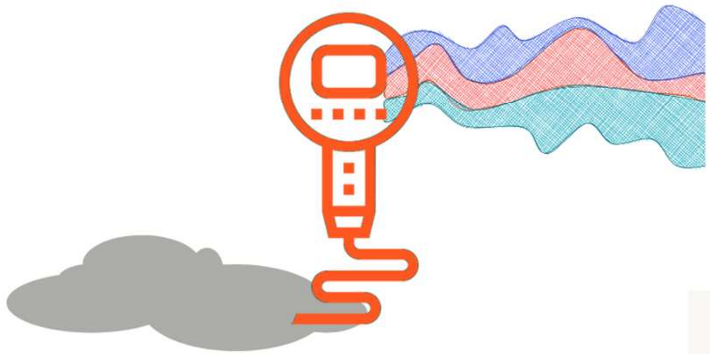
How to Visualize Ambient Monitoring Data

EXAMPLE WAYS



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Visualizing Ambient Monitoring Data

The study of air quality should not stop at merely collecting ambient air quality data.

Many national agencies, academic institutions, and global organizations are now actively conducting ambient air quality monitoring to address the data gaps highlighted in recent reports. Efforts are underway to expand ground-level monitoring using both traditional reference-grade monitors and emerging low-cost sensors. As equipment becomes more accessible and training is provided for its use, one persistent gap remains clear -- what to do with the data once it is collected?

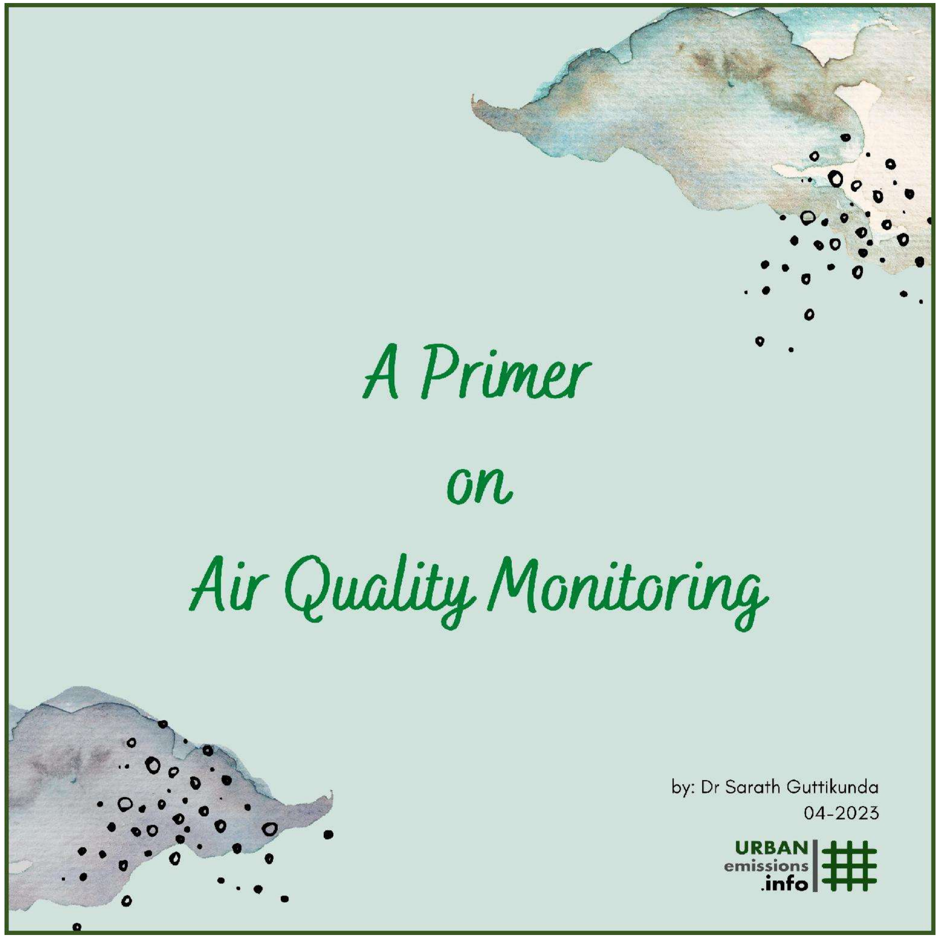
This question often arises in online discussions and workshops, underscoring the need for greater focus on data analysis, interpretation, and application in air quality management.

Air quality management does not begin and end with data collection or with drawing a few graphs and creating summary tables. Instead, assessments and interpretations must go beyond basic visualizations. We need platforms that allow data to be visualized in diverse and dynamic ways, making it accessible and meaningful to various stakeholders who may be examining the same problem from different perspectives.

Visualizing Ambient Monitoring Data

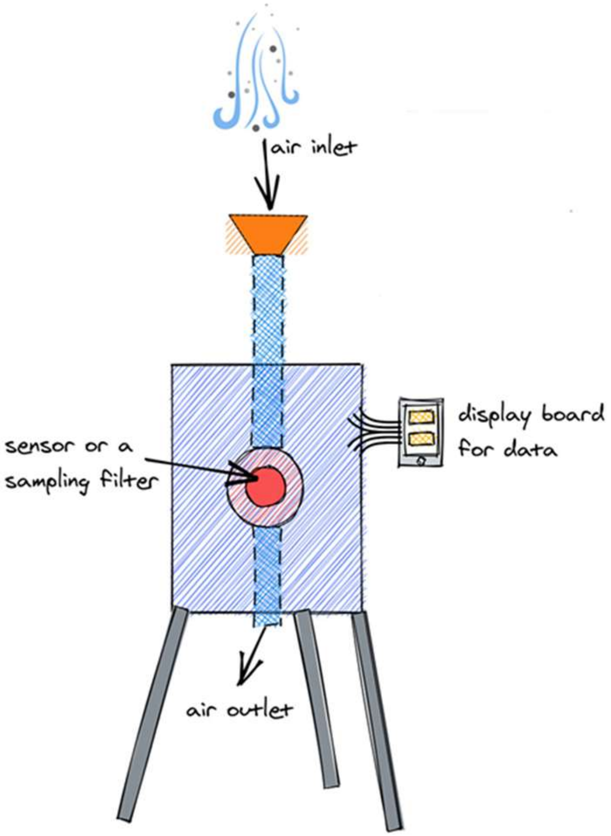
At UrbanEmissions, we have developed a primer on air quality monitoring that covers the basic methods, general principles, expected outcomes, and practical applications of ambient monitoring.

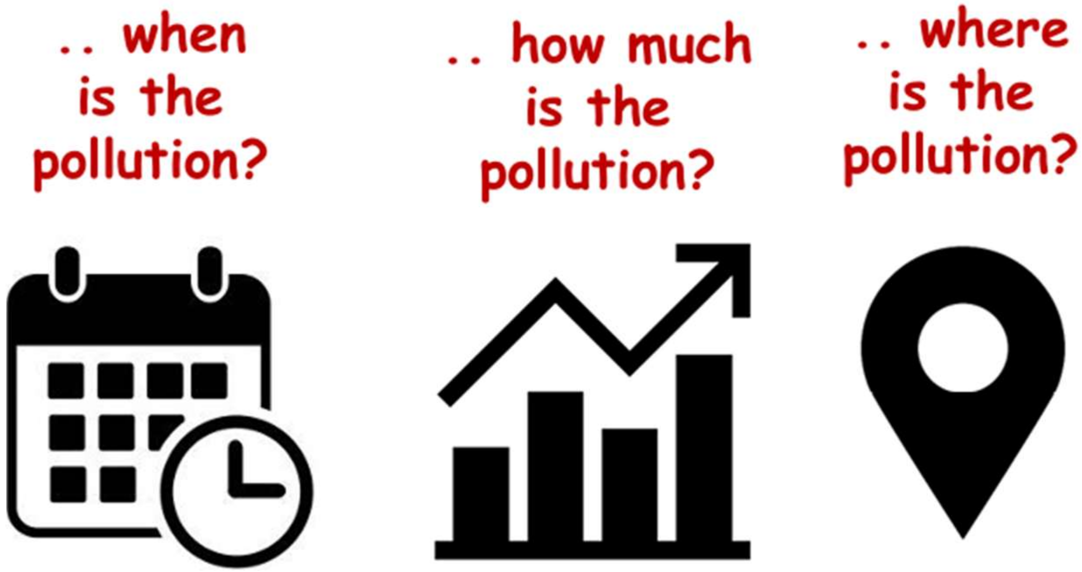
This working paper aims to guide readers through not just the process of monitoring but also what can be done once reliable and representative data is available. We focus on how to visualize and interpret this data effectively, and how it can be applied to support air quality management decisions. Ultimately, the goal is to help users understand how to maximize the value of monitoring efforts, by ensuring that the information collected is not only accurate but also communicated in ways that enable broader stakeholder engagement and informed action.



Why monitor ambient air pollution?

Ambient monitoring is the most critical step in air quality management. It not only informs us about the levels, locations, and timing of pollution but also serves as a crucial step in documenting the nature and extent of the air pollution problem on streets, in houses, and across cities and regions.





Why monitor ambient air pollution?

Let us be clear about one important point: increasing ambient air quality monitoring data does not, by itself, solve the problem of air pollution. The goal of expanding monitoring is to gain a clearer understanding of the problem. It helps us answer key questions:

- Is pollution increasing or decreasing?
- Where are the pollution hotspots?
- Which areas and populations are most vulnerable?
- Are there locations that need more monitoring?

This information not only deepens our understanding of air quality in an airshed (urban or regional) but also enables us to make informed decisions about what more needs to be done -- both in terms of enhancing monitoring and implementing effective pollution management strategies.

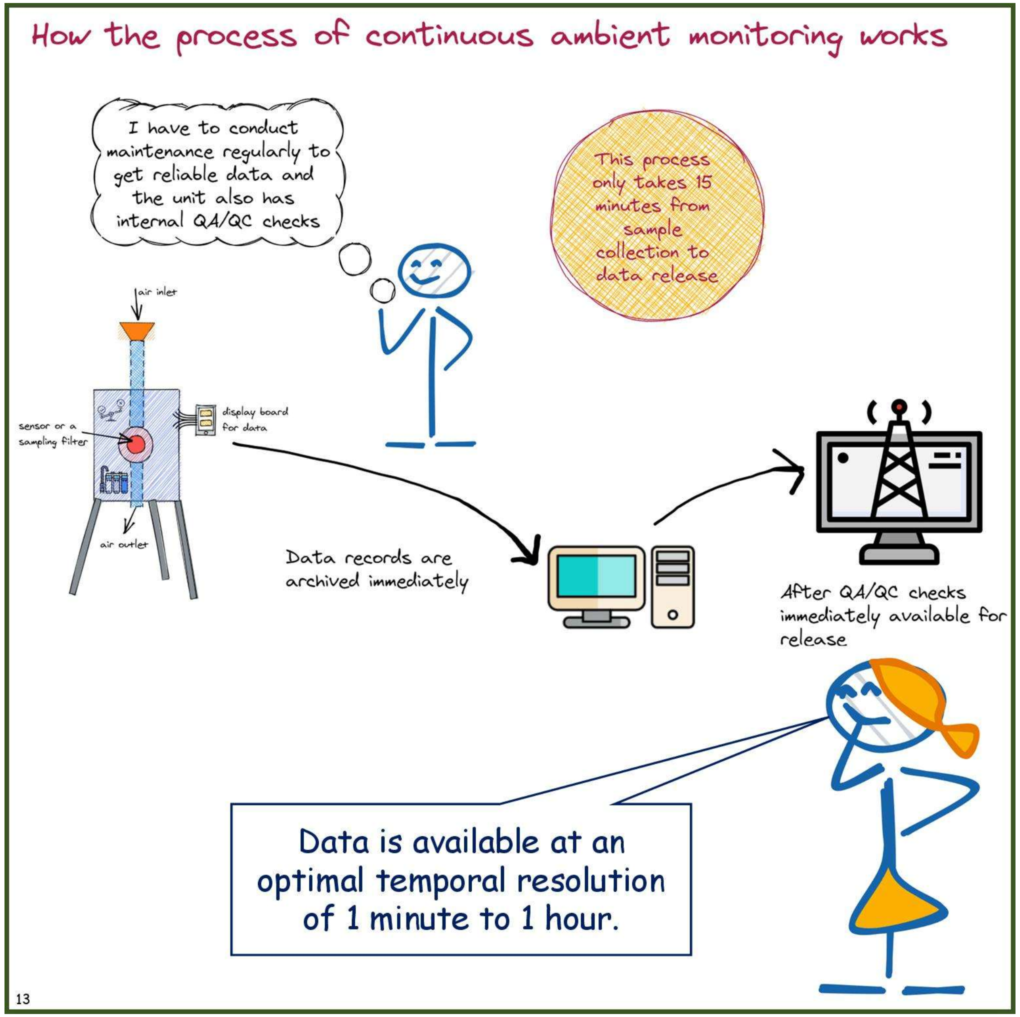
Why monitor ambient air pollution?

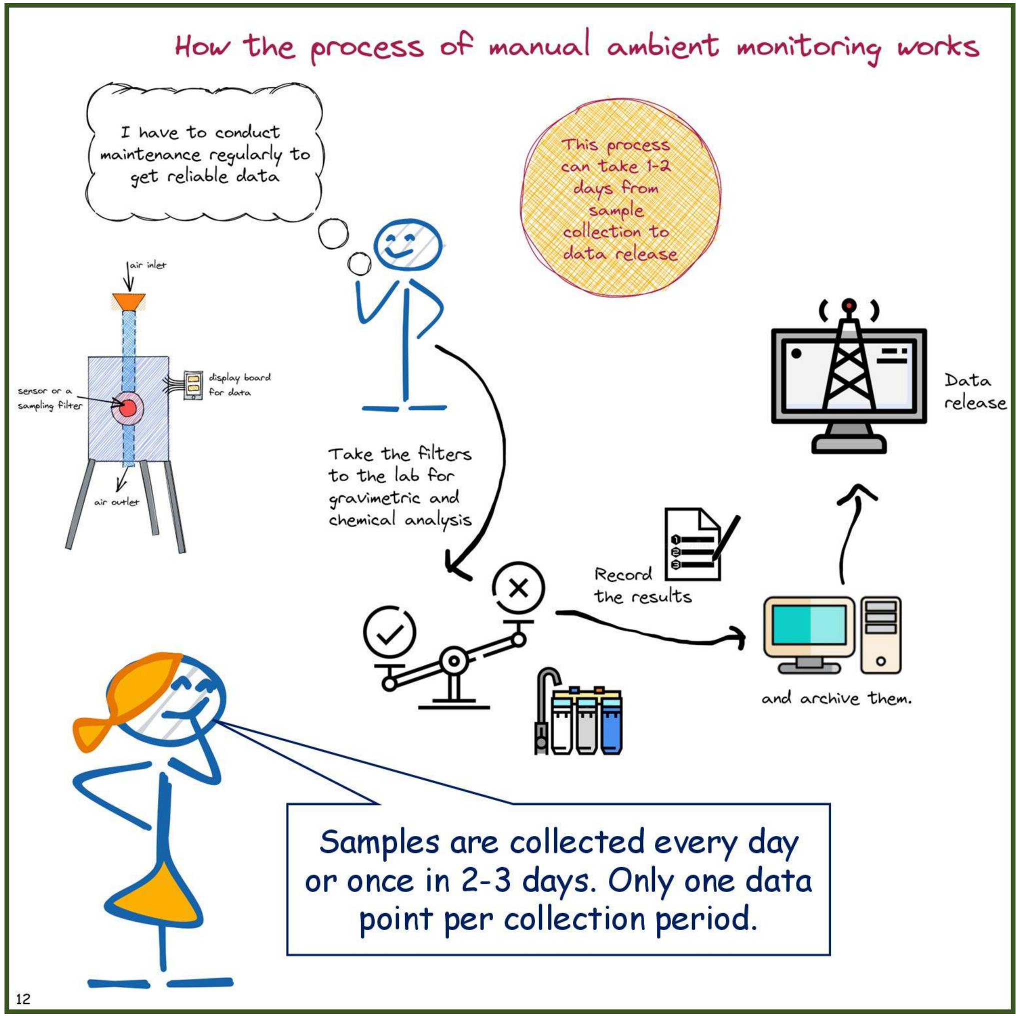
Let us also be clear that our goal is to reduce emissions to improve air quality. Achieving clean air requires targeted action across well-known sectors: transportation, industry, household cooking and heating, waste management, road and construction dust control, and a broader shift away from fossil fuel use.

The emphasis on ambient air quality monitoring is not about planning itself. Air quality management plans can be developed even with limited monitoring data and with a good understanding of the emission sources in the airshed.

Rather, the role of monitoring is to ensure we have a clearer understanding of the scale and distribution of the problem. Once clean air action plans are implemented, this data becomes essential for conducting audits, tracking progress (or lack thereof), and making informed adjustments to strategies aimed at achieving cleaner air.

Air quality monitoring methods





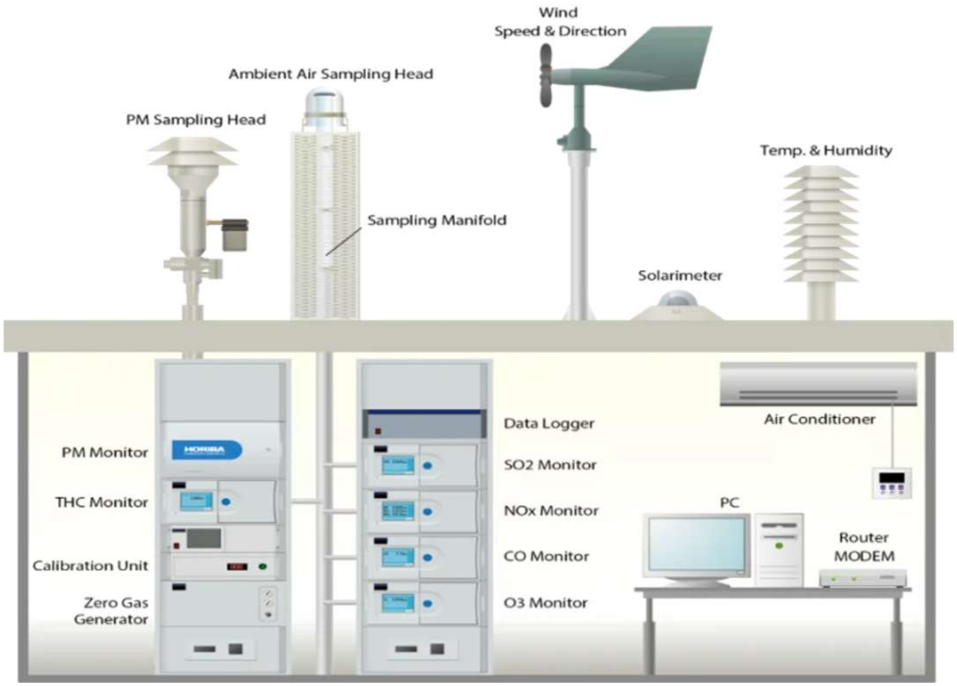
Air quality monitoring methods

Ambient air quality monitoring is neither simple nor inexpensive. It demands significant technical expertise. Traditionally, the equipment used is costly, and its operation and maintenance also require substantial investment. This remains true whether we use conventional air quality monitoring stations or emerging low-cost sensor technologies.

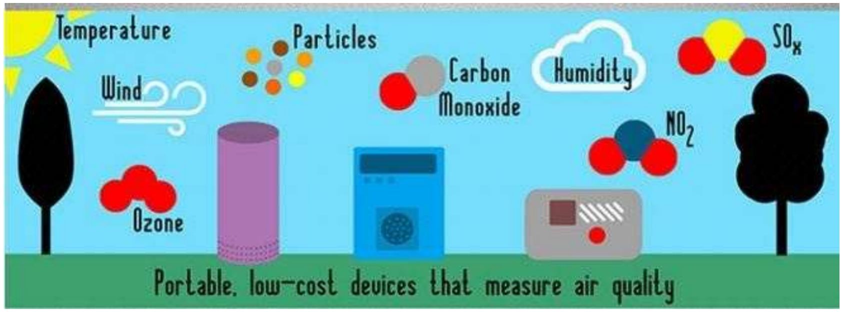
Proper operation and maintenance are essential and cannot be overlooked, because without reliable equipment, we cannot obtain accurate data to effectively study, analyze, and evaluate ongoing air quality management programs.

Air quality monitoring equipment

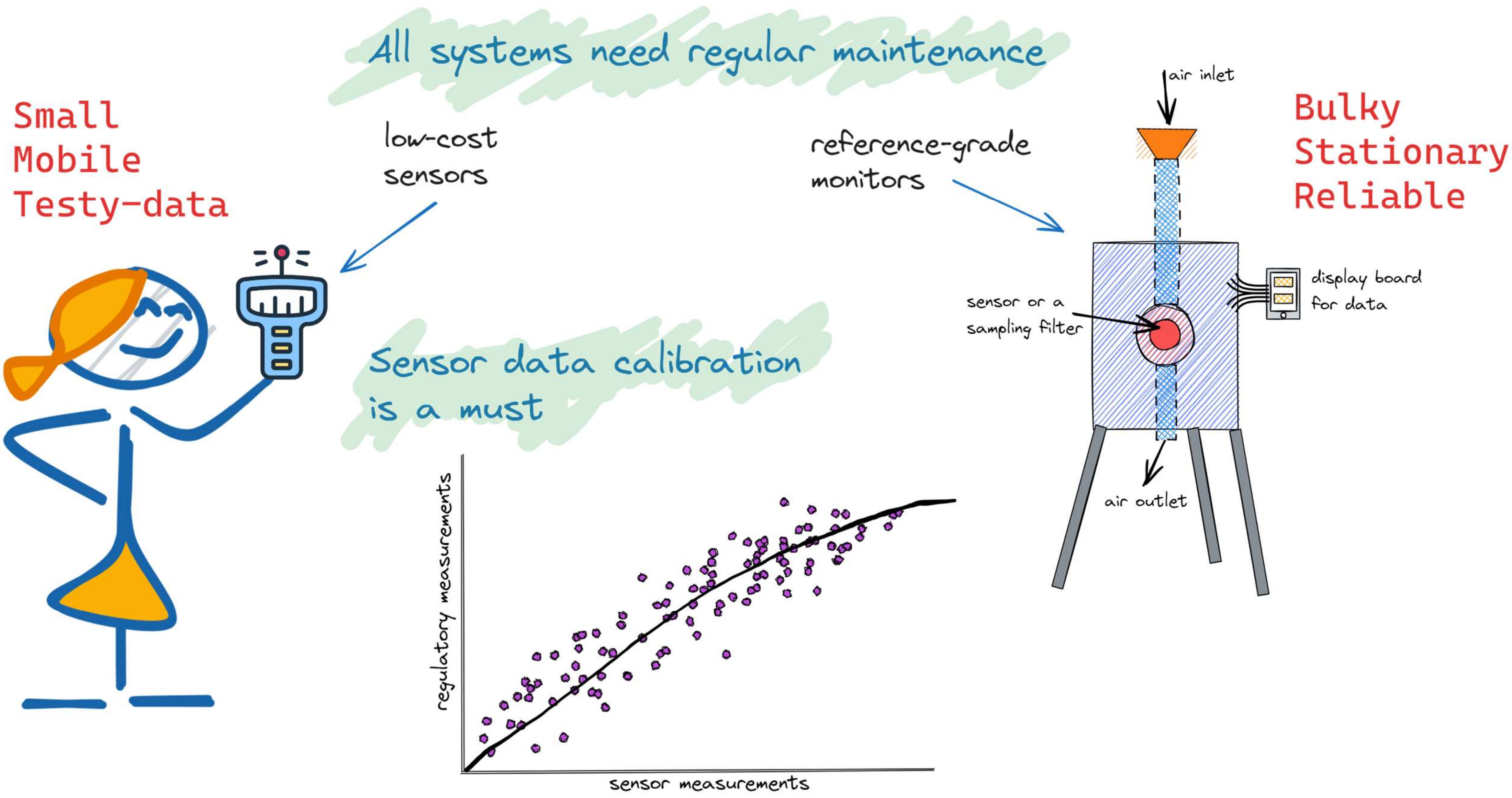
Traditional



Emerging



Challenges – calibration, maintenance, integration



All systems need regular maintenance
Small
Mobile
Testy-data
low-cost
sensors
reference-grade
monitors
Bulky
Stationary
Reliable
air inlet
display board
for data
sensor or a
sampling filter
air outlet
Sensor data calibration
is a must
regulatory measurements
sensor measurements

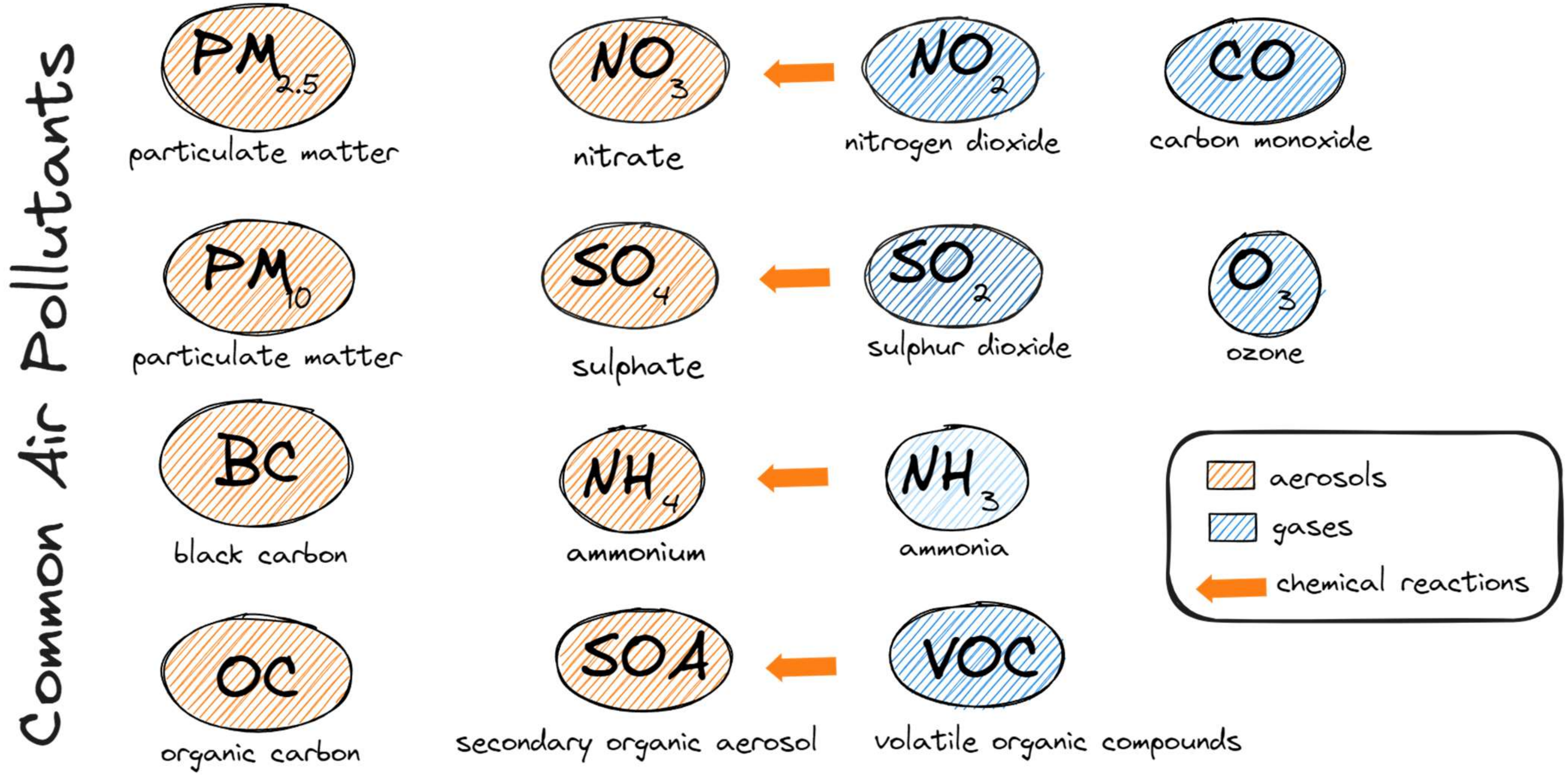
Air quality monitoring data access

In addition to access to equipment for conducting ambient air quality monitoring, access to the data itself is equally important. Data from these monitoring networks is often not publicly available or is not provided in a format that can be readily used for air quality analysis.

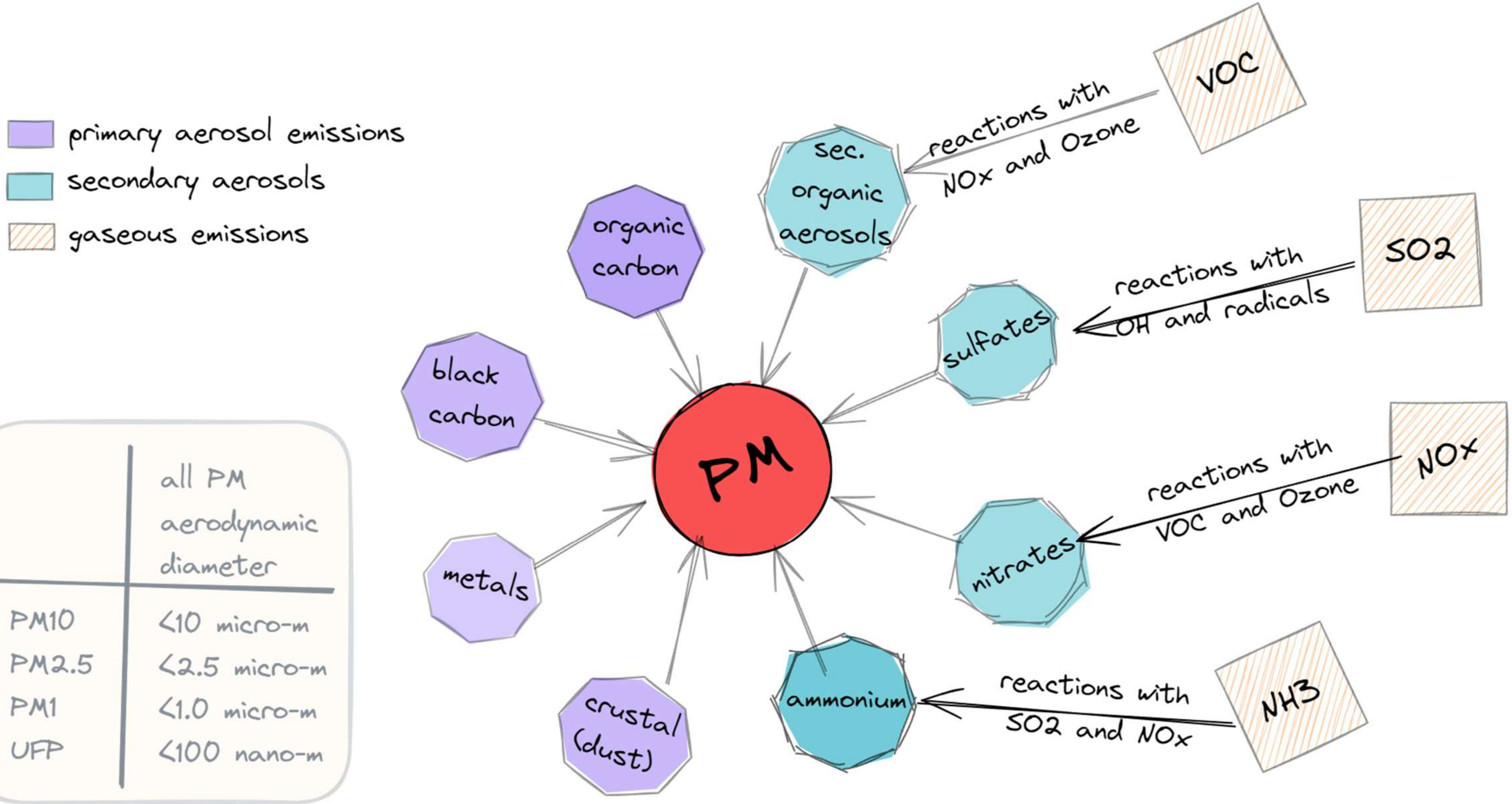
A report by the Energy Policy Institute at the University of Chicago (EPIC) highlights stark global inequalities in air quality monitoring, particularly in low- and middle-income countries (LMICs). Although regions like Asia, Africa, and Latin America account for 96% of the global burden of life years lost due to particulate pollution, they receive only a small fraction of funding for air quality monitoring. For example, Africa receives less than $300,000 annually. In contrast, wealthier regions with only 4% of the burden receive the bulk of support. This underinvestment has led to significant data gaps, with few LMIC governments producing publicly accessible air quality data. EPIC stresses that closing these gaps through local monitoring efforts and investments is essential for informed policymaking, public engagement, and improving health outcomes in the most affected regions.

https://aqfund.epic.uchicago.edu/about/the-case-for-the-fund

Air pollutants to monitor

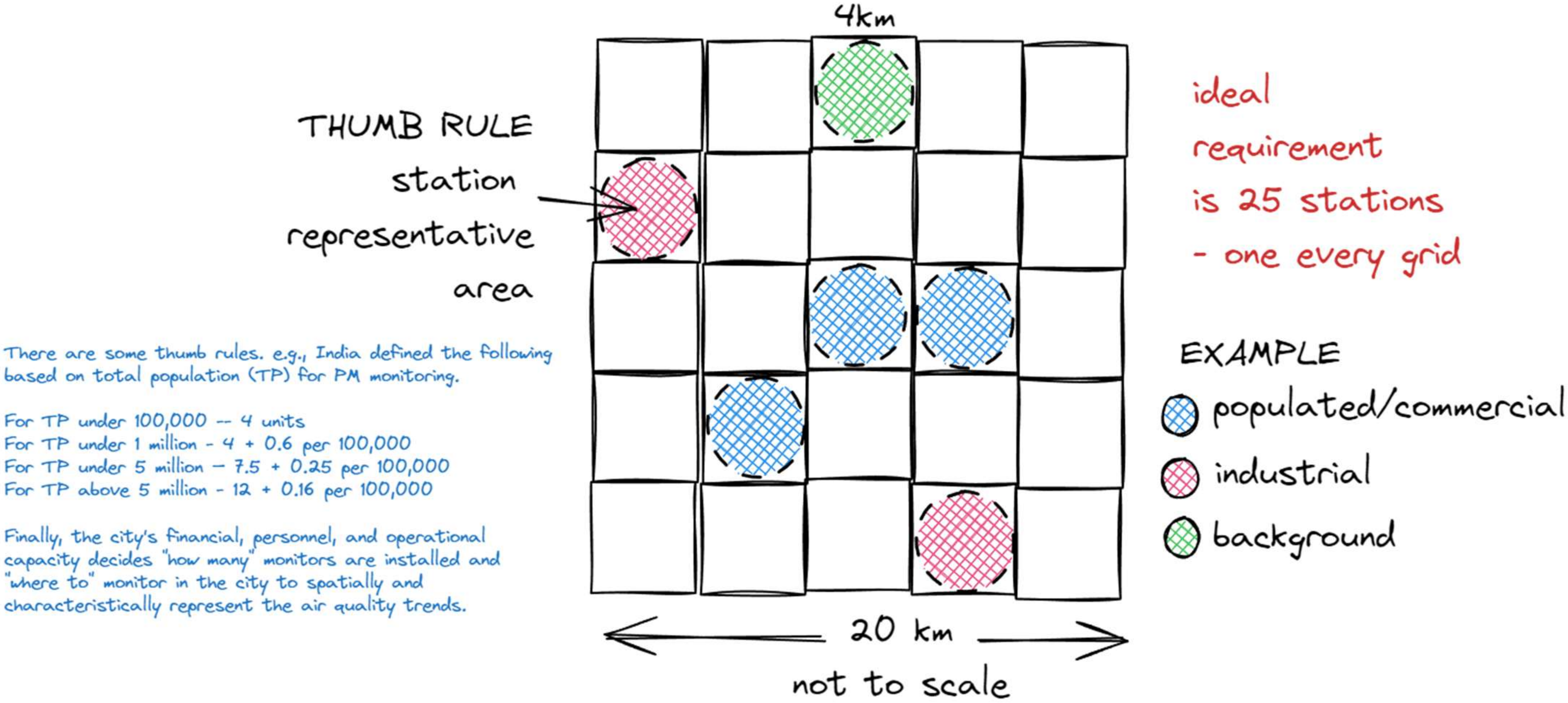


PM (2.5 and 10) is the most monitored



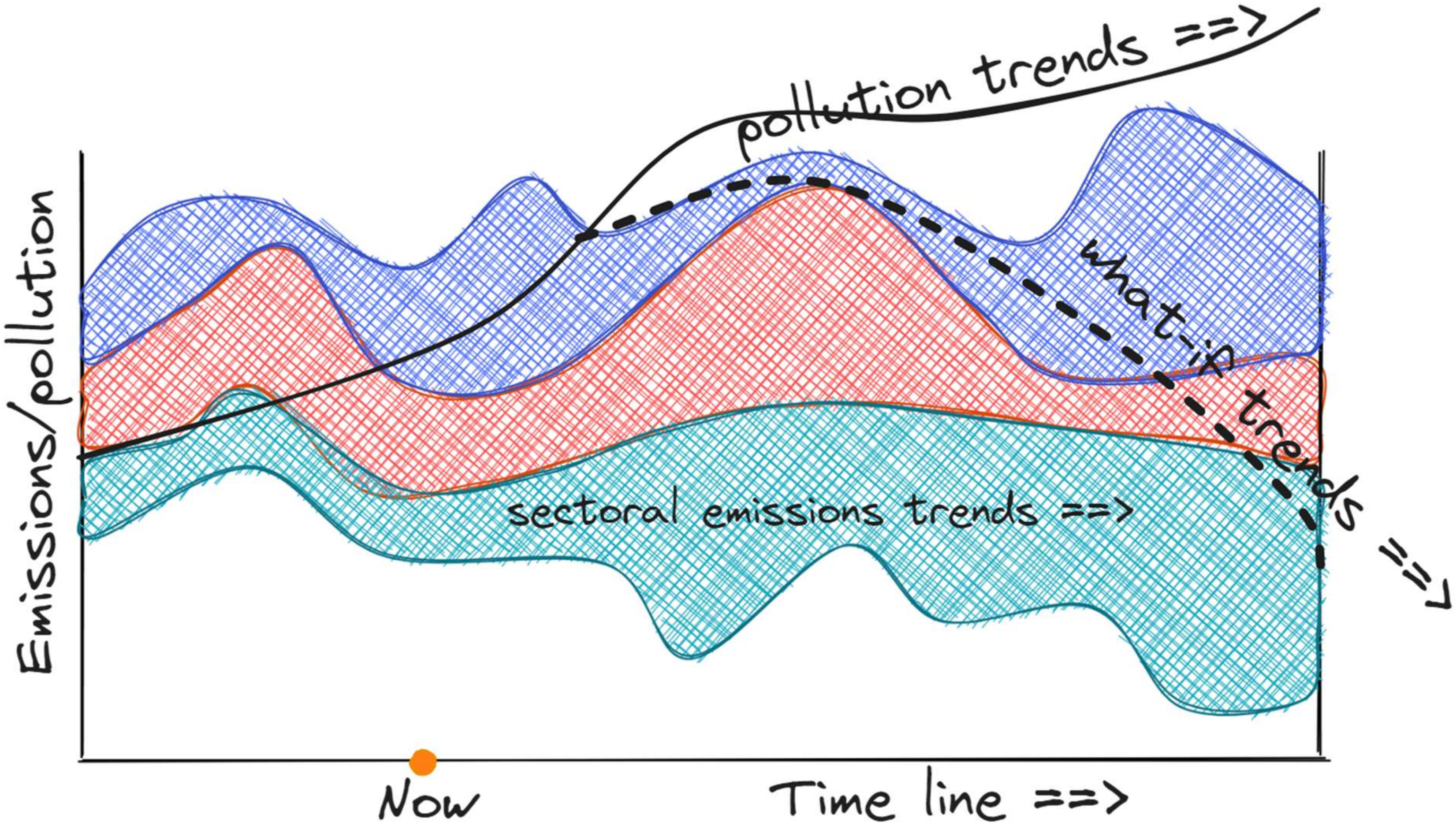
	all PM aerodynamic diameter
PM10	<10 micro-m
PM2.5	<2.5 micro-m
PM1	<1.0 micro-m
UFP	<100 nano-m

Preferred ambient air monitoring settings



- Need as many representative locations as possible of residential, industrial, commercial, traffic and background activities
- Data from a small network of stations is unreliable and unrepresentative

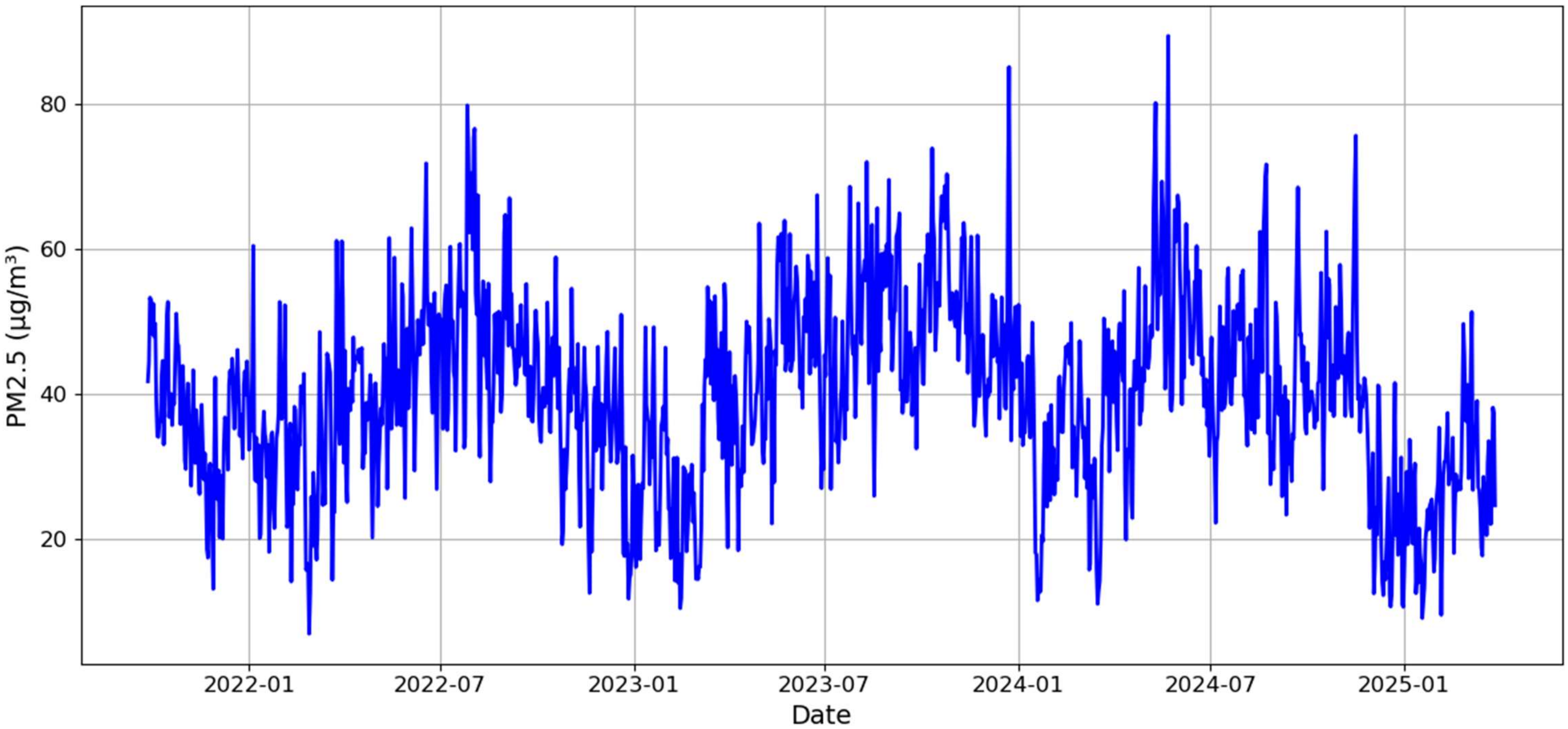
Preferred long-term monitoring data



Example Visualizations

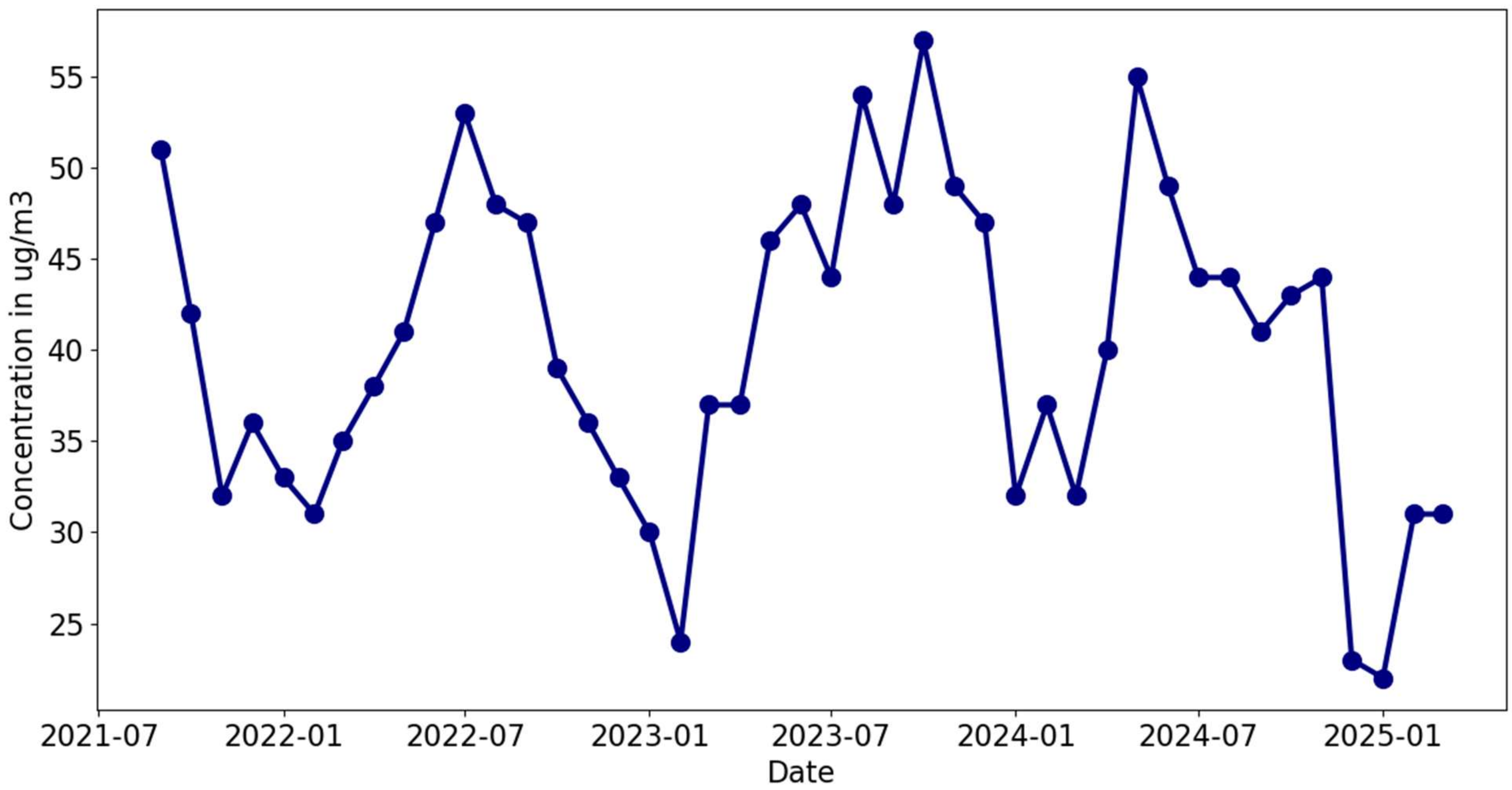
Time-series Plots

Day averages



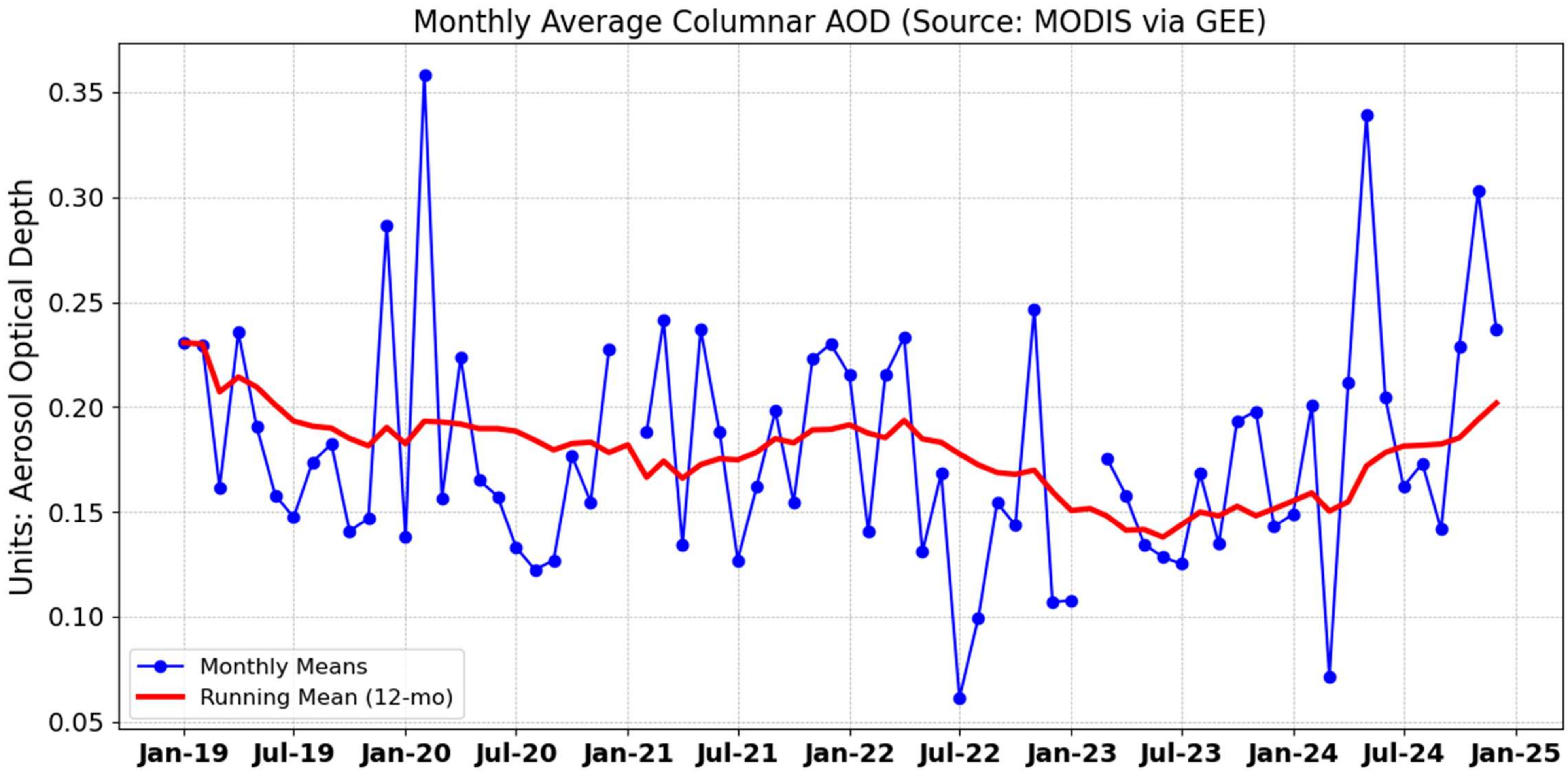
Time-series Plots

Monthly averages



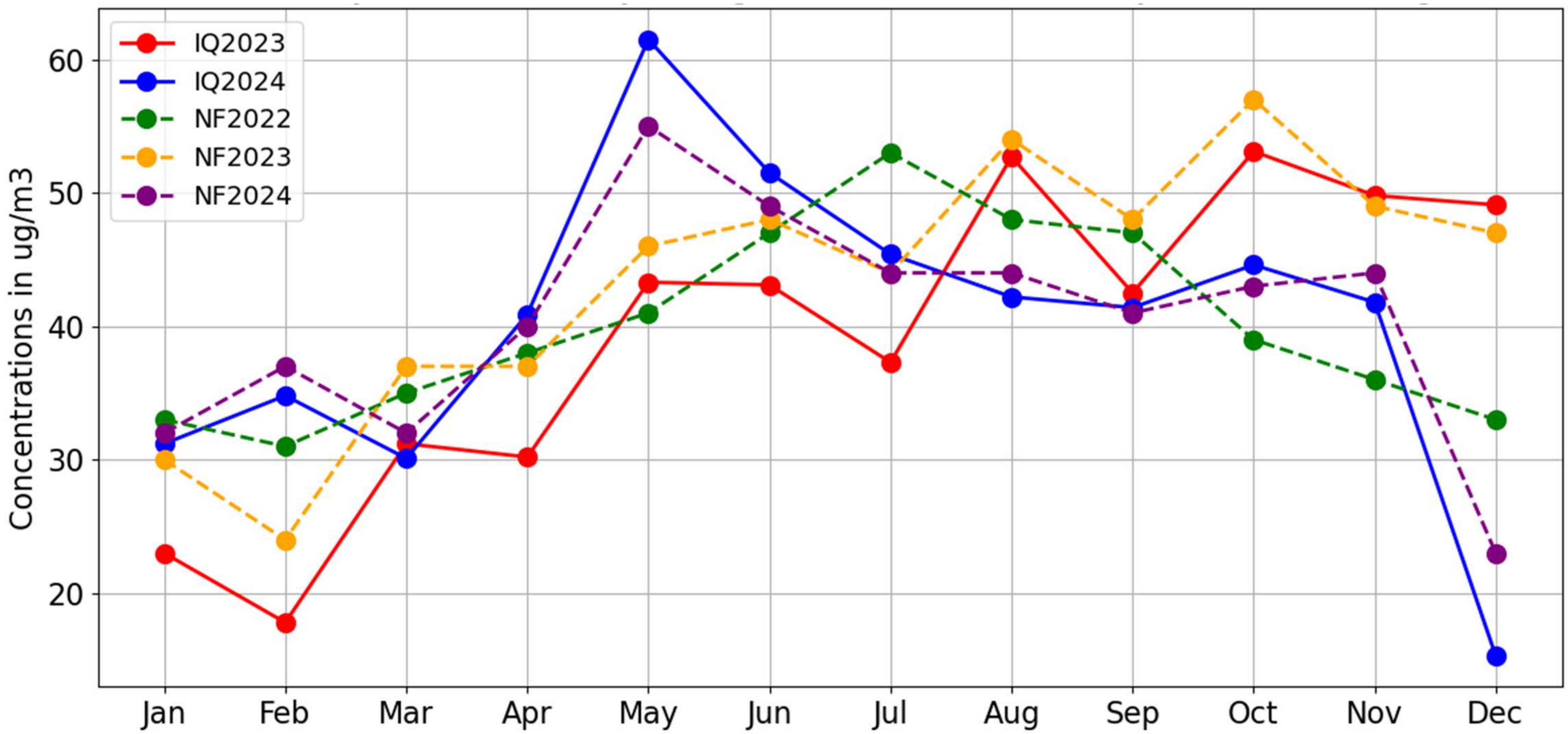
Time-series Plots

Monthly averages with running means



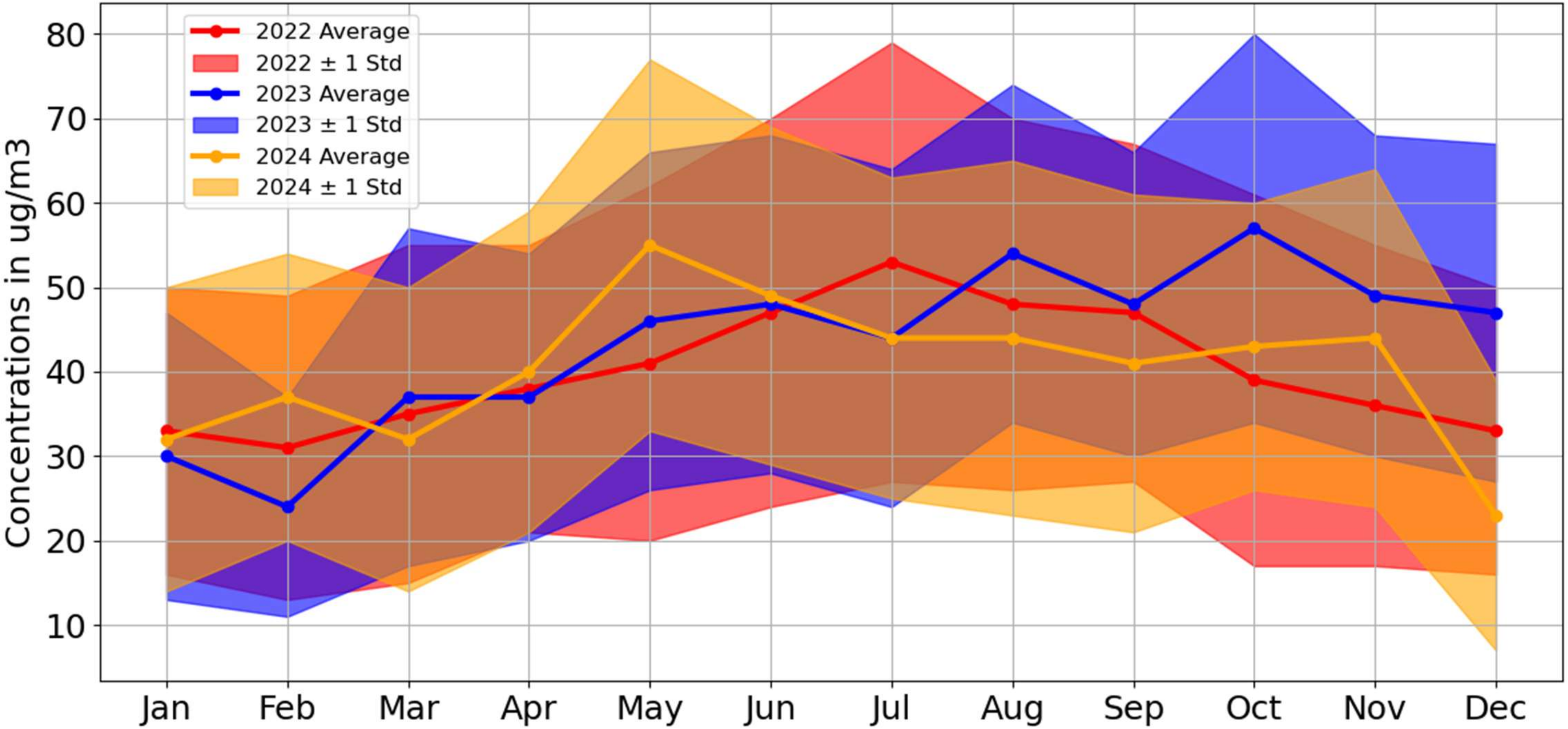
Time-series Plots

Monthly averages – Comparison



Time-series Plots

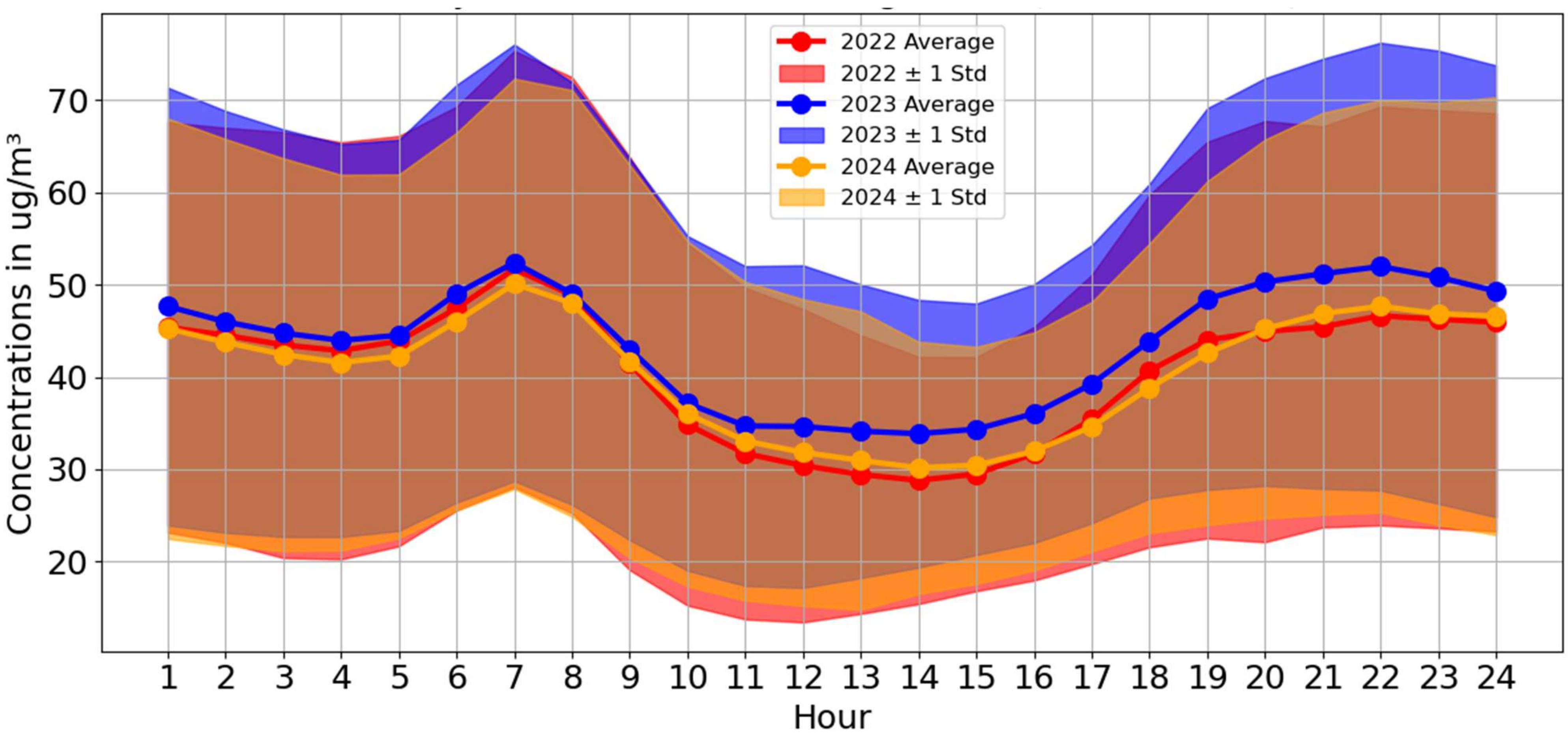
Monthly averages with variation in day-averages



- Ribbon can be presented ± standard deviation or $10^{th}/5^{th}$ and $90^{th}/95^{th}$ percentiles

Time-series Plots

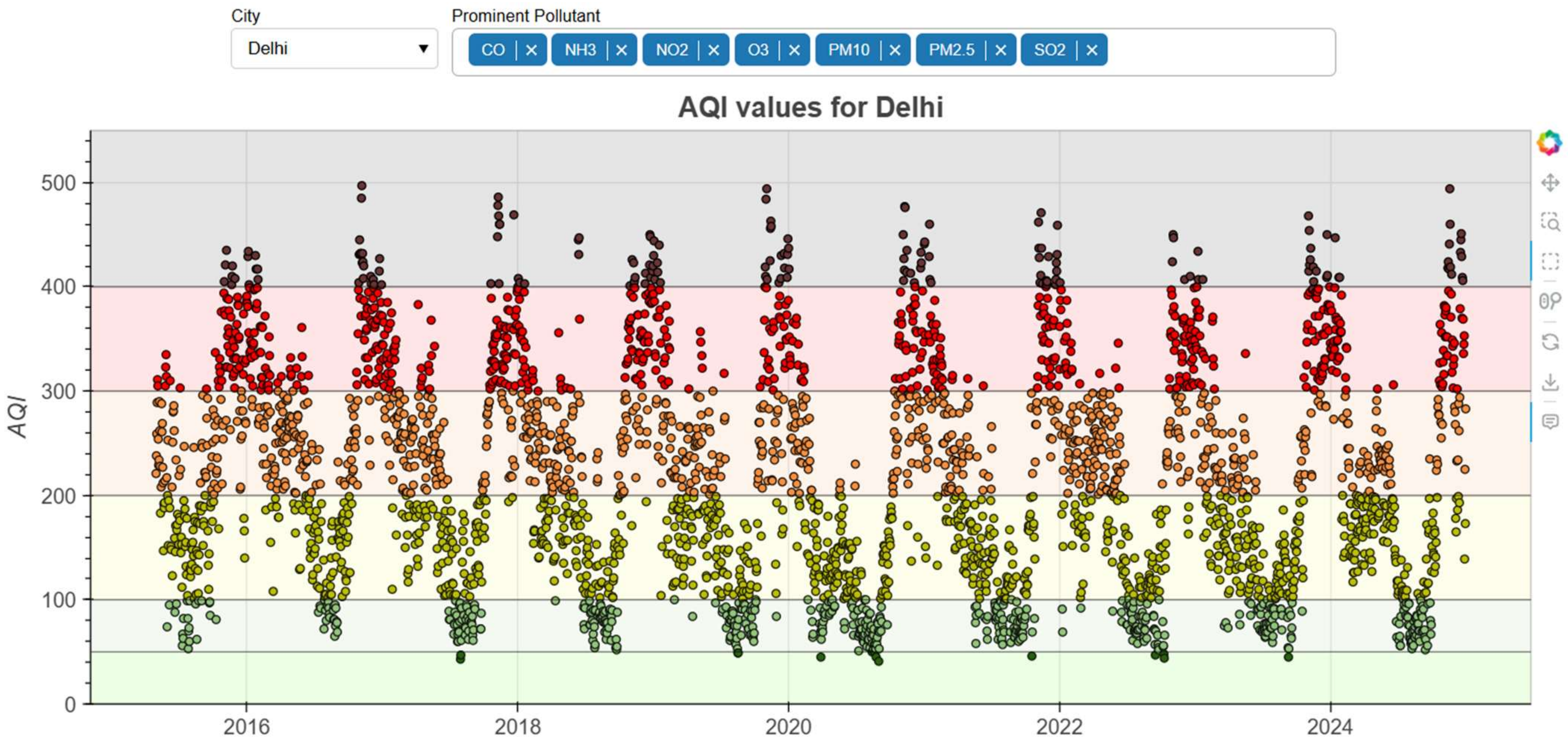
Diurnal averages and variation in hourly averages



- Ribbon can be presented ± standard deviation or 10th/5th and 90th/95th percentiles

Interactive Scatter Plots

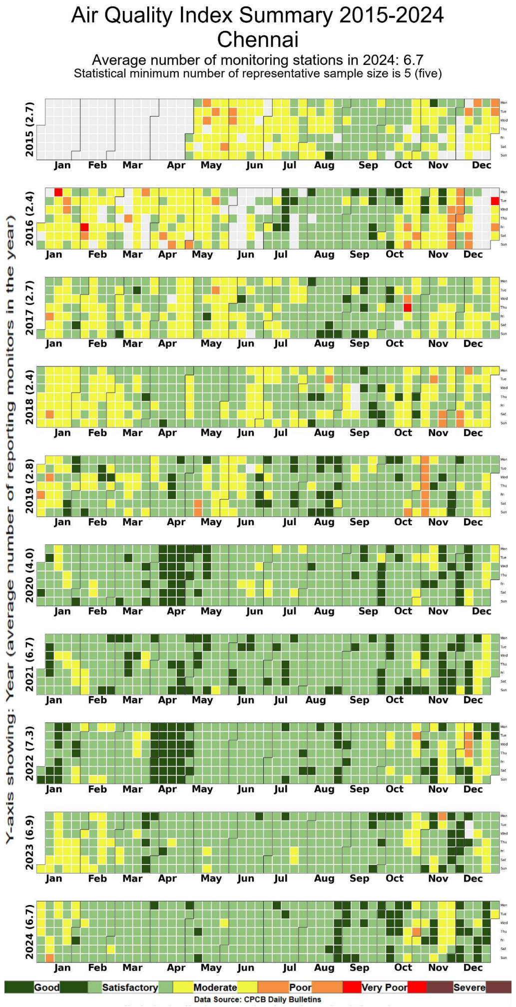
Air Quality Index (AQI) Classification

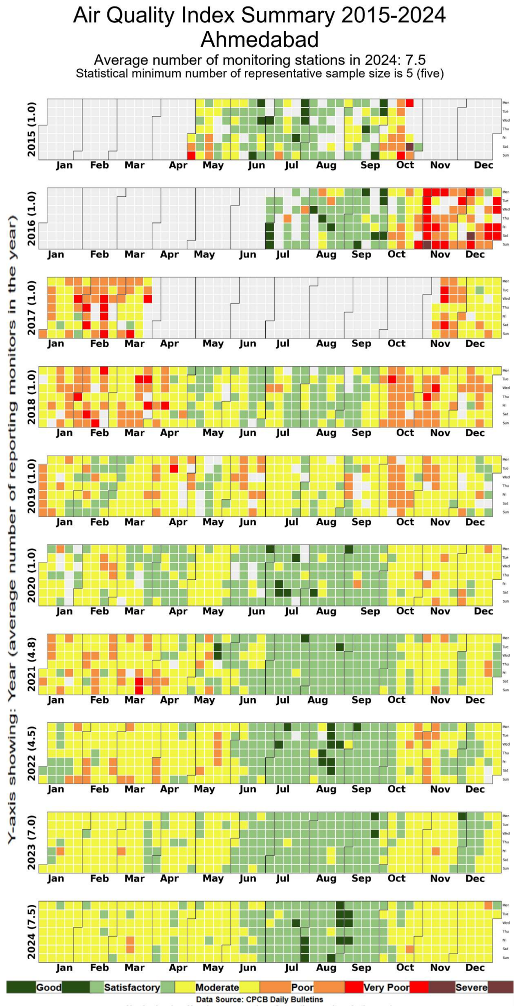


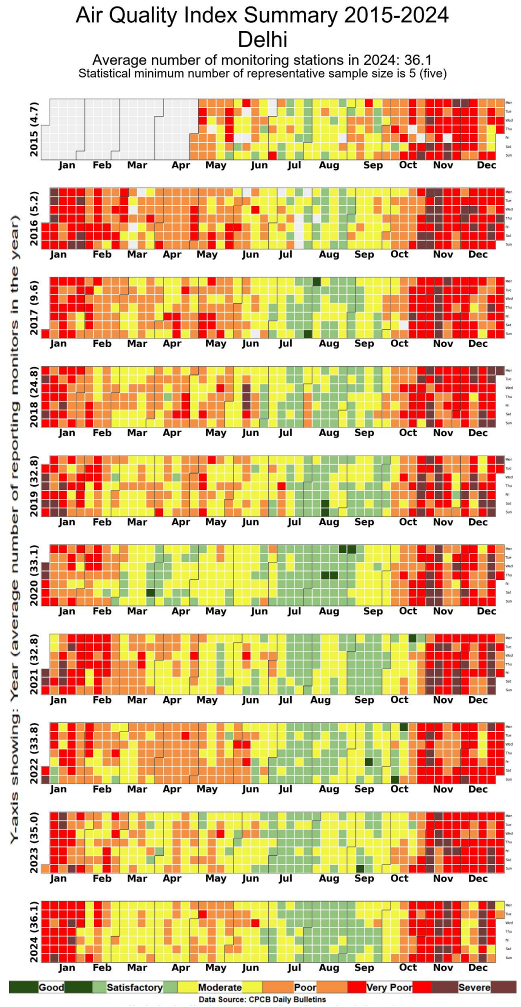
- Each dot represents a day for the select city

Calendar (heat) Plots

Day averages



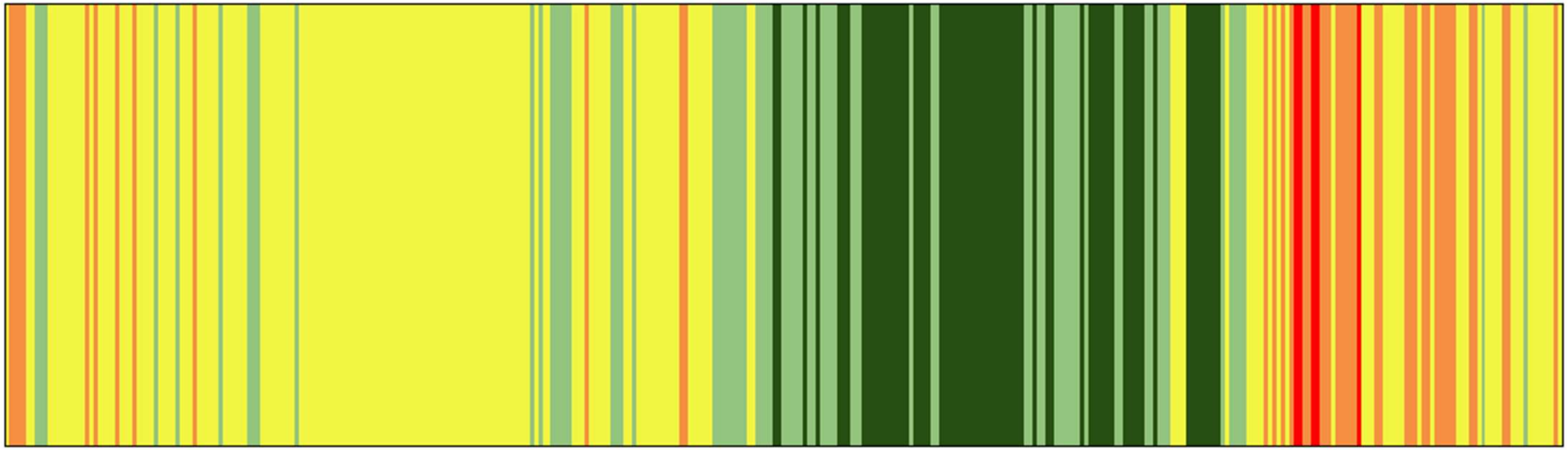




- Each dot represents a day for the select city

Stripes Plot

Day averages



- Each line represents a day for the select city

Calendar (heat) Plots

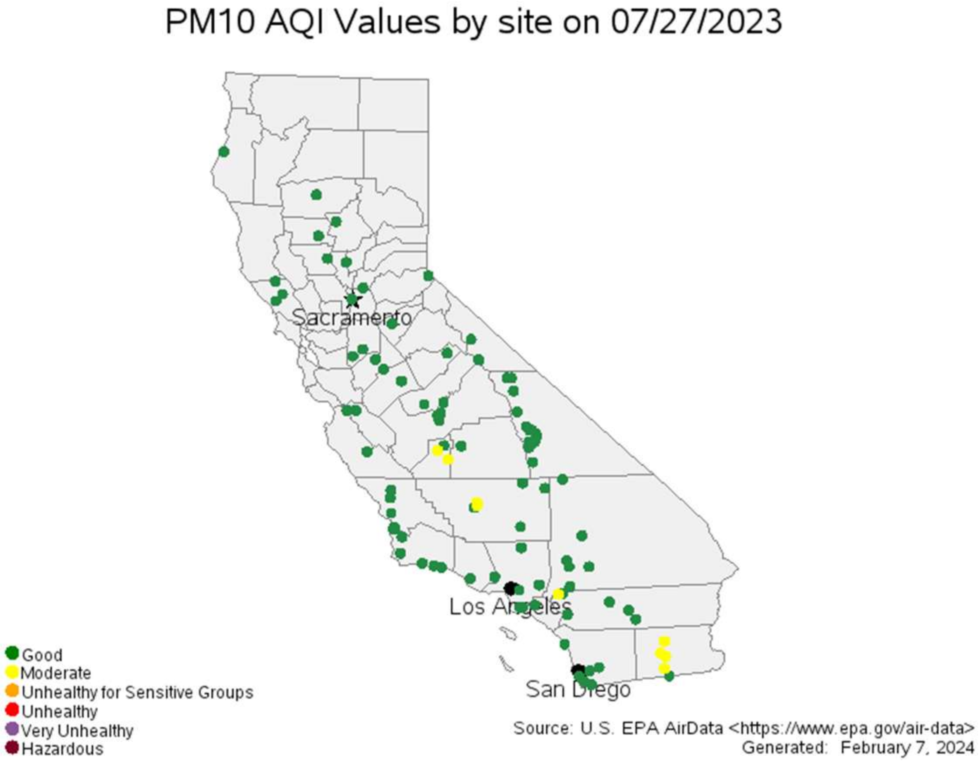
Monthly averages

Avg. AQI	J	F	M	A	M	J	J	A	S	O	N	D
in 2015					98	84	86	62	82	104	106	109
in 2016	103	103	107	100	85	79	112	58	73	103	85	55
in 2017	57	72	76	68	79	74	65	73	60	79	97	109
in 2018	113	117	109	93	99	76	80	60	66	106	115	121
in 2019	142	123	118	133	115	90	69	65	56	87	155	184
in 2020	151	168	118	100	69	56	34	40	60	90	165	212
in 2021	269	194	183	127	81	98	56	56	54	94	154	195
in 2022	197	182	186	124	106	62	81	66	80	128	219	230
in 2023	250	266	181	139	82	116	59	55	62	173	162	160

- Each dot represents a month average for the select city

Concentration Maps

More spatial-temporal plots



Data can be further explored spatially and temporally, assuming there is enough spatial representation of the ambient monitors in the select airshed – all the above examples can be repeated for more granular assessment

- Monthly, daily, and hourly time series plots by station, zone, district, and province
- Comparison plots between the stations, zones, districts, and provinces
- Comparison plots in space and time between the zones, districts, and provinces

Tables

Air Quality Index (AQI) Classification

	Good	Satisfactory	Moderate	Poor	Very Poor	Severe
2015	8%	33%	31%	13%	11%	3.0%
2016	11%	27%	35%	14%	9.3%	3.9%
2017	8%	33%	34%	14%	8.7%	2.4%
2018	8%	31%	38%	14%	7.3%	1.5%
2019	11%	33%	36%	13%	5.3%	1.2%
2020	20%	38%	29%	10%	3.6%	0.7%
2021	19%	35%	29%	12%	4.8%	0.6%
2022	17%	34%	31%	12%	4.1%	0.5%
2023	17%	37%	32%	10%	3.2%	0.3%

Other Tables

Of concentrations and processed AQI information

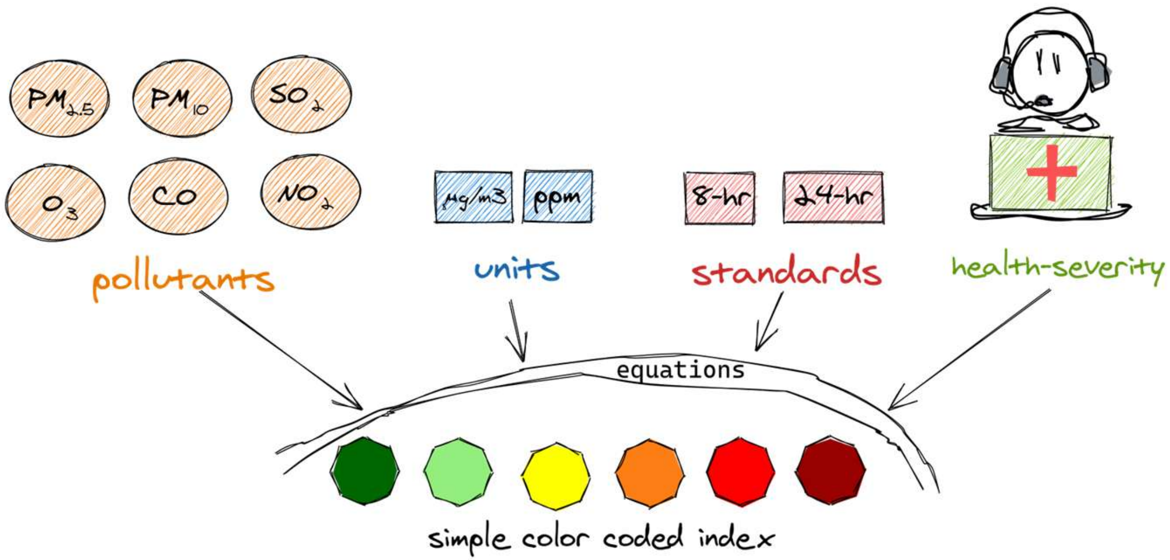
- Annual, seasonal, monthly, daily, and hourly averages, maximums, standard deviations, percentiles and others by station, zone, district, and province

- Comparison of averages and variations between the stations, zones, districts, and provinces

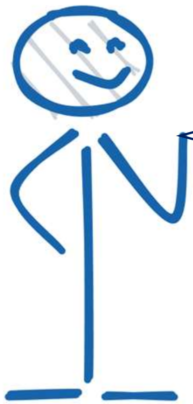
Example Applications of Ambient Monitoring Data

use 1

Very first is its use in calculating air quality index (AQI) - a unit less number which unifies all the complicated (a) science of pollution composition (b) health severity (c) ambient standards and (d) measurement and standard protocols, into simple color-coded alerts of good or bad or severe air pollution categories.

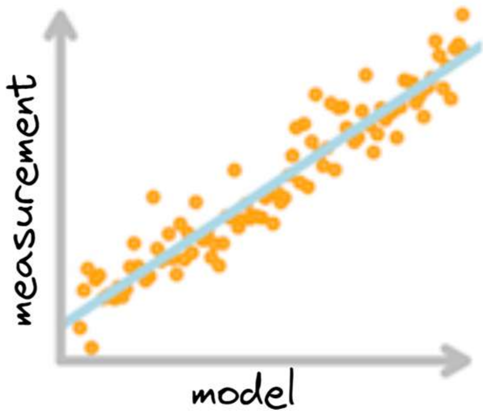


use 2



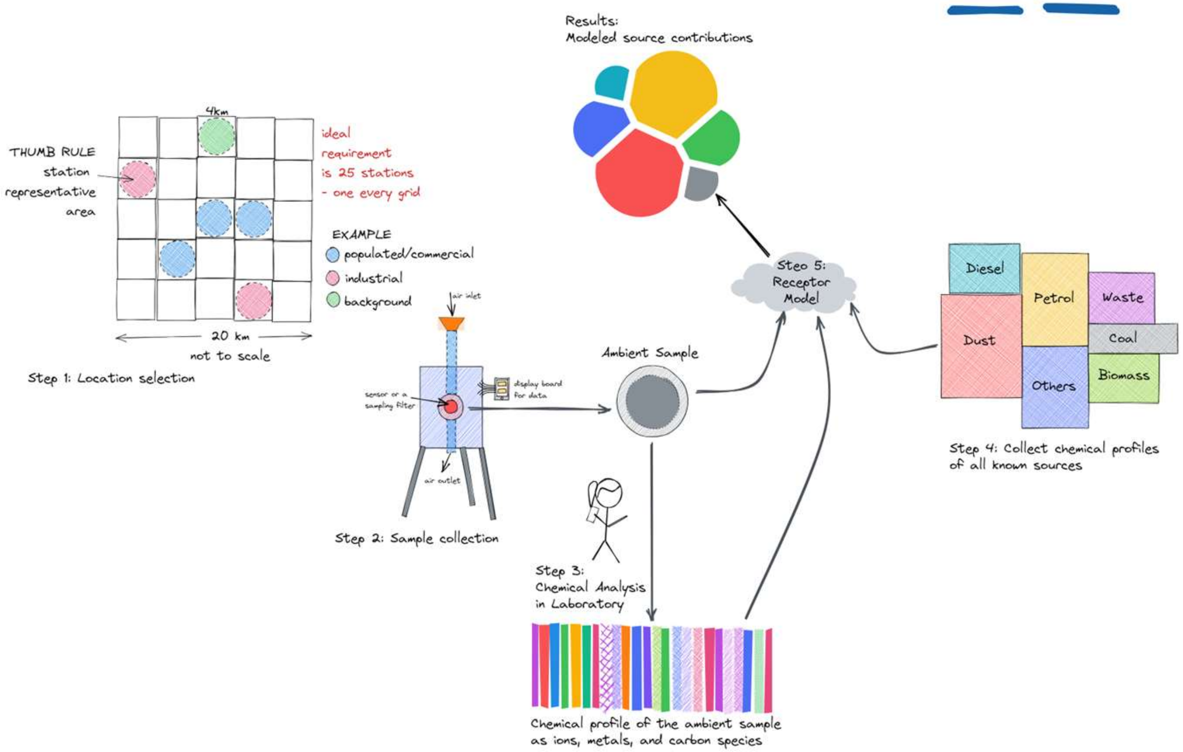
A large pool of monitoring data means a better understanding of the spatial and temporal trends in pollution.

This will also support the modeling efforts trying to understand these trends. Data is used for validating the models and increasing their confidence levels.



use
3

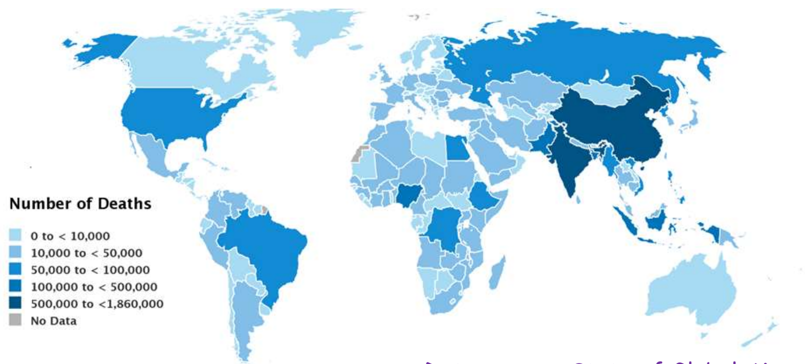
Filters collected at the manual stations can be used for chemical analysis-based assessment of source contributions.



use
4

One of the biggest uses of ambient air monitoring data is to establish a nexus with health impacts, which range from

* cases of ischemic heart disease (heart attacks)
* cerebrovascular disease (strokes)
* chronic obstructive pulmonary diseases
* lower respiratory infections
* cancers (in trachea, lungs, and bronchitis)
* obesity
* diabetes and
* Alzheimer’s disease.

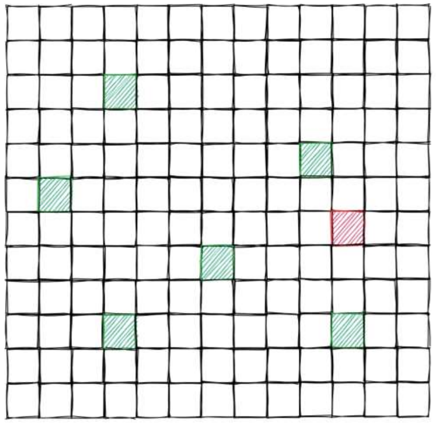


Data source: State of Global Air

Land Use Regression (LUR) or Hyperlocal models offer an alternative to computationally demanding chemical transport models. These models can predict pollution levels at high resolutions, even in areas with limited monitoring data or just some modeled values, along with spatial predictor variables, primarily obtained through GIS

use 5

Example LUR Model

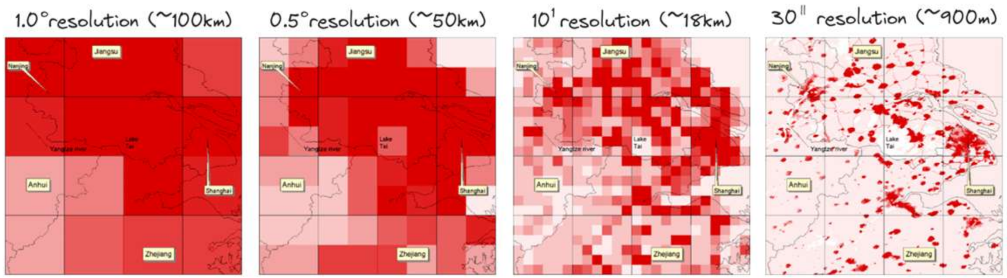


Monitored areas.
Measured pollution values (Y_i)

Predict pollution value (Y) in unsampled grid using the model

```
Y = Yo + A * POP_DENSITY
       + B * INDUSTRIAL_AREA
       + C * ROAD_DENSITY
       + D * LANDFILL_AREA
       + E * TRAFFIC
       + ...... + e
```

Estimate Yo and all A, B, C, D ... coefficients.



Library of Tools & Training Materials

A library of Python scripts is also available for visualizing air quality data, particularly the visuals presented in the annex of this document. All these scripts can be accessed through the UrbanEmissions GitHub portal.
https://github.com/urbanemissionsinfo/ClimateVisuals
https://urbanemissionsinfo.github.io/AQI_bulletins

A library of tools, particularly Excel-based tools, is also available to guide users through a complete analytical cycle from monitoring data to emissions, pollution levels, and impact assessment. These tools are openly accessible through the UrbanEmissions website (https://urbanemissions.info/tools) and are designed to support a wide range of users in applying air quality data for meaningful analysis and decision-making.

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