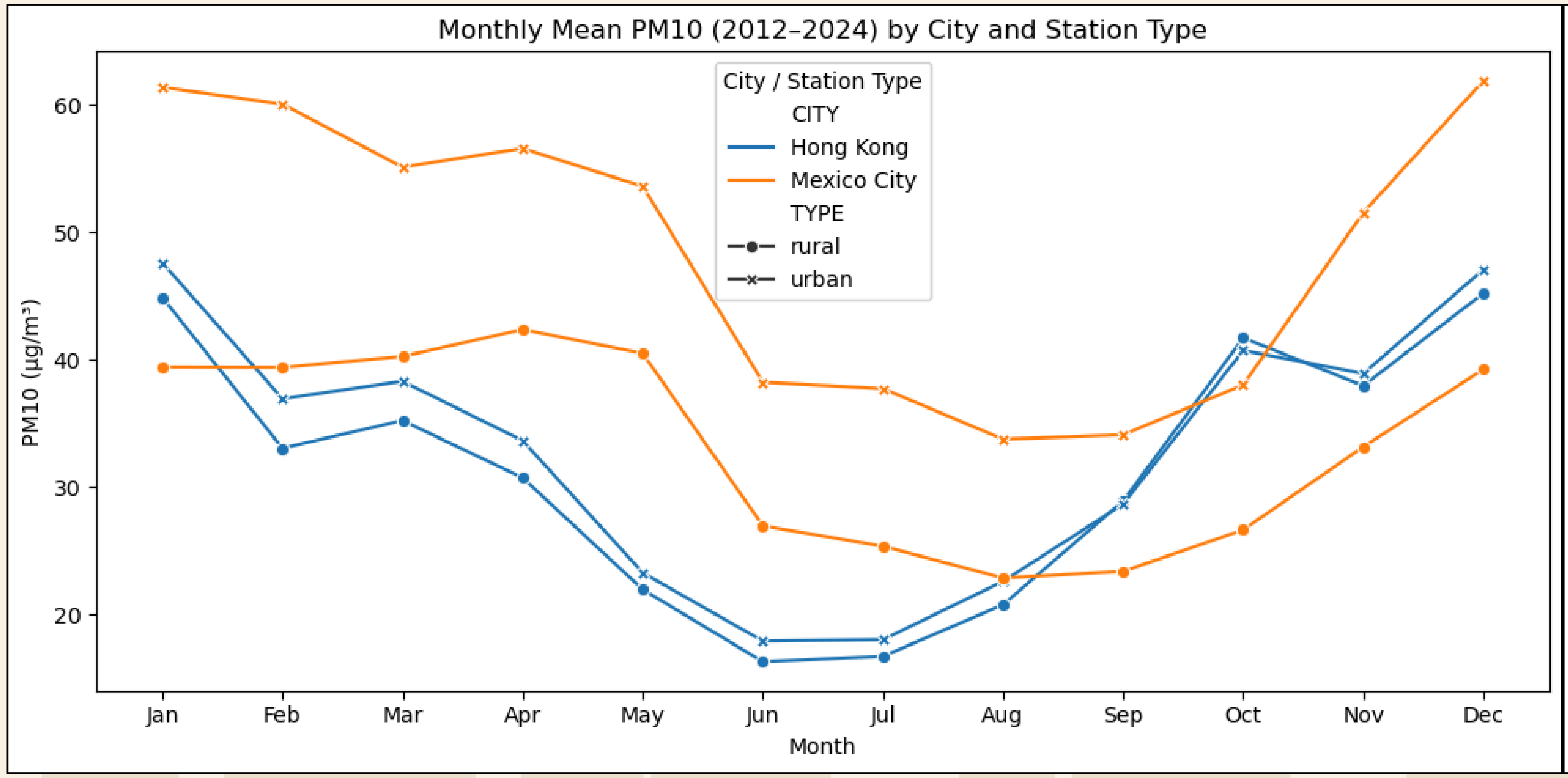
SEE4994
RICO ESPARZA, Erick
26/09/2025

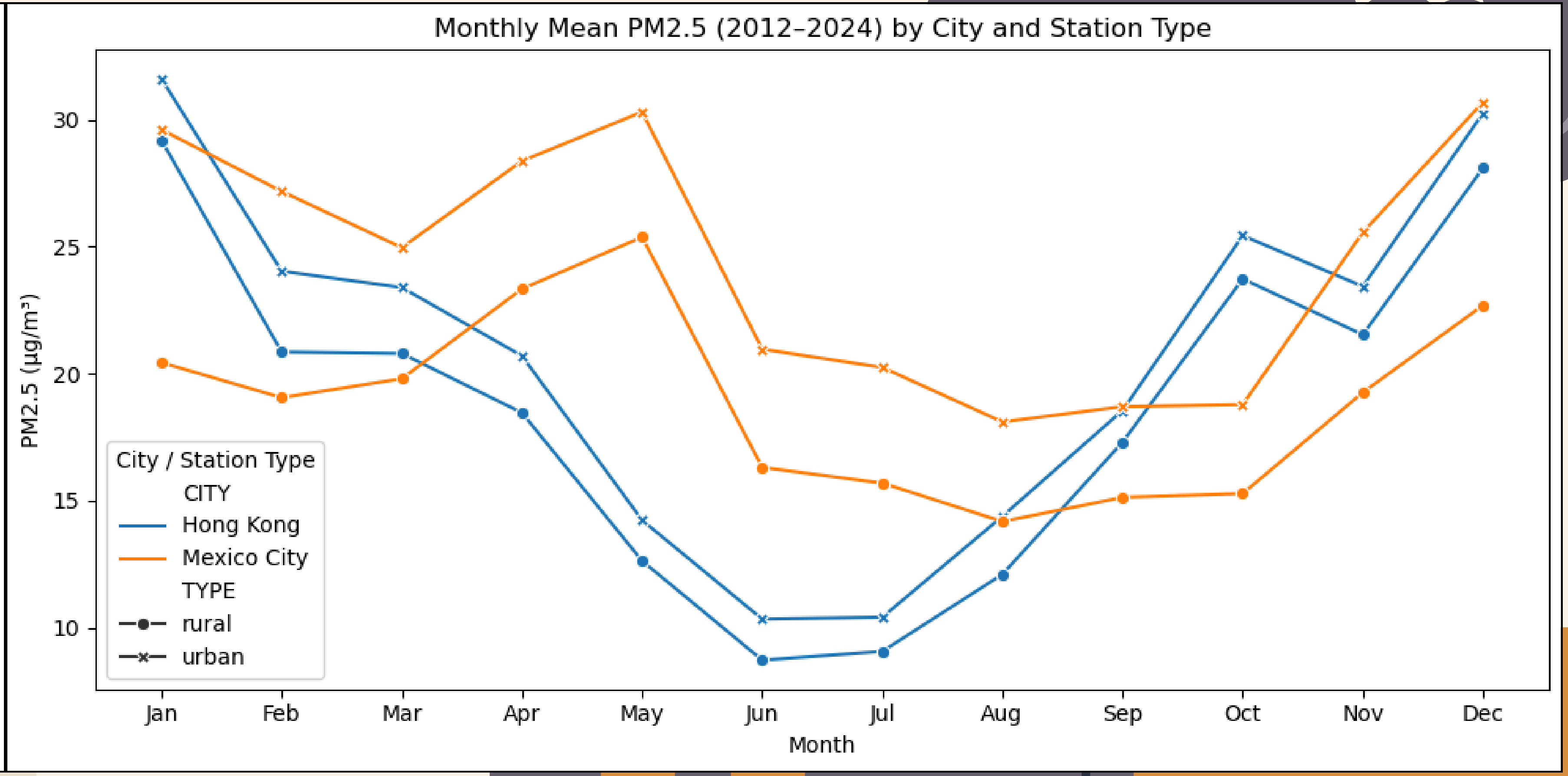
# AIR QUALITY COMPARISON: FROM SEASONAL TRENDS TO INDICES

*Week 3 – Literature Review and Air Quality Indices*

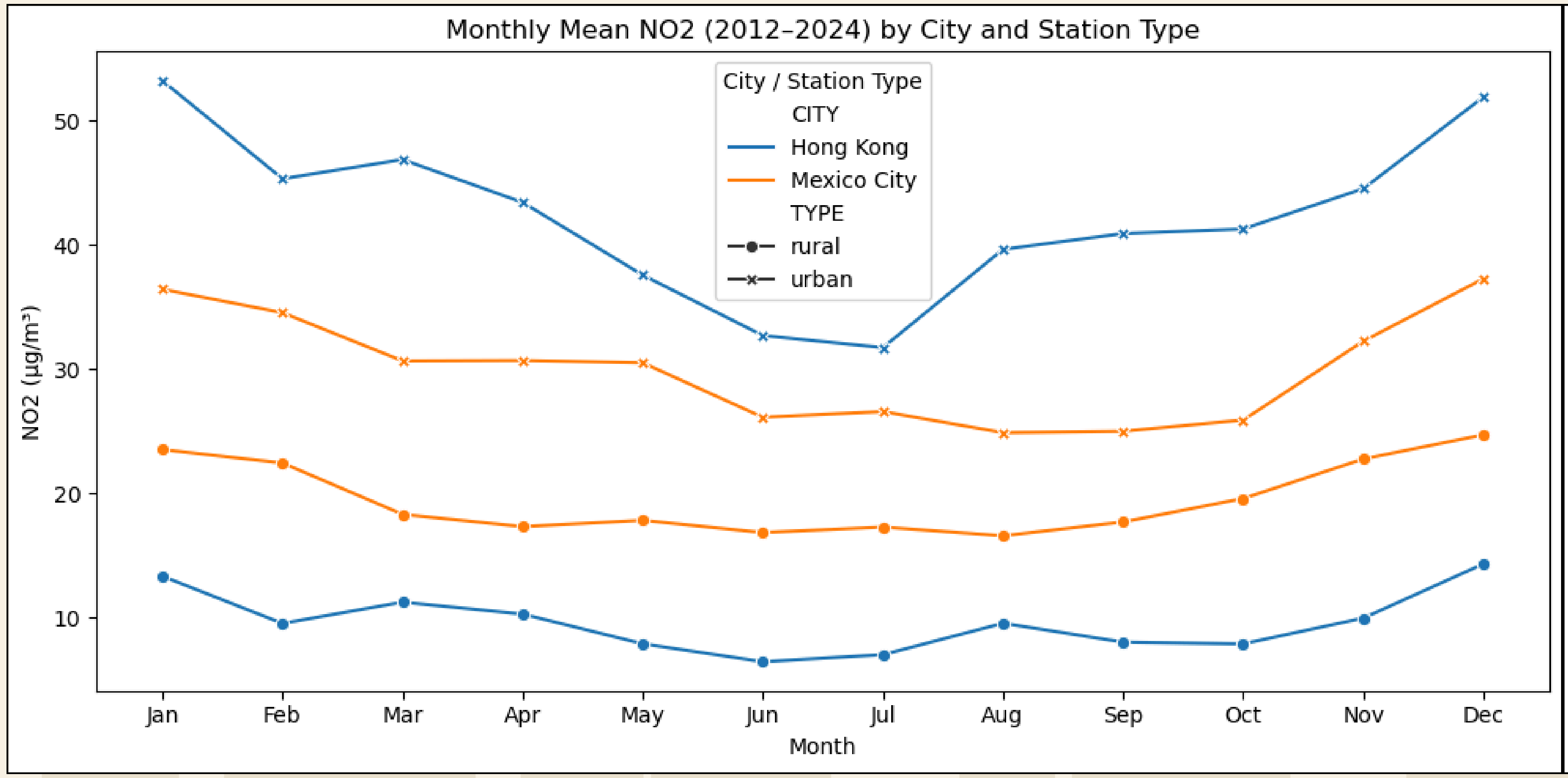
Focused on meteorological context, pollution sources, and comparative frameworks for air quality indices. Includes continuation of seasonal/monthly analyses from Week 2 (slides 2-5).

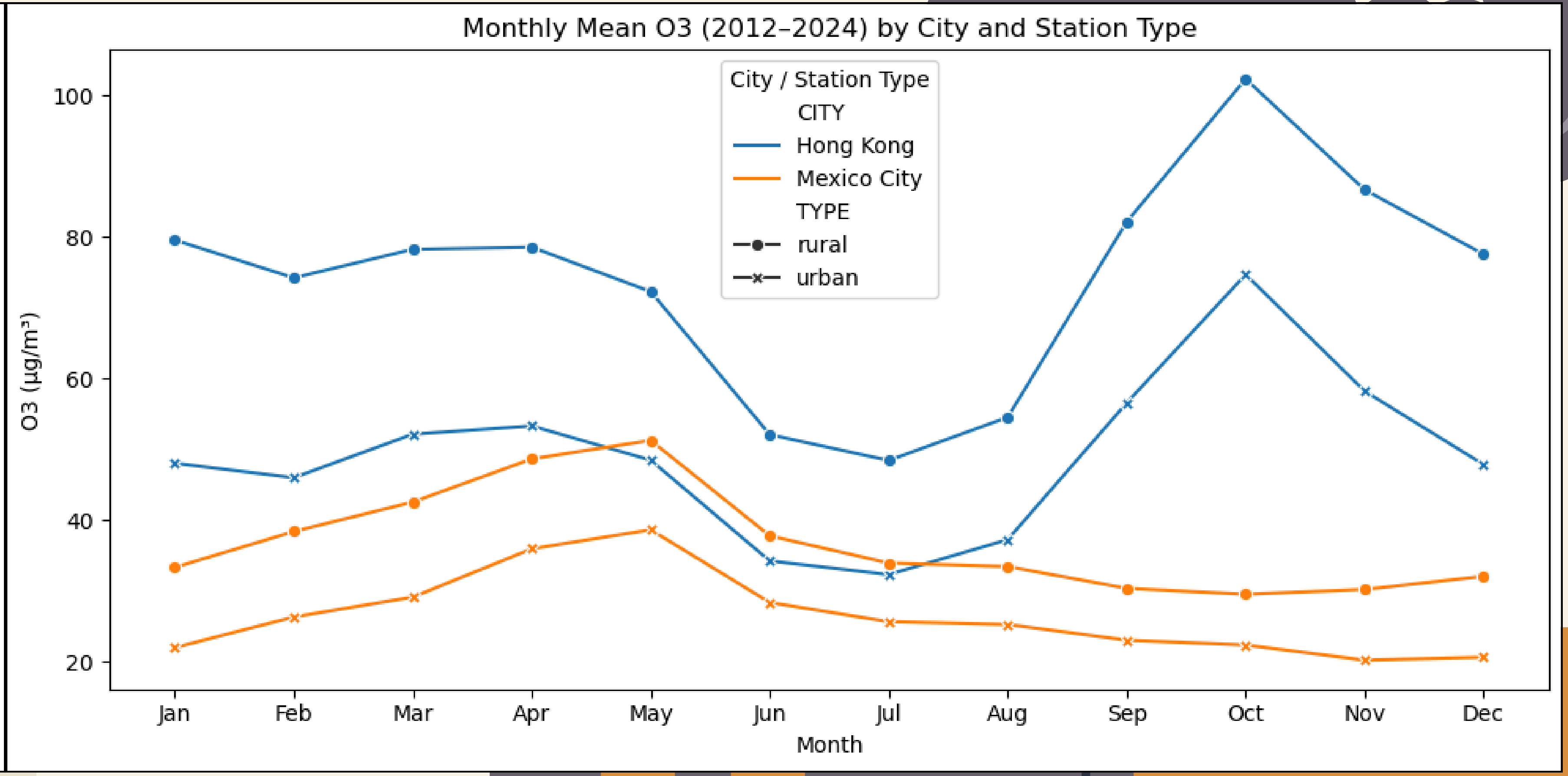
# MONTHLY TRENDS: HONG KONG VS. MEXICO CITY (1/3)



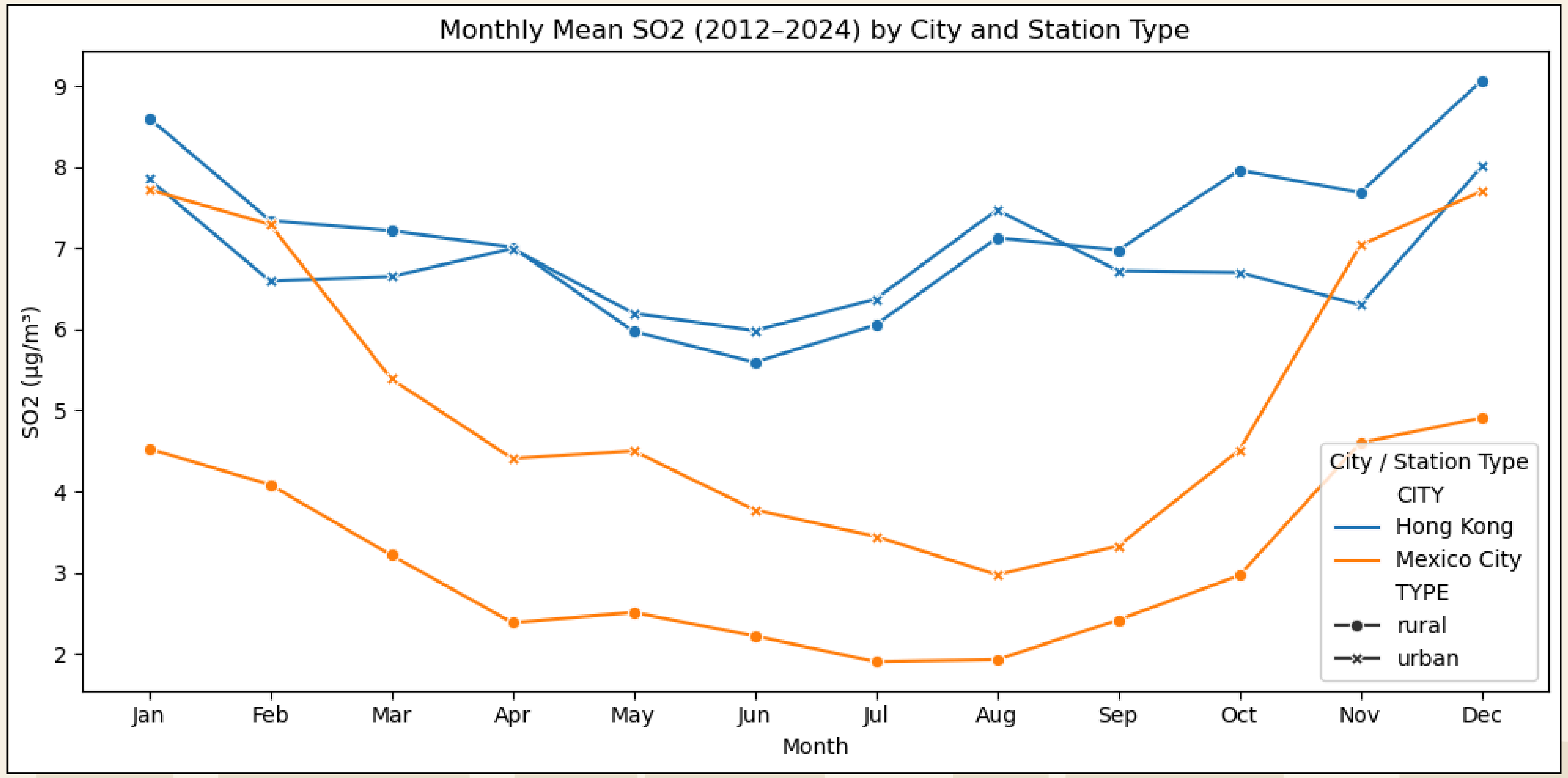



# MONTHLY TRENDS: HONG KONG VS. MEXICO CITY (2/3)



# MONTHLY TRENDS: HONG KONG VS. MEXICO CITY (3/3)




**Pollutants and Patterns**

- PM10 and PM2.5: Both are highest in Mexico City, especially in urban areas, with distinct winter peaks.
- Ozone ($O_3$) and Nitrogen Dioxide ($NO_2$): Hong Kong has significantly higher levels, with a sharp autumn peak for $O_3$ (rural sites) and a strong winter peak for $NO_2$ (urban sites).

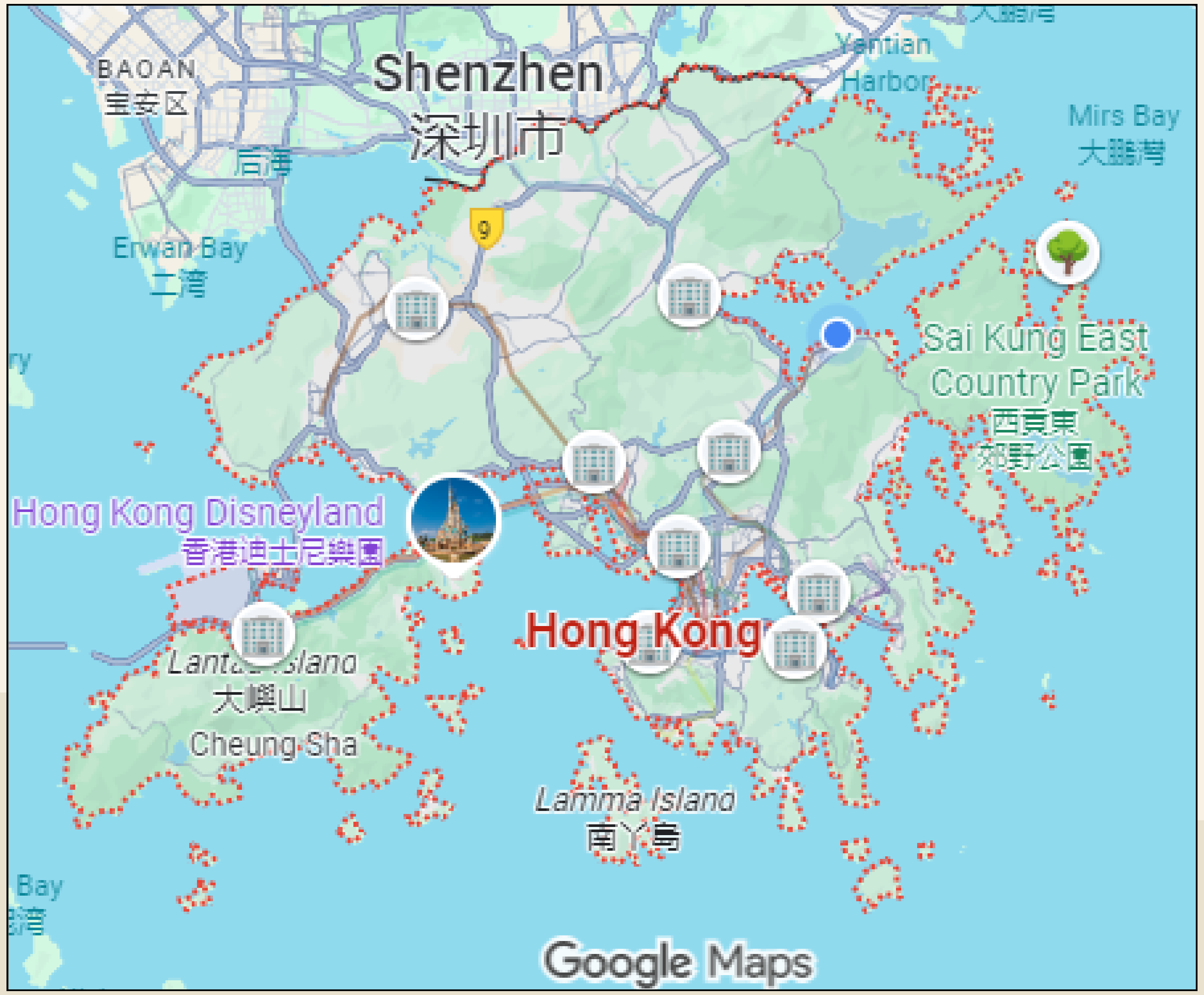
**Seasonal Trends**

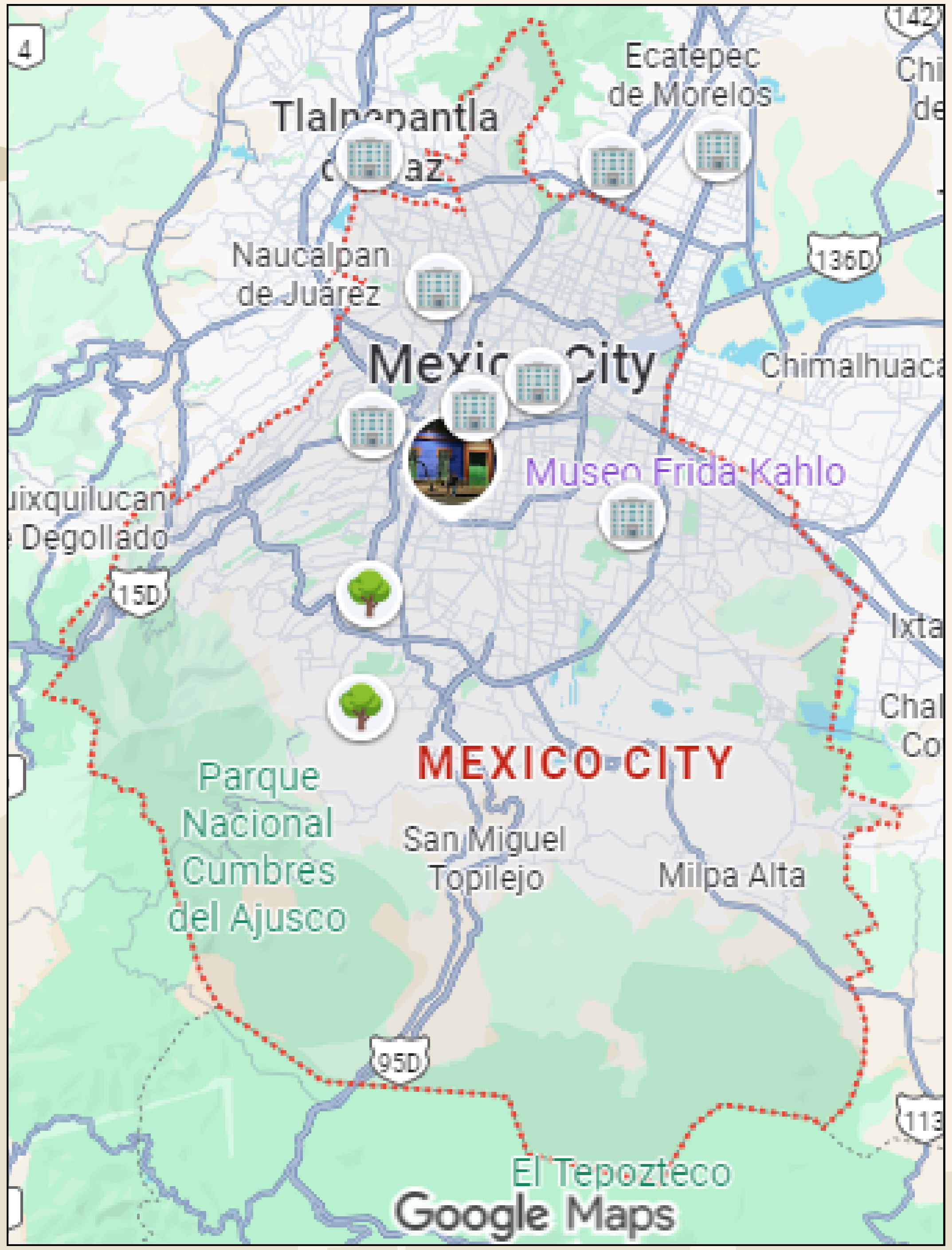
- Winter: The most polluted season for most contaminants (PM10, PM2.5, $NO_2$, $SO_2$) in both cities, likely due to stagnant atmospheric conditions.
- Summer: Generally the cleanest season for most pollutants.
- Autumn: The time of highest Ozone ($O_3$) concentration, particularly in Hong Kong.

**Urban vs. Rural**

- Urban sites in both cities show higher overall pollution and more pronounced seasonal changes, except for Ozone.
- Rural sites in Hong Kong show the highest Ozone ($O_3$) levels, suggesting a regional transport of pollutants.

# GEOGRAPHIC DISTRIBUTION OF SELECTED STATIONS




**LEGEND**

- Urban
- Rural

# CONCEPTUAL MAP: METEOROLOGY, CLIMATE, AND POLLUTION SOURCES IN MEXICO CITY

## Meteorology

- Boundary Layer Dynamics: (inversions, shallow ABL in winter/spring).
- Synoptic Patterns: (mid-tropospheric highs).
- Urban Heat Island (UHI): (+3 °C long-term, stronger at night).
- Seasonality: (dry season Nov–May, thus worst episodes).

## Processes

- Reduced dispersion (weak winds, stable layers).
- Accumulation of precursors.
- Enhanced photochemistry (more solar radiation).
- UHI–UPI synergy (temperature rise + higher PM).

## Pollution Outcomes

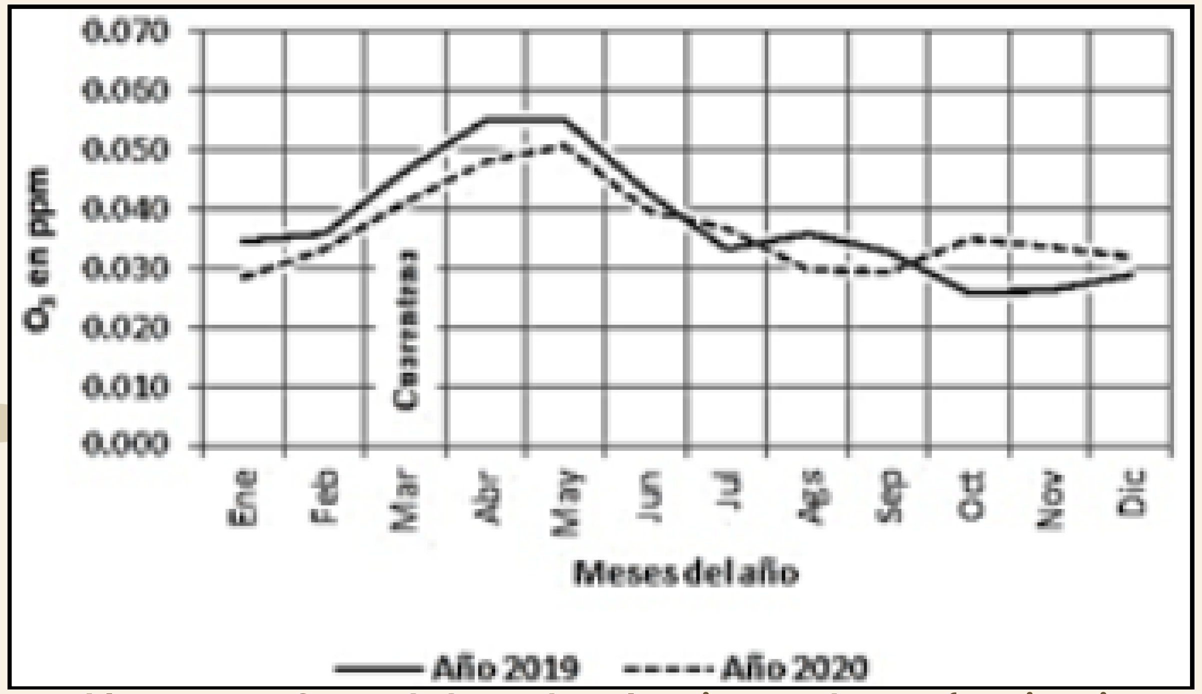
- High $O_3$ peaks in spring (photochemistry)
- $NO_2$ & $PM_{2.5}$ peaks in winter (inversions).
- $PM_{10}$ episodes throughout the year.
- Long-term high concentration in $O_3$ linked to CO & UHI.

## Sources

- Traffic & mobile sources, linked to CO, NOx.
- VOCs (solvents, LPG leaks), linked to $O_3$ precursors.
- PM from vehicles, biomass burning, dust.

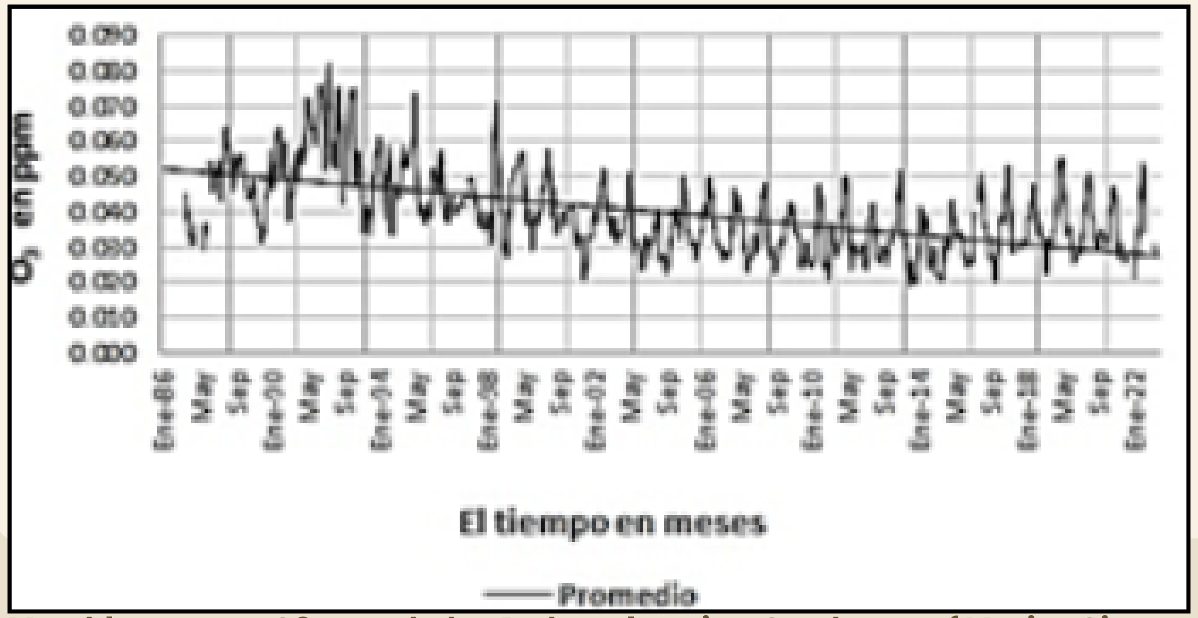
# LITERATURE REVIEW (1/5)

*Long-term trends in southwest Mexico City*

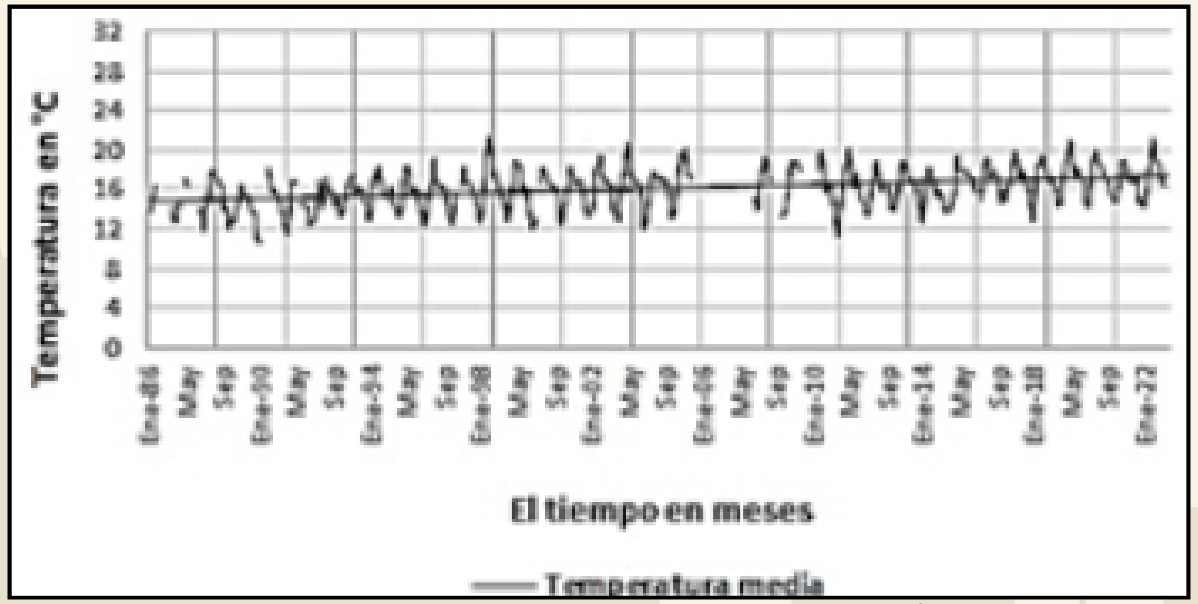



Monthly average O3 recorded at Pedregal station, southwest of Mexico City.


Average annual temperature recorded at the Pedregal station, southwest of Mexico City. Period 1986–2022.

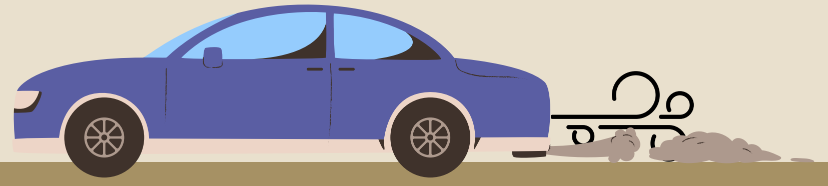



Monthly average O3 recorded at Pedregal station. Southwest of Mexico City. Period 1987-2022




Average monthly temperature recorded at the Pedregal station, southwest of Mexico City. Period 1986–2022.

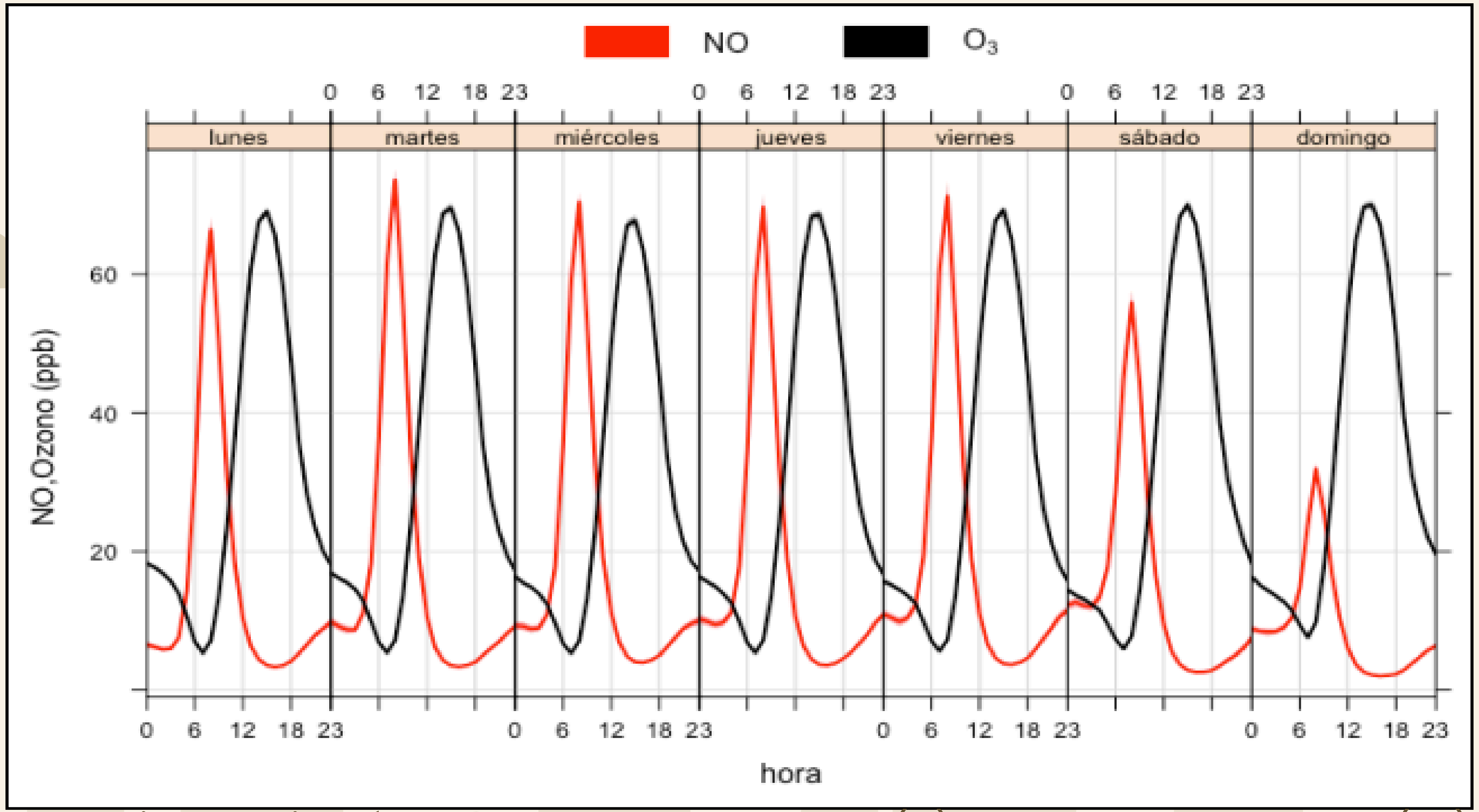
- **Historical trend (1987–2022):** $O_3$ decreased by 24% in three decades, but increased by 17% in the last 8 years, linked to CO emissions from *mobile sources* (R=0.81).
- **Thermal increase:** Average annual temperature rose 3°C in 37 years (from 14.5°C to 17.5°C), *associated with CO and the urban heat island.*
- **Seasonality:** Spring (March–May) presents a smaller reduction in $O_3$, remaining critical for pollution episodes.



García, A. C. (2023). Evaluación de ozono y temperatura al suroeste de la ciudad de México. Conciencia Tecnológica, (66), 23-33.

# LITERATURE REVIEW (2/5)

*Chemical mechanisms and policies in Mexico City*




**Concentraciones promedio por día de la semana del 2016 a 2019 para NO y ozono (O3) en ppb en la ZMCM con datos de SEDEMA (2021)**

- **Nonlinear formation:** $O_3$ depends on NOx and VOCs; reducing NOx alone does not guarantee lower $O_3$, meaning that in Mexico City, atmosphere is sensitive to VOCs.
- **"Weekend effect":** Less traffic (-50% NO on Sundays) does not lower $O_3$, which confirms sensitivity to VOCs.
- **Effective control:** Reducing VOCs emissions (solvents, LP gas leaks, incomplete combustion, household products) is required, not just NOx.

**García-Reynoso, J. A., Almanza-Veloz, V., & Torres-Jardón, R. La contaminación por ozono en la Ciudad de México: ¿cómo podemos controlarla? Enseñanza y Comunicación de las Geociencias, 2(2), 24-27.**

# LITERATURE REVIEW (3/5)

*Boundary layer structure and contamination*

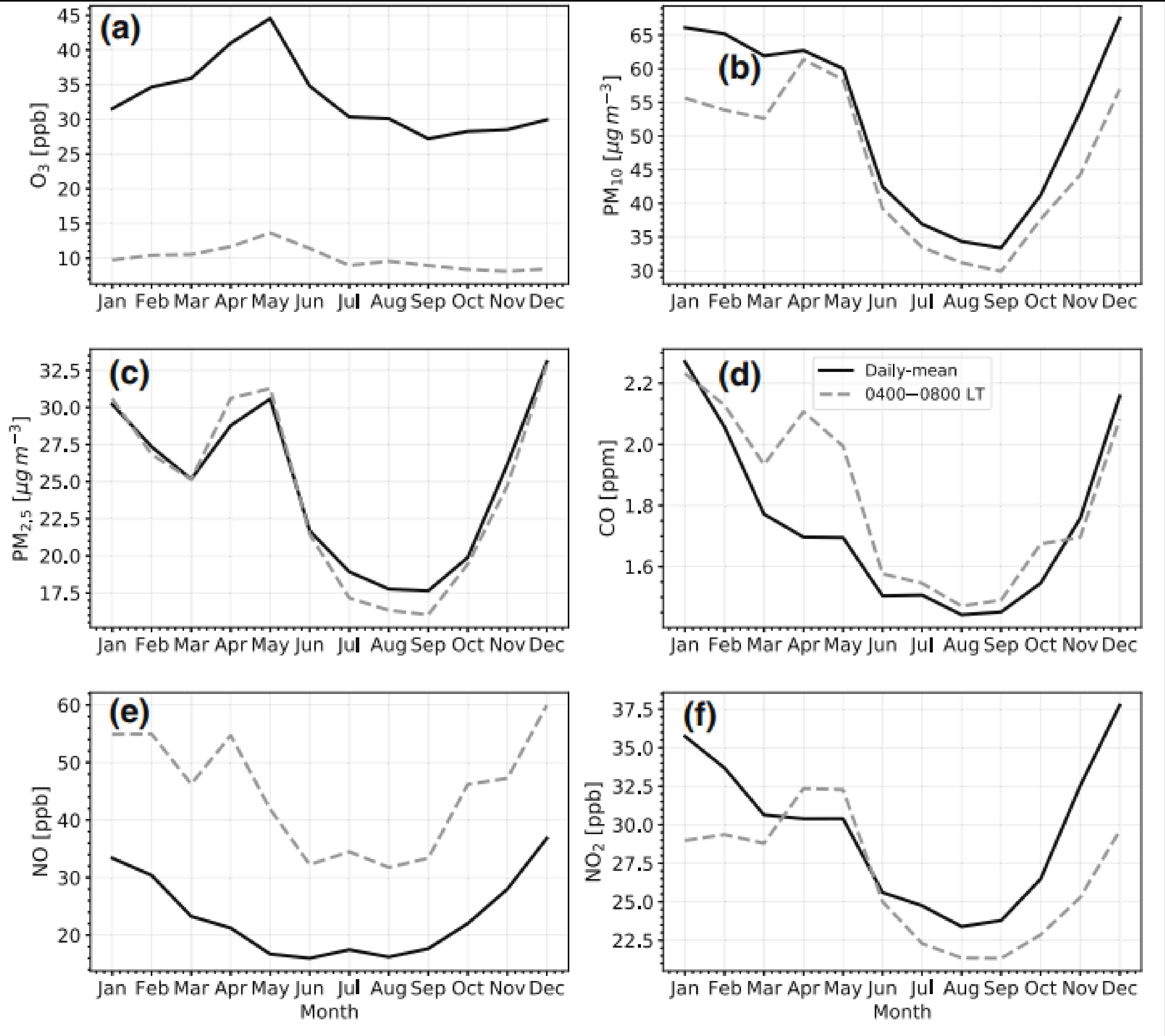



**Fig. 8** Monthly mean values of **a** ozone, **b** $PM_{10}$, **c** $PM_{2.5}$, **d** CO, **e** NO and **f** $NO_2$. Results are shown for daily means and mean values between 0400 to 0800 LT for the period 1990–2017, using all available stations of the RAMA network (http://www.aire.cdmx.gob.mx/)

- Frequent thermal inversions in winter and spring, which favor the accumulation of pollutants.
- Greater stability of the ABL in the dry season (November–May) than in the rainy season, correlated with pollutant peaks.
- Multilayered inversions observed, which hinder vertical dispersion, which is key during critical episodes.


**Burgos-Cuevas, A., Adams, D. K., García-Franco, J. L., & Ruiz-Angulo, A. (2021). A seasonal climatology of the Mexico City atmospheric boundary layer. Boundary-Layer Meteorology, 180(1), 131-154.**

# LITERATURE REVIEW (4/5)

## *Atmospheric patterns and seasonality*

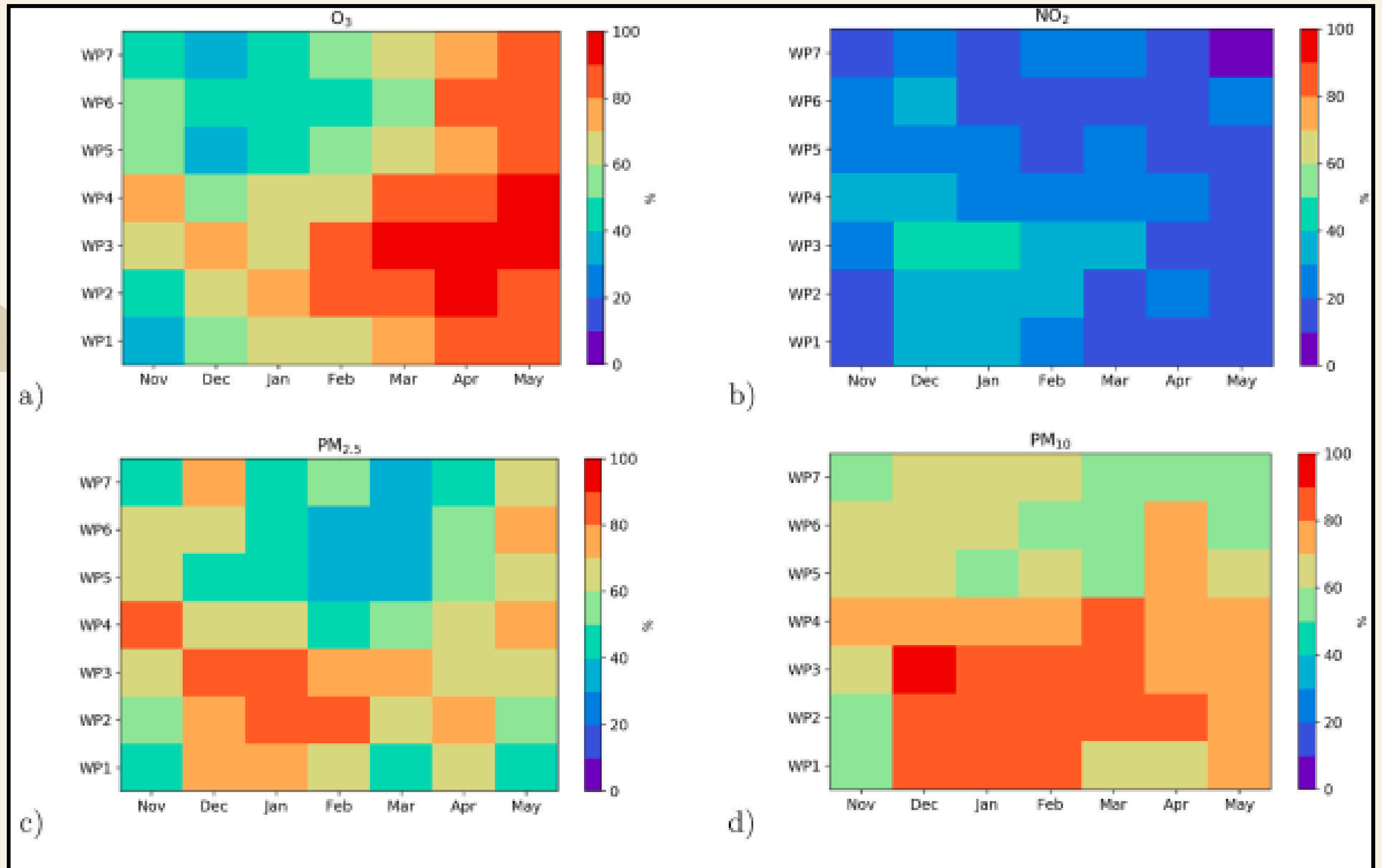



Fig. 12. Seasonal occurrence of high pollution events: fraction of polluted event days for every month and weather pattern.

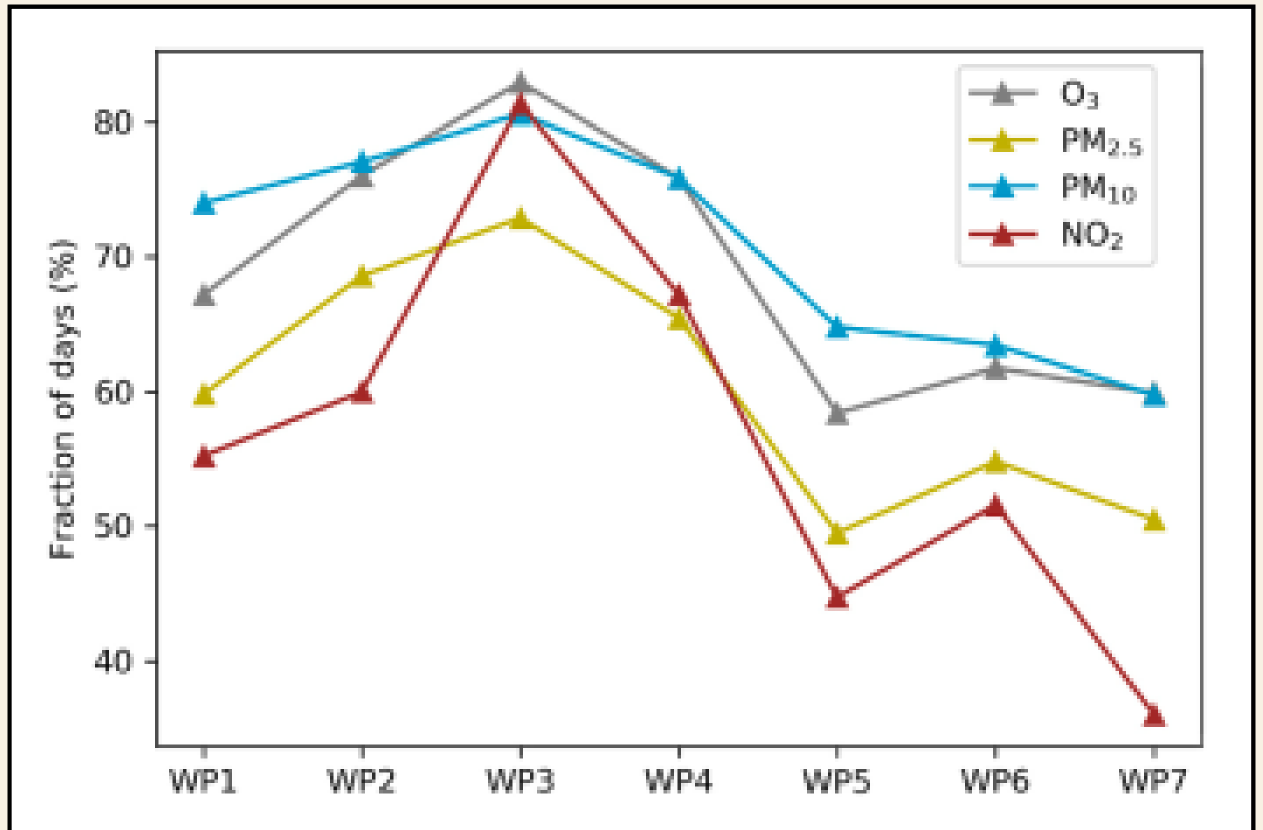



Fig. 11. Fraction of days where the concentration of pollutants exceeded the World Health Organization air quality guideline values, for each weather pattern.

- *WP1, WP2, WP3*: High-pressure ridges. WP2 is the most relevant for **Mexico City because it is centered over the region.**
- *WP4*: Strong pressure gradient with strong winds.
- *WP5, WP6, WP7*: Low-pressure troughs. They bring cold air and strong winds.

- They identified synoptic high-pressure patterns at 500 hPa that are relatated with pollution.
- **Seasonality:** highest $O_3$ in March–May; $NO_2$ and $PM_{2.5}$ in December–February.
- La Niña = more poor air quality events; El Niño = fewer.
- There is a clear peak of pollutants for WP3 for % of days that exceeded WHO standards.


**Díaz-Esteban, Y., Barrett, B. S., & Raga, G. B. (2022). Circulation patterns influencing the concentration of pollutants in central Mexico. Atmospheric Environment, 274, 118976.**
https://doi.org/10.1016/j.atmosenv.2022.118976

# LITERATURE REVIEW (5/5)

*Urban heat islands and pollution*

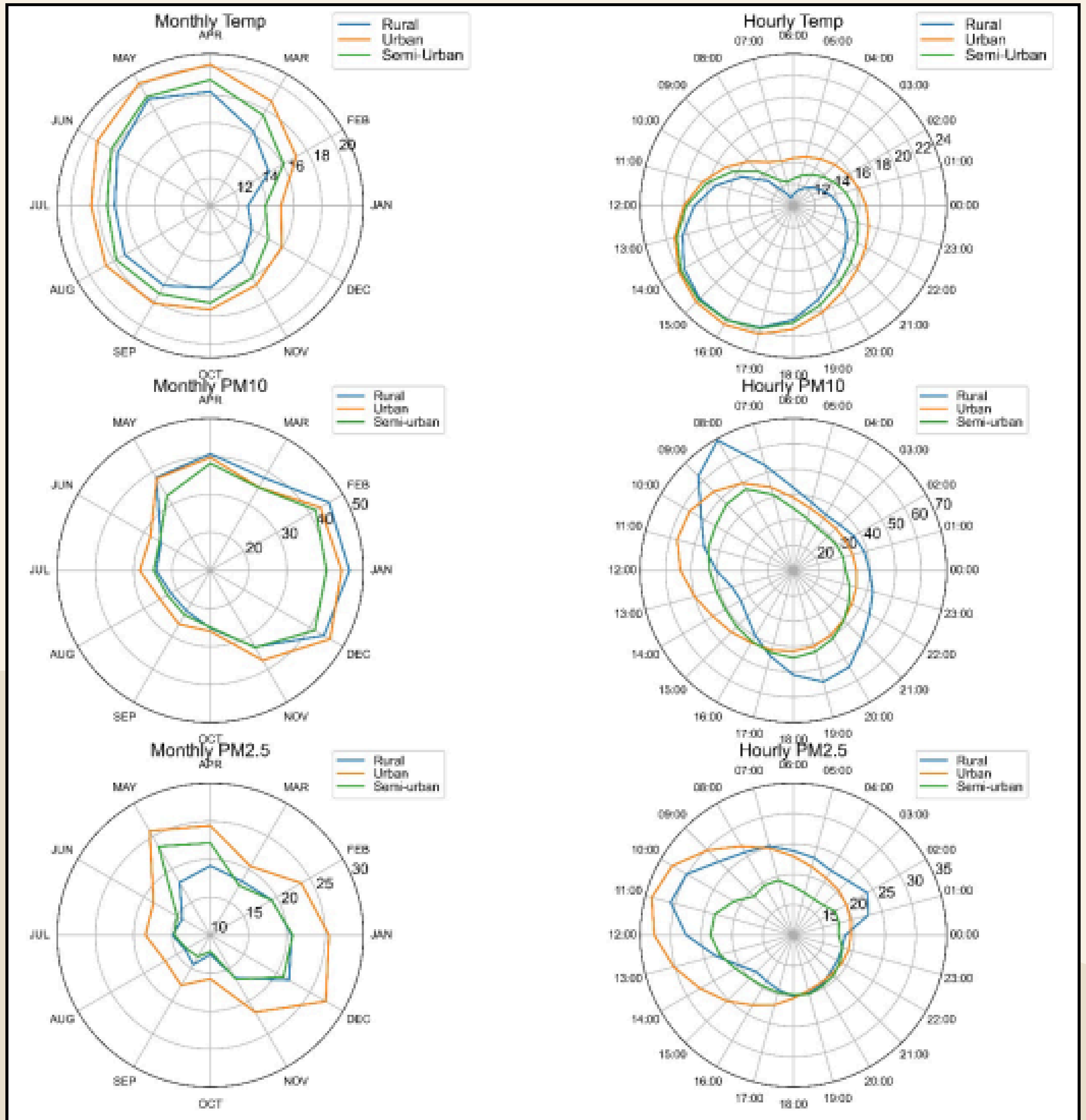
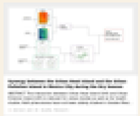



**Fig. 2.** Average monthly and diurnal cycle in local time of temperature and Particulate Matter concentrations for urban, semi-urban and rural stations.

- Positive correlation between nighttime UHI and UPI: r = 0.39 ($PM_{2.5}$) and r = 0.50 ($PM_{10}$). AUHI peak intensity ≈ 3.4°C at 7:00 a.m. LT.
- $PM_2$.5 is higher in urban areas year-round; $PM_{10}$ can be higher in rural areas (bare soil); traffic and other anthropogenic sources directly influence this.
- Warmer urban surface: average SUHI ≈ 2.3°C urban–rural.

- UHI: Urban Heat Island.
- UPI: Urban Pollution Island.
- AUHI: Air Urban Heat Island.
- SUHI: Surface Urban Heat Island.



**Mendez-Astudillo, J., Caetano, E., & Pereyra-Castro, K. (2022). Synergy between the urban heat island and the urban pollution island in Mexico city during the dry season. Aerosol and Air Quality Research, 22(8), 210278.**

# AIR QUALITY INDICES

*Frameworks for communicating pollution and health risk*

- Air Quality Indices (AQIs) are simplified tools to translate pollutant concentrations into categories relevant to health.
- Both Mexico City (IAyS, NOM-172-SEMARNAT-2023) and Hong Kong (AQHI) have updated standards.
- Indices differ in:
    - Pollutants included.
    - Averaging times.
    - Health risk communication.

# MEXICO CITY AIR QUALITY INDEX (1/2)

*IAyS: NOM-172-SEMARNAT-2023 (New framework)*

- **International alignment:** Adoption of the 12-hour NowCast formula for PM10/PM2.5 (like EPA).
- **Stricter thresholds:** Progressive tightening (2023 to 2026) for PMs.
- **Simplified communication:** Ozone index ($O_3$) now based only on the 1-hour average, replacing mixed approach (1h/8h).
- **Health focus:** Specific recommendations by population group (children, older adults, etc.).

| PM10 (12h NowCast) | | | | |
|---|---|---|---|---|
| **Air Quality** | **Risk Level** | **2023 (initial)** | **From Jan 2024** | **From Jan 2026** |
| Good | Low | ≤ 45 µg/m³ | ≤ 45 | ≤ 45 |
| Acceptable | Moderate | 46–70 | 46–60 | 46–50 |
| Poor | High | 71–132 | 61–132 | 51–132 |
| Very Poor | Very High | 133–213 | 133–213 | 133–213 |
| Extremely Poor | Extreme | >213 | >213 | >213 |
| **PM2.5 (12h NowCast)** | | | | |
| **Air Quality** | **Risk Level** | **2023 (initial)** | **From Jan 2024** | **From Jan 2026** |
| Good | Low | ≤ 15 µg/m³ | ≤ 15 | ≤ 15 |
| Acceptable | Moderate | 16–41 | 16–33 | 16–25 |
| Poor | High | 42–79 | 34–79 | 26–79 |
| Very Poor | Very High | 80–130 | 80–130 | 80–130 |
| Extremely Poor | Extreme | >130 | >130 | >130 |

*SEMARNAT, 2023*

https://rama.edomex.gob.mx/sites/rama.edomex.gob.mx/files/files/NOM-172-SEMARNAT-2023.pdf

# MEXICO CITY AIR QUALITY INDEX (2/2)

*$SO_2$, $NO_2$, $O_3$: updated thresholds and bands*

- **$NO_2$:** Stricter bands aligned with WHO evidence.
- **$SO_2$:** Bands updated (1h) for higher sensitivity.
- **$O_3$:** 1h bands clearly defined, replacing mixed approach.
- Colors and risk levels consistent with international practice
- Norm also includes a table for carbon monoxide (CO) which I do not include here.

| $O_3$, $NO_2$, $SO_2$ (1h average) | | | | |
|---|---|---|---|---|
| **Air Quality** | **Risk Level** | **$O_3$ (ppm)** | **$NO_2$ (ppm)** | **$SO_2$ (ppm)** |
| Good | Low | ≤ 0.058 | ≤ 0.053 | ≤ 0.035 |
| Acceptable | Moderate | >0.058–0.090 | >0.053–0.106 | >0.035–0.075 |
| Poor | High | >0.090–0.135 | >0.106–0.160 | >0.075–0.185 |
| Very Poor | Very High | >0.135–0.175 | >0.160–0.213 | >0.185–0.304 |
| Extremely Poor | Extreme | >0.175 | >0.213 | >0.304 |

*SEMARNAT, 2023*

*https://www.dof.gob.mx/nota_detalle.php?codigo=5715154&fecha=25/01/2024*

# REMINDER: AIR QUALITY INDEX (IAYS) STRUCTURE

**Table G. Mexico City Air Quality and Health Index (IAyS)**

| Air Quality & Health Index | Associated Risk Level | Recommendations | | |
|---|---|---|---|---|
| | | Cardiovascular/Respiratory Patients & >60 years | Children <12 & Pregnant Women | General Population |
| **Good** | **Low** – minimal or no health risk | Enjoy outdoor activities. | | |
| Acceptable | Moderate – Sensitive groups to $O_3$) or particulate matter ($PM_{10}$, $PM_{2.5}$) may experience eye irritation and respiratory symptoms. | Light outdoor physical activity such as walking, cycling, skateboarding, etc. is possible. Reduce vigorous outdoor physical activity. If you experience symptoms, consult a doctor. Monitor air quality. | You can do outdoor activities. Check the air quality. | |
| Poor | High – In sensitive population, there is an increased risk of respiratory symptoms and/or decreased lung function. The likelihood of involvement in the general population is low. | Reduce all outdoor physical activity. If you experience symptoms, consult a doctor. Check the air quality. | You can engage in light outdoor physical activity such as walking, cycling, skateboarding, etc., with rest periods. Reduce vigorous outdoor activities. If respiratory or cardiac symptoms occur, discontinue the activity and seek medical advice. Check the air quality. | You can engage in outdoor activities. If you experience symptoms such as coughing or shortness of breath, take breaks and reduce the intensity of your activity. Check the air quality. |
| Very Poor | Very High – General population may experience health problems. In vulnerable populations, the risk of worsening asthma, COPD, or cardiovascular events increases. | You can engage in indoor physical activity, as long as it's tobacco-free. Avoid physical activity and going outdoors. If you experience symptoms, consult a doctor. Check the air quality. | Reduce outdoor physical activity; indoor activities are fine, as long as they are tobacco-free. Avoid vigorous or prolonged outdoor physical activity. Check the air quality. | |
| Extremely Poor | Extremely High – Entire population is at greater risk of experiencing serious health effects. | Stay indoors where you can engage in physical activity, reschedule your outdoor activities, and if you experience respiratory and/or cardiac symptoms, seek medical advice. Check the air quality. | | |

*Aire CDMX, 2025*
*https://www.aire.cdmx.gob.mx/default.php?opc=%27ZaBhnml=&dc=%27Zw==*

# HONG KONG AIR QUALITY HEALTH INDEX (AQHI)

*Risk-based approach, updated April 2025*

- Based on 3-hour moving average of 4 pollutants: $O_3$, $NO_2$, $SO_2$, PM ($PM_{2.5}$/$PM_{10}$).
- Weighted by local health risk studies.
- Categories: Low (1–3), Moderate (4–6), High (7), Very High (8–10), Serious (10+).
- Public advice focuses on sensitive groups.


| | | | |
|---|---|---|---|
| 1–3 | Low | → | No significant risk |
| 4–6 | Moderate | → | Some risk for sensitive groups |
| 7 | High | → | Sensitive groups advised to reduce outdoor activities |
| 8–10 | Very High | → | General public may be affected |
| 10+ | Serious | → | Entire population at risk |

*EPD, 2025*

*https://www.aqhi.gov.hk/en/what-is-aqhi/about-aqhi.html*
*https://www.aqhi.gov.hk/en/what-is-aqhi/about-aqhi77ba.html?start=1*
*https://www.epd.gov.hk/epd/english/environmentinhk/air/air_quality_objectives/air_quality_objectives.html*

# COMPARATIVE TABLE: AQHI (HONG KONG) VS. IAYS (MEXICO) VS. WHO AQGS

*Comparative Air Quality Indices and Guidelines: Categories, thresholds, and methodologies*

- **Hong Kong AQHI:** Risk-based, 3-hour moving average of $O_3$, $NO_2$, $SO_2$, PM. Categories 1–10+.
- **Mexico IAyS (NOM-172-2023):** NowCast 12h (PMs), 1h for gases; progressive tightening for PM10/PM2.5 (2023 to 2026).
- **WHO AQGs (2021):** Strictest global guidelines, 24h and annual values; health-based only.

**AQHI vs. IAyS vs. WHO AQGs**

| Pollutant | Hong Kong (AQOs/AQHI) | Mexico City (IAyS, NOM-172-2023) | WHO AQGs (2021) |
|---|---|---|---|
| **PM10** | 24h: 75 µg/m$^3$ (≤9 exceed./yr). Annual: 30 µg/m$^3$. | 12h NowCast: Good ≤45 µg/m$^3$; Acceptable 46–60 µg/m$^3$ (2024) / 46–50 µg/m$^3$ (2026); Poor >60–132 µg/m$^3$ (2024) / >50–132 µg/m$^3$ (2026); Very Poor 133–213 µg/m$^3$; Extreme >213 µg/m$^3$. | 24h: 45 µg/m$^3$. Annual: 15 µg/m$^3$. |
| **PM2.5** | 24h: 37.5 µg/m$^3$ (≤18 exceed./yr). Annual: 15 µg/m$^3$. | 12h NowCast: Good ≤15 µg/m$^3$; Acceptable 16–33 µg/m$^3$ (2024) / 16–25 µg/m$^3$ (2026); Poor >33–79 µg/m$^3$ (2024) / >25–79 µg/m$^3$ (2026); Very Poor 80–130 µg/m$^3$; Extreme >130 µg/m$^3$. | 24h: 15 µg/m$^3$. Annual: 5 µg/m$^3$. |
| **$O_3$** | 8h: 160 µg/m$^3$ (≈0.08 ppm, ≤9 exceed./yr). Peak season: 100 µg/m$^3$. | 1h: Good ≤0.058 ppm; Acceptable 0.059–0.090 ppm; Poor 0.091–0.135 ppm; Very Poor 0.136–0.175 ppm; Extreme >0.175 ppm. | 8h: 100 µg/m$^3$ (≈0.05 ppm). |
| **$NO_2$** | 1h: 200 µg/m$^3$ (≈0.106 ppm, ≤18 exceed./yr). 24h: 120 µg/m$^3$. Annual: 40 µg/m$^3$. | 1h: Good ≤0.053 ppm; Acceptable 0.054–0.106 ppm; Poor 0.107–0.160 ppm; Very Poor 0.161–0.213 ppm; Extreme >0.213 ppm. | 24h: 25 µg/m$^3$ (≈0.013 ppm). Annual: 10 µg/m$^3$ (≈0.005 ppm). |
| **$SO_2$** | 10-min: 500 µg/m$^3$ (≤3 exceed./yr). 24h: 40 µg/m$^3$. | 1h: Good ≤0.035 ppm; Acceptable 0.036–0.075 ppm; Poor 0.076–0.185 ppm; Very Poor 0.186–0.304 ppm; Extreme >0.304 ppm. | 24h: 40 µg/m$^3$ (≈0.015 ppm). |

*https://en.air-q.com/einheiten-umrechner*

*WHO, 2025*
*https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines*

# DISCUSSION

- Conceptual differences:
  - Mexico IAyS: pollutant-specific thresholds, NowCast (PM), 1h for gases, progressive tightening (2023-2026).
  - Hong Kong AQHI: composite risk index ($O_3$, $NO_2$, $SO_2$, PM), 3h moving average, categories 1-10+.
  - WHO AQGs: strict health-based guidelines, not operational indices.
- Comparability challenges:
  - Methodology: risk-based (HK) vs. pollutant-by-pollutant (Mexico City).
  - Averaging times: 1h, 3h, 12h NowCast, 24h, thus difficult to align.
  - Categories & health messaging: Mexico = 5 color bands; HK = 5 risk levels; WHO = numeric guidelines only.
  - Datasets: HK provides hourly index per station (2013–2025); CDMX datasets inconsistent (sometimes only 1–2 pollutants, sometimes more).
- Threshold alignment:
  - Mexico (NOM-172-2023): Progressive tightening of PMs (2023 to 2026), approaching WHO guideline values.
  - Hong Kong (AQOs): Defines maximum allowable concentrations and exceedances, but does not specify category bands as in the Mexican IAyS.
  - Ozone & PM: Hong Kong objectives are generally higher (less strict) than Mexico's updated thresholds.
  - Nitrogen dioxide: WHO limits remain significantly stricter than both Mexico and Hong Kong.

# CONCLUSIONS & NEXT STEPS

- **Conclusions:**
  - Mexico's NOM-172-2023 represents clear progress: stricter PM thresholds (phased 2023 to 2026), adoption of NowCast from EPA, and pollutant-specific health-based categories.
  - Hong Kong's AQHI is innovative in its risk communication approach (composite 3h index), but its Air Quality Objectives (AQOs) are set at higher values and lack detailed category bands like Mexico's IAyS.
  - WHO AQGs (2021) remain the strictest global benchmark; both Mexico and Hong Kong fall short, but Mexico's phased tightening shows closer alignment.
  - Comparability is limited by differences in averaging times, methodologies (pollutant-specific vs. composite risk), and reporting structures across the three systems.

- **Next Steps:**
  - Large raw datasets of pollutants (1986–2024):
    - Could be used to recalculate indices with all pollutants simultaneously (station × hour × pollutant).
    - Not a current goal, but an exploratory line for improving indices datasets quality.
  - Comparative frameworks:
    - Mexico's IAyS = explicit pollutant thresholds for each category.
    - Hong Kong's AQHI = composite health risk, categories derived from a 3h risk model.
    - Since HK lacks explicit category thresholds, it may be more meaningful to test the opposite direction, that is: *"How would IAyS categories classify HK pollution levels?"*
  - Meteorology integration:
    - Option to add temperature, humidity, wind data to understand pollution episodes.
  - Policy implications:
    - Stricter thresholds result in more "poor" air days, leading to stronger public health messaging.

# THANK YOU!

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