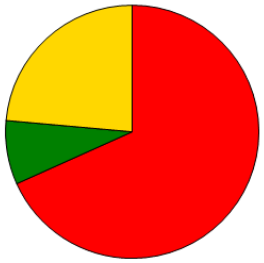
Factor Contribution > 0.05 %
- Factor 1 = 7.36010 (64.0 %
- Factor 2 = 1.98730 (17.3 %
- Factor 3 = 1.35080 (11.8 %
- Factor 4 = 0.79764 (6.9 %)

Houston Aldine - Run 13



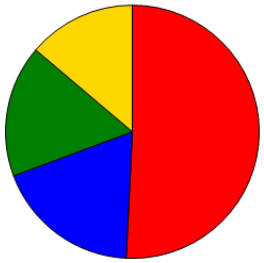
Factor Contribution > 0.05 %
- Factor 1 = 6.17000 (60.8 %)
- Factor 2 = 0.28275 (2.8 %)
- Factor 3 = 1.18670 (11.7 %)
- Factor 4 = 2.51680 (24.8 %)

Houston North Wayside - Run 13

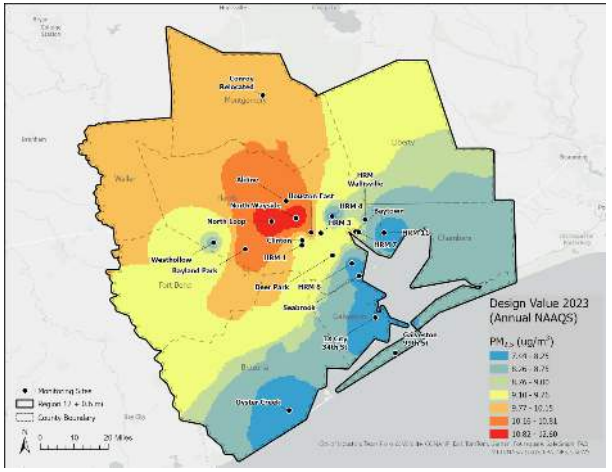


Factor Contribution > 0.05 %
- Factor 1 = 8.27440 (68.3 %)
- Factor 3 = 0.98780 (8.2 %)
- Factor 4 = 2.85660 (23.6 %)

Houston East - Run 13

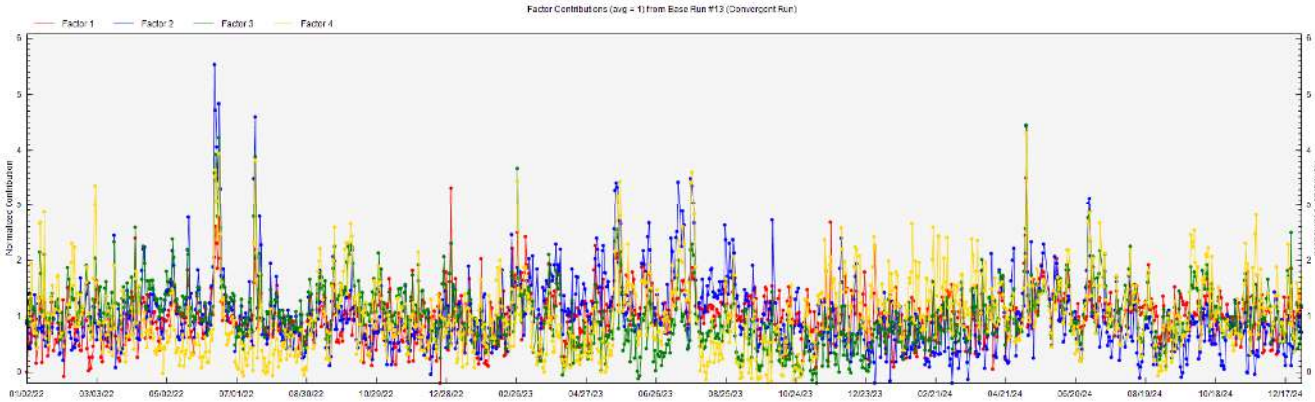


Factor Contribution > 0.05 %
- Factor 1 = 5.08210 (50.8 %)
- Factor 2 = 1.85650 (18.6 %)
- Factor 3 = 1.68730 (16.9 %)
- Factor 4 = 1.38080 (13.8 %)

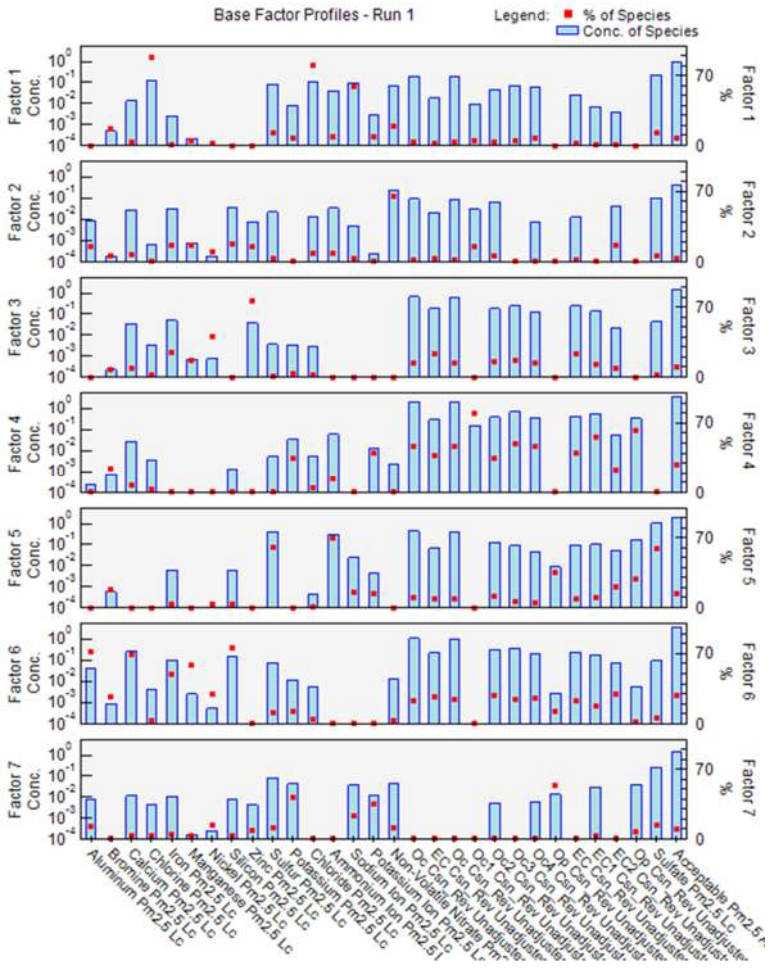


Map of interpolated 2023 design value in the HGB region

Factor 1: Local/Urban Core
Factor 2: Marine/Gulf Coast
Factor 3: Regional
Factor 4: Mixed Urban / Local / Industrial



Factor Profiles for Houston North Wayside (base model vs. rotation model)



Factor 1: Cl, $[Cl]^-$, Na, $[K]^+$ and NO_3

Factor 2: $[NO_3]^-$, EC2, OC1, $[NH]_4^+$, Al, Fe and Mn

Factor 3: Zn, Ni, Fe, OC and EC

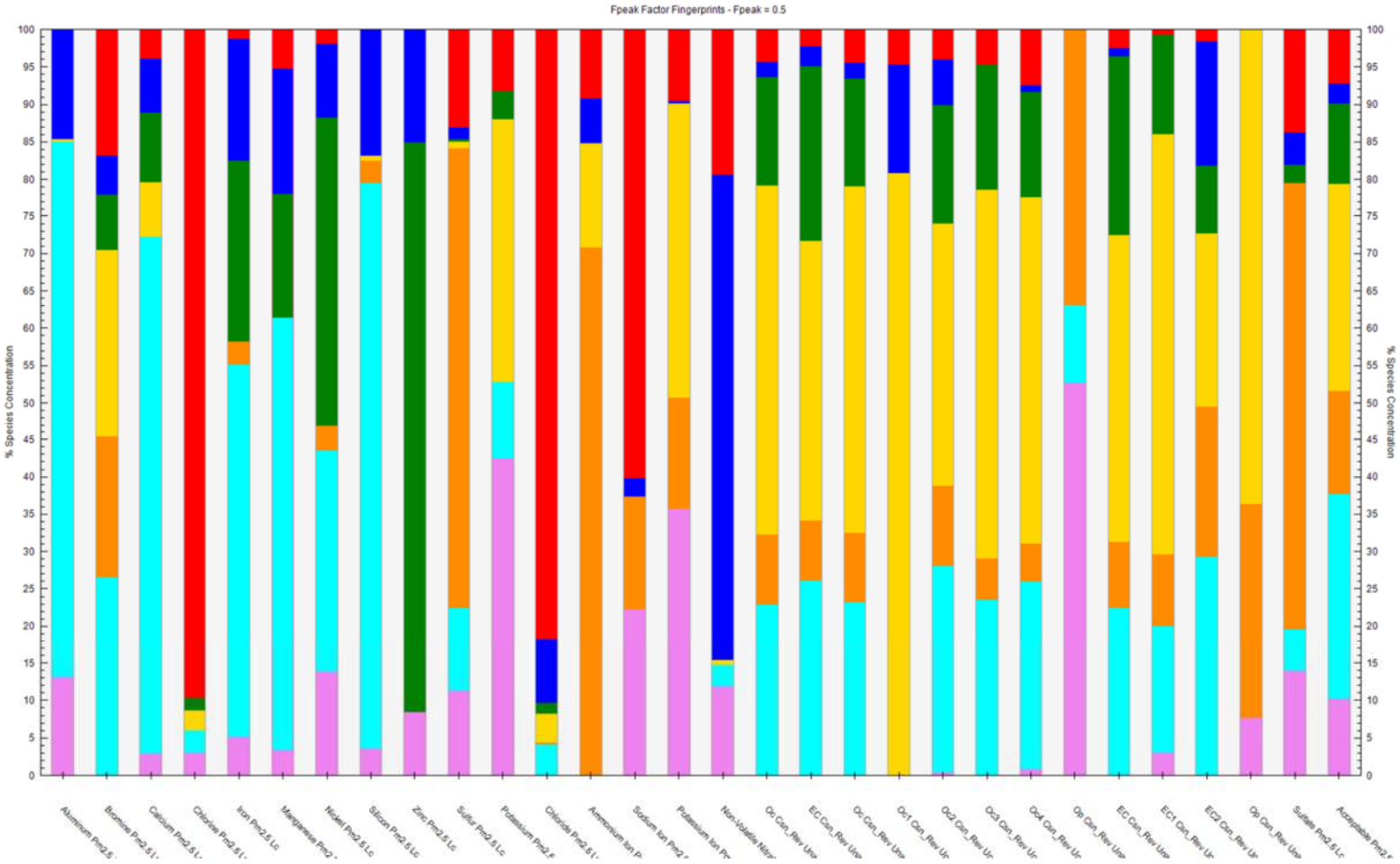
Factor 4: $[SO_4]^{2-}$, OC1, OC, EC, $[K]^+$, K, Br and $[NH_4]^+$

Factor 5: $[SO_4]^{2-}$, OP, EC, Br, $[Na]^+$, $[K]^+$ and $[NH_4]^+$

Factor 6: Si, Al, Ca, Fe, Ni, OC and EC

Factor 7: K, K^+, OP, $[SO_4]^{2-}$, $[NO_3]^-$, S, Ni, Zn, and Al

PMF: Factor fingerprints with 7-factor solution at Houston North Wayside



Factor 1: Sea Salt

Factor 2: Diesel / Road Dust / Crustal

Factor 3: Industrial / Combustion

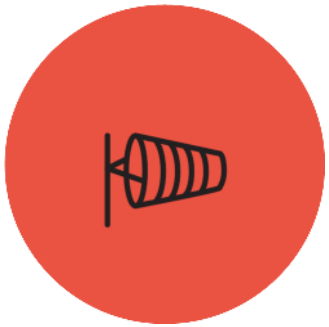
Factor 4: Biomass Burning

Factor 5: Secondary / $(NH_4)_2SO_4$

Factor 6: Crustal

Factor 7: Sea Salt / Road Dust

Findings



$PM_{2.5}$ concentrations relatively lower near the coast due to stronger winds

Regional smoke from Central America and Mexico influence $PM_{2.5}$ mass concentrations

Biomass burning can contribute to $PM_{2.5}$ mass concentrations, driving the relatively clean rural sites to have comparable $PM_{2.5}$ concentrations to urban sites

Diurnal trend
Spikes during rush hour

Some seasonal variations likely driven by biomass burning (residential fires, agricultural burning, and wildfires)

HGB Monitors mainly showed daily $PM_{2.5}$ concentrations below the 24-h average NAAQS of 35 $\mu g/m^3 g$ with high outliers observed

Thank you.

AECOM

Delivering a
better world