

Multi-scale drivers of PM_{2.5} and PM₁₀ extremes in the Valley of Mexico: Synoptic regimes, boundary-layer stability, and ENSO modulation

stage 1.3

Context & Objective

From hourly climatology to contingency-level exceedances and Z500' patterns

- Validate diurnal + semidiurnal structure (24h + 12h) using RAMA hourly data
- Benchmark typical cycles against PCAA Phase I/II particle thresholds
- Build monthly Z500' composites for policy-based exceedance days (MA24)

Data & Methodology

Two event-detection branches + harmonic diagnostics

- **RAMA* hourly (worst-station / area_max):** PM10 (1995–2023), PM2.5 (2003–2023).
- **Monthly-hourly climatology:** mean concentration by hour (1–24) for each month.
- **Harmonic fit:** Fourier series with two harmonics (24h + 12h) fitted to monthly mean.
- **PCAA* exceedance days:** 24h moving average \geq Phase I / Phase II thresholds.
- **Synoptic composites:** Z500' + 500 hPa winds; monthly multipanel composites (same as Stage 1.2 workflow).

*RAMA: Mexico City automatic air-quality monitoring network (hourly station data).

*PCAA: Official contingency program defining Phase I-II thresholds based on 24-h averages.

All-years diurnal + semidiurnal harmonics (with PCAA thresholds)



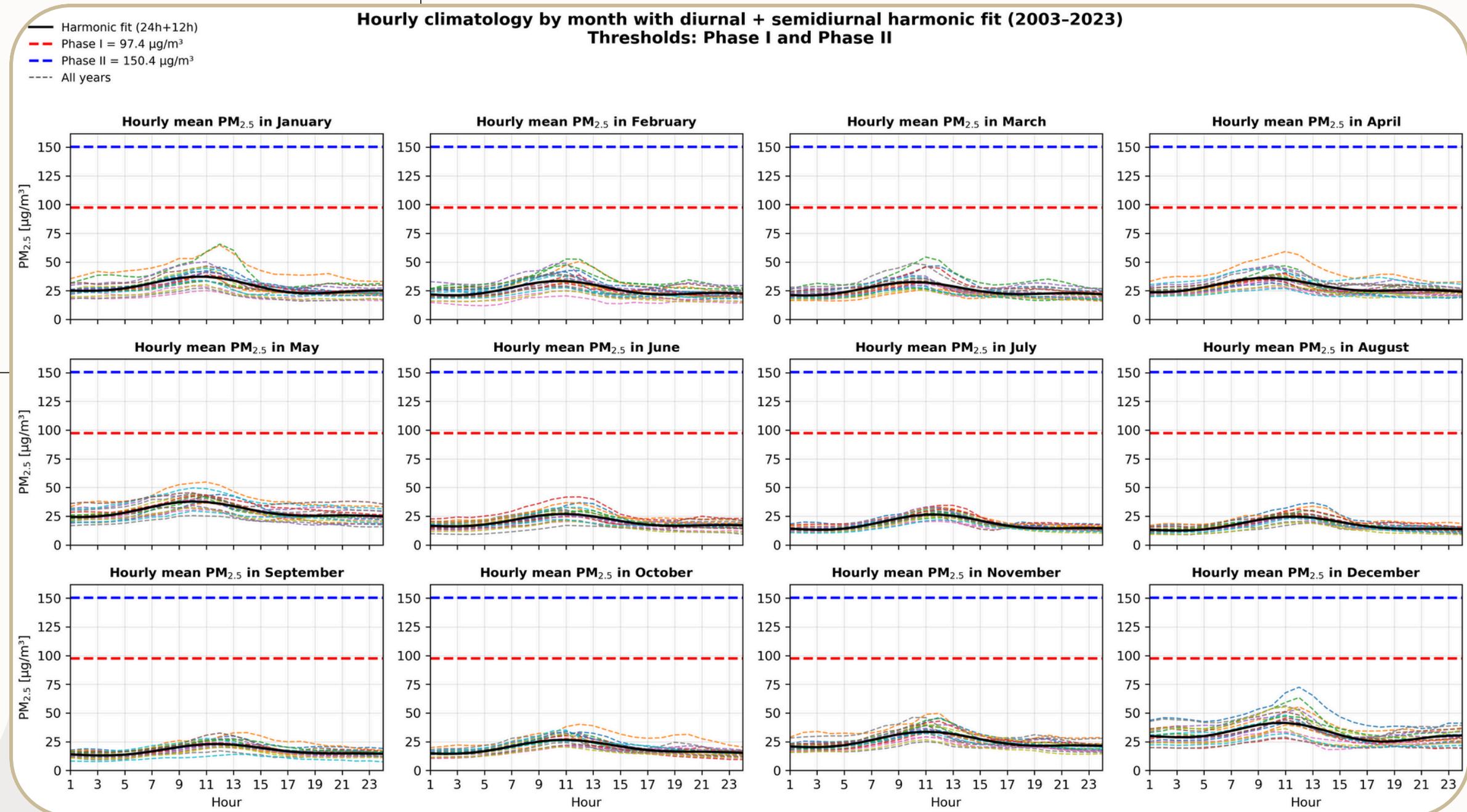
- 12 panels = monthly “typical” hourly cycle across the full record.
- Threshold lines = PCAA Phase I (red) and Phase II (blue).



PM2.5

All years + thresholds

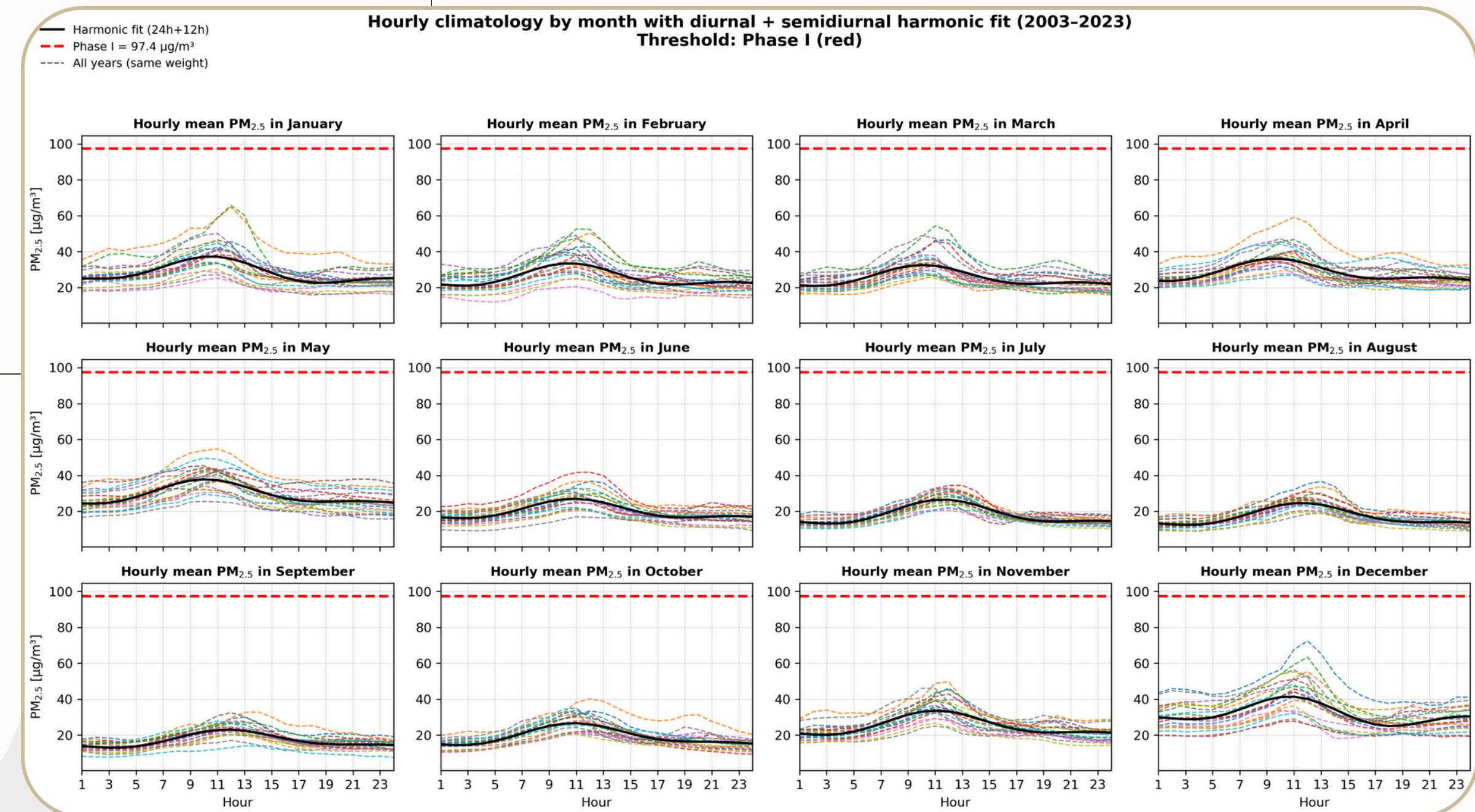
- Phase I (97.4) and Phase II (150.4 $\mu\text{g}/\text{m}^3$) sit well above monthly hourly climatology.
- PM2.5 shows a clearer midday enhancement than PM10 (mixing/secondary formation timing).
- The gap confirms thresholds target rare tail events, not typical monthly conditions.



PM2.5

Phase I only for readability

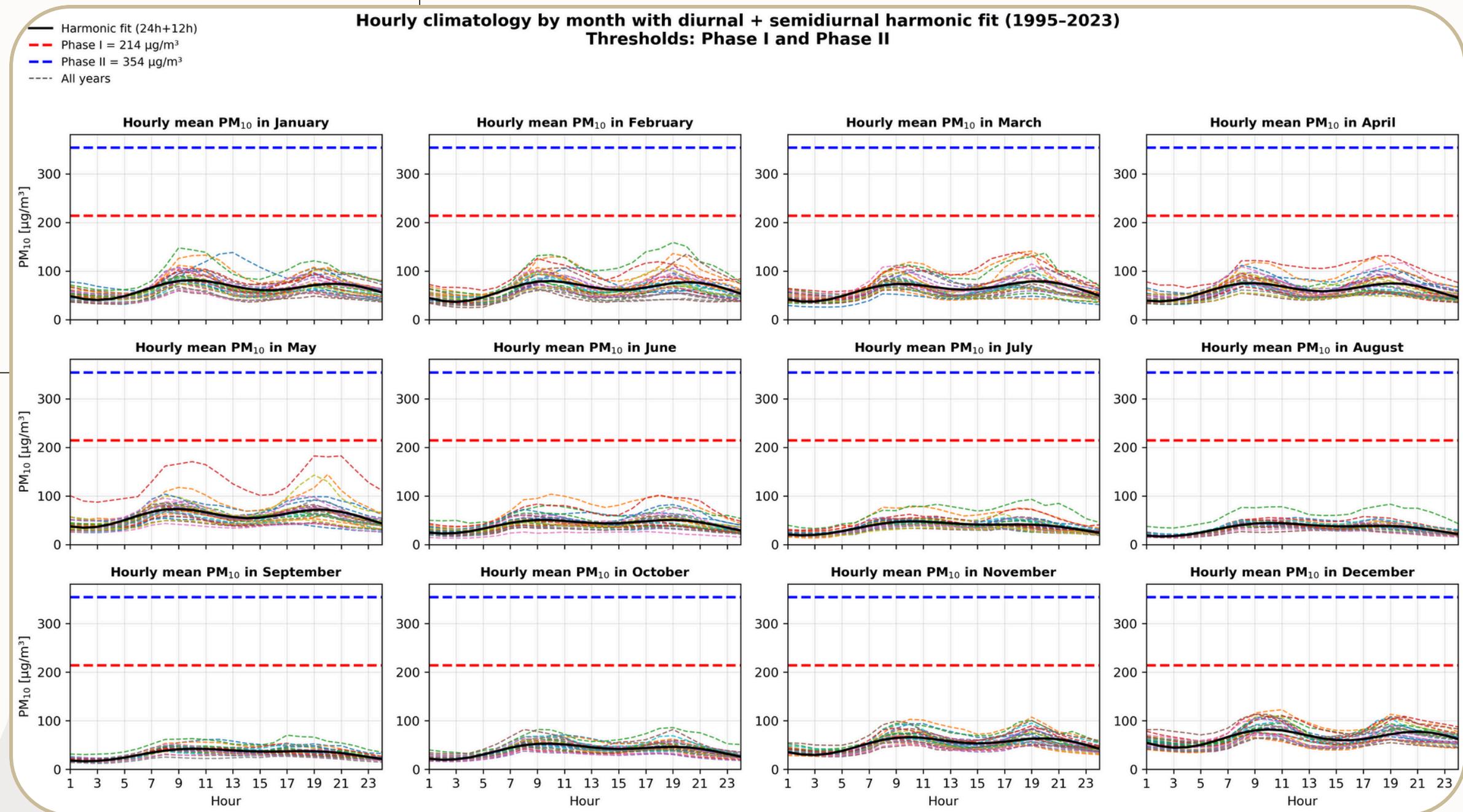
- Same as previous, zoomed to Phase I line to improve visual contrast.



PM10

All years + thresholds

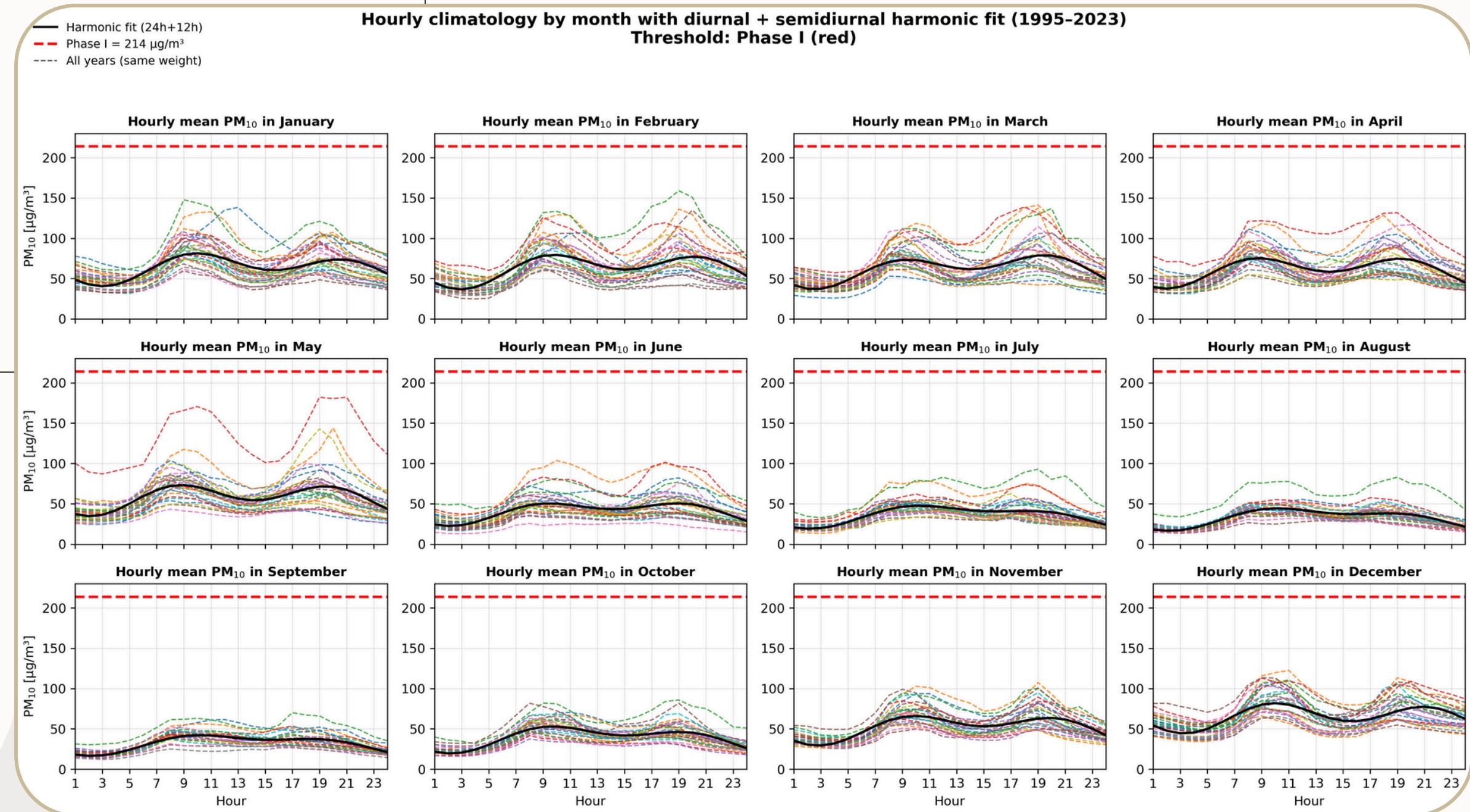
- Phase I (214) and Phase II (354 $\mu\text{g}/\text{m}^3$) are never approached by monthly hourly means.
- Diurnal cycle is consistent: morning minimum, stronger amplitude in cold months.
- Interannual variability exists, but remains systematically below Phase I \rightarrow very permissive thresholds relative to climatology.



PM10

Phase I only for readability

- Same as previous, zoomed to Phase I line to improve visual contrast.



Last-4-years focus + harmonic coefficients



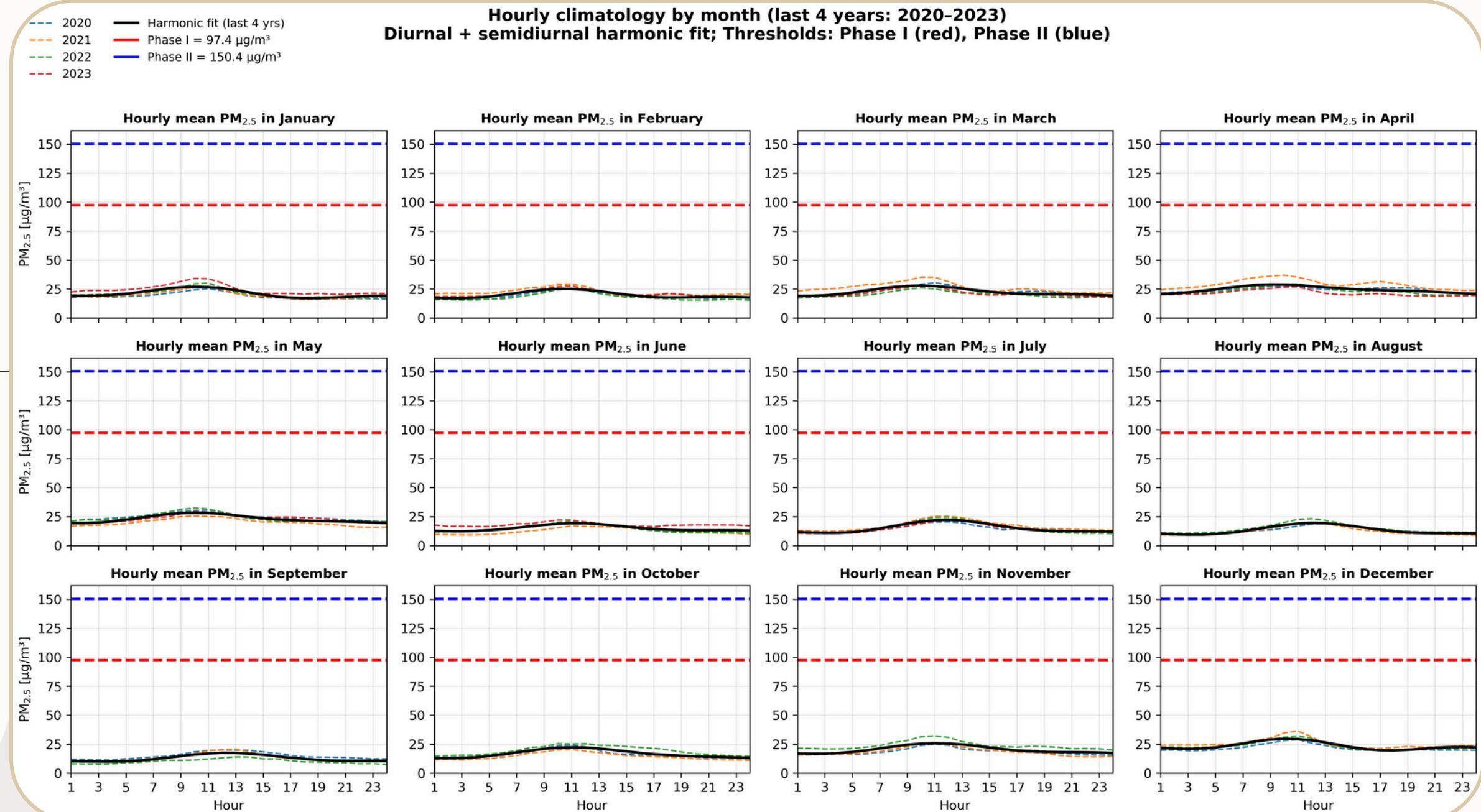
- Motivation: verify recent years vs the multi-year fit (avoid visual bias)
- Output: last 4 years only + harmonic fit + printed coefficients (24h/12h amplitudes).



PM2.5

Last 4 years + thresholds

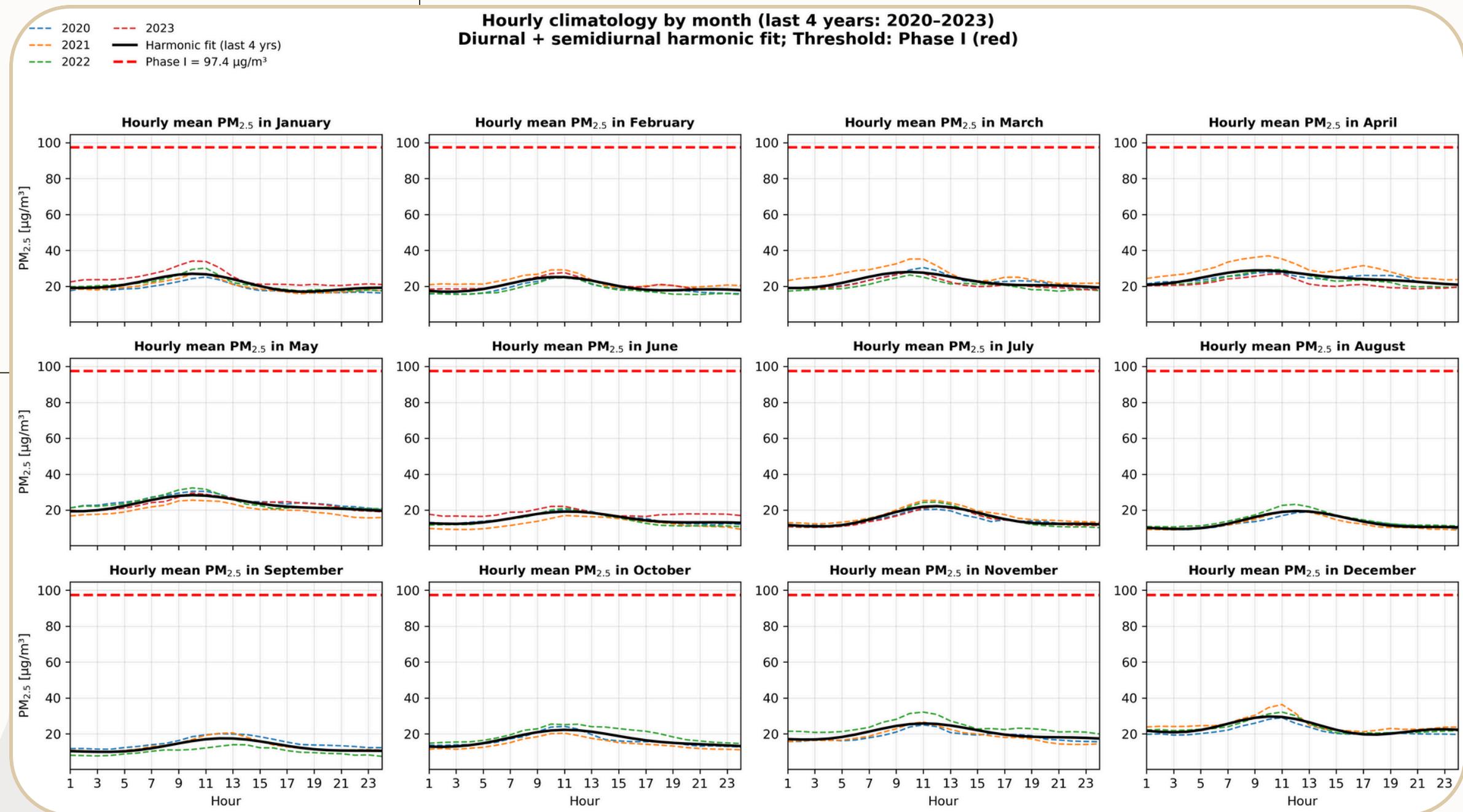
- Recent curves (2020–2023) cluster tightly
→ stable diurnal morphology.
- Harmonic fit reproduces midday peak and morning minimum with minimal residual.
- Thresholds remain far above typical hourly levels across all months.



PM2.5

Last 4 years, Phase I only

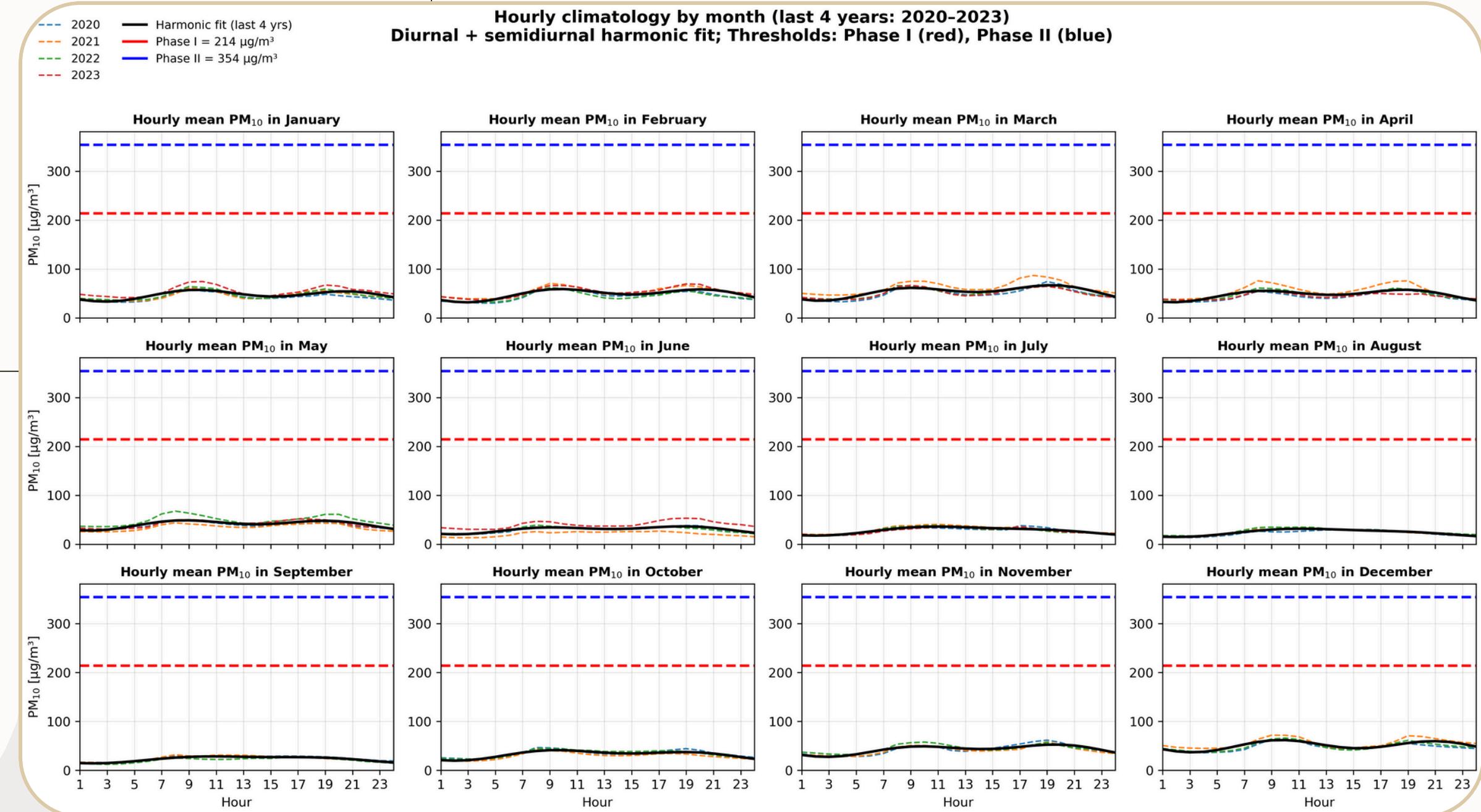
- Same as previous, zoomed to Phase I line to improve visual contrast.



PM10

Last 4 years + thresholds

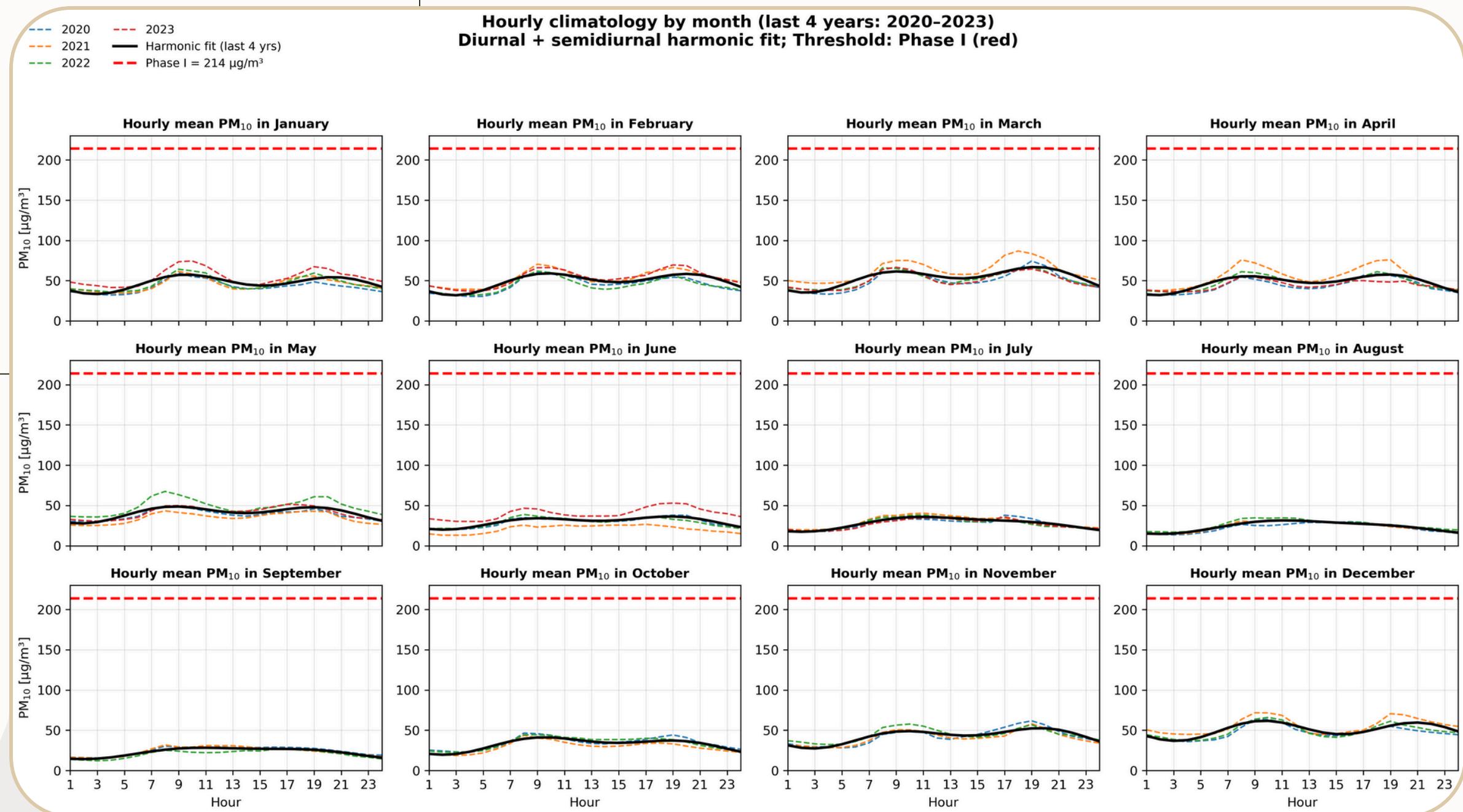
- Low spread among 2020–2023 suggests consistent recent diurnal structure.
- 24h+12h fit remains robust even in a short window.
- Thresholds Phase I/II remain non-binding relative to typical hourly cycle.



PM10

Last 4 years, Phase I only

- Same as previous, zoomed to Phase I line to improve visual contrast.



PCAA Phase I composites (MA24 ≥ Phase I threshold)

- • PM10 Phase I (2012–2023): total 28 days.
 - by month: Jan 13, Feb 2, Mar 4, Apr 2, Dec 7 (others 0).
- PM2.5 Phase I (2012–2023): total 49 days.
 - by month: Jan 18, Feb 2, Mar 1, Apr 5, May 7, Dec 16 (others 0).

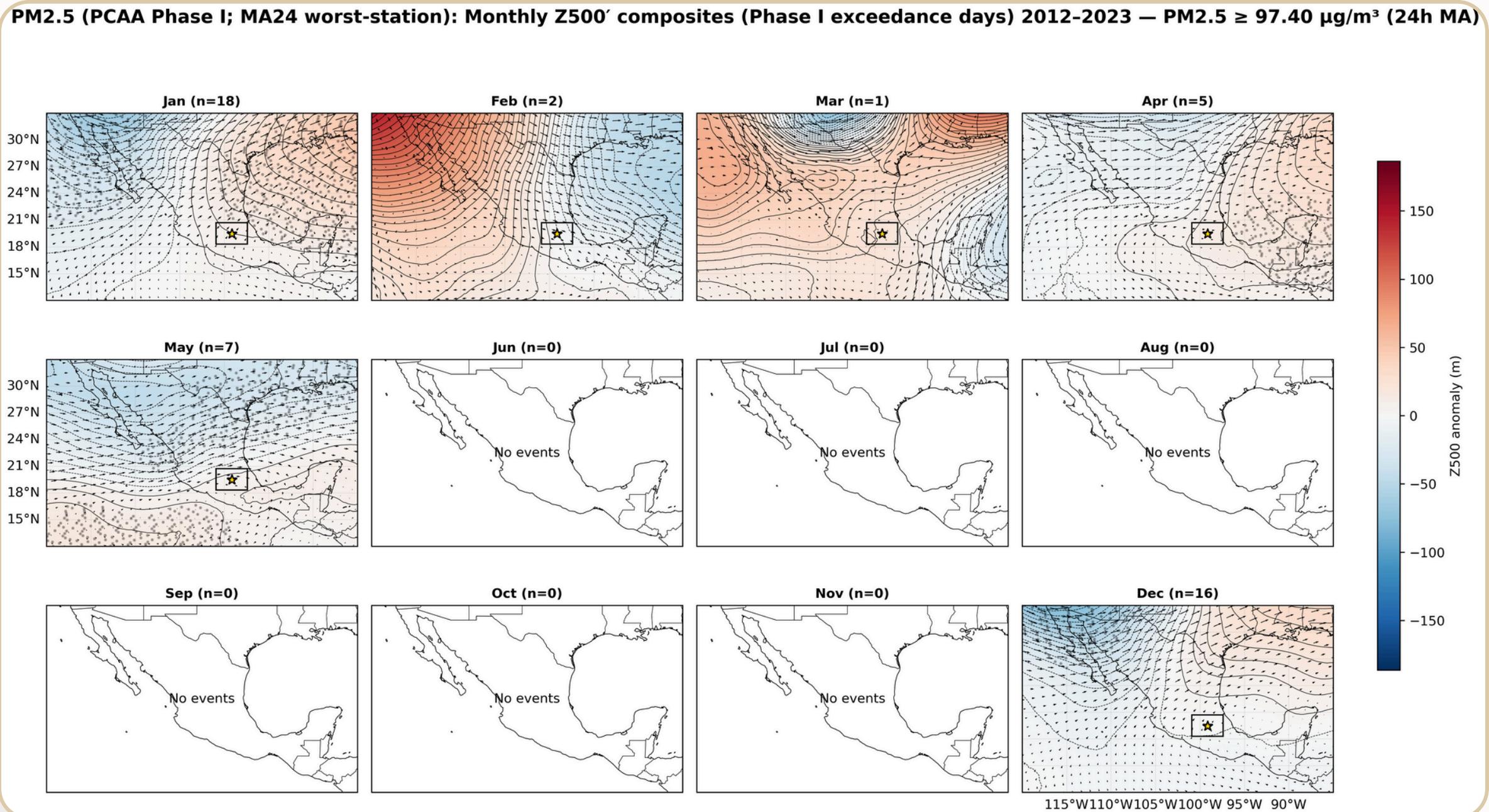
*MA24: 24-hour moving average concentration.



PM2.5

Phase I composite

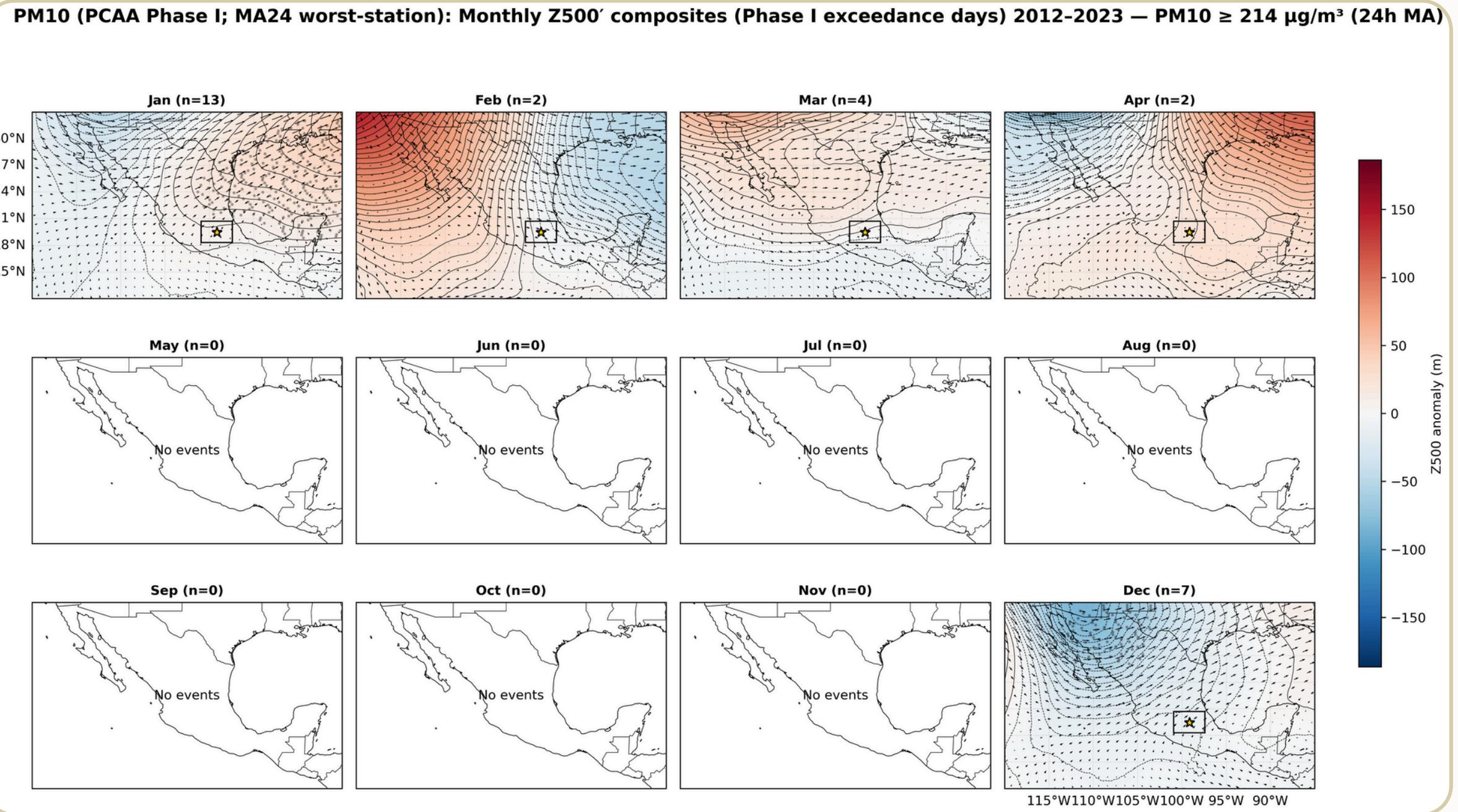
- More frequent than PM10; seasonality includes winter + spring shoulder (Apr-May).
- Winter signal consistent with stagnation/ridge-like configurations favoring accumulation.
- Spring occurrences suggest additional role of radiative/chemical environment under weak ventilation.



PM10

Phase I composite

- Concentrated in cold-dry season (Jan/Dec), absent in rainy months.
- Signals indicate episodic stagnant conditions, but small-N months limit robustness.
- Suggests Phase I for PM10 captures very rare extremes → complements percentile-based definitions.



PCAA Phase II composites (MA24 ≥ Phase II threshold)



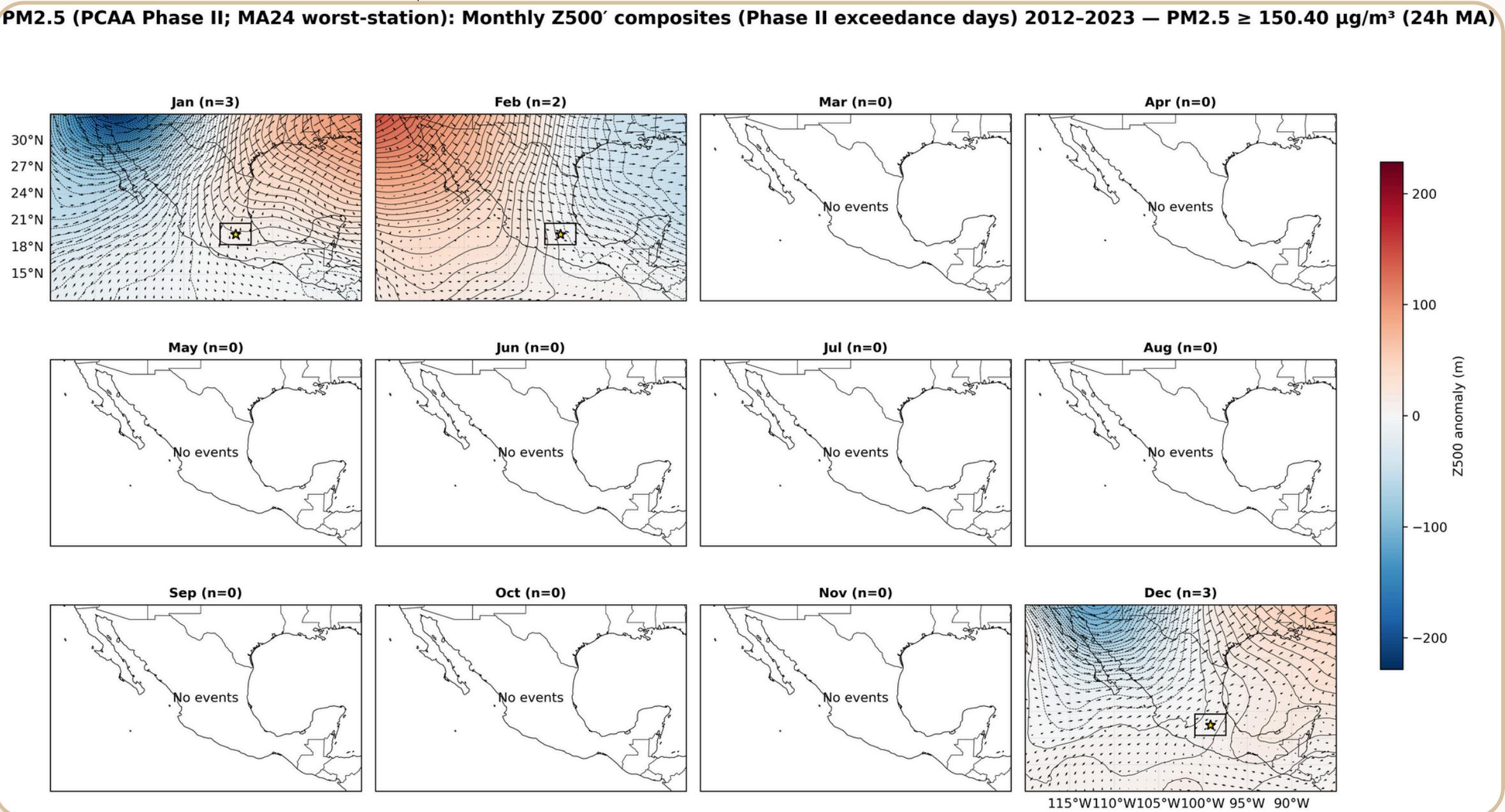
- PM10 Phase II (2012–2023): total 0 days → no composite produced.
- PM2.5 Phase II (2012–2023): total 8 days.
 - by month: Jan 3, Feb 2, Dec 3 (others 0).



PM2.5

Phase II composite

- Phase II is extremely rare → winter-only tail events (8 days / 12 years).
- Pattern suggests stronger/less common circulation anomalies than Phase I (amplified synoptic forcing).
- Low-N means limited stability → Phase II is best treated as a “case set”, not a primary climatology for regimes.



Conclusions + Discussion



Why PCAA thresholds are never crossed in harmonic climatologies?

- Harmonic figures represent monthly hourly climatology (mean behavior); rare extreme episodes are statistically diluted by averaging over many non-event days.
- PCAA Phase I/II thresholds are designed for tail events, typically associated with multi-day stagnation, not with typical diurnal conditions.
- Therefore, threshold exceedances are not expected in climatological means; proximity to thresholds is better assessed using high percentiles (p95–p99) or daily extremes, not harmonic averages.

Key methodological implication

- Harmonic analysis is diagnostic of typical diurnal structure, not of contingency activation.
- Event-based synoptic analysis requires a daily metric that preserves extremes and provides sufficient sample size.

Proposed dataset & episode-definition framework (to unlock Stage 2)

Main thesis pathway (core analysis):

- City-mean daily PM (2012–2024) with percentile-based episodes (p90, by month).
- Provides robust N for monthly composites, regime classification, lagged analysis, and ENSO stratification.
- Best aligned with the research question focused on regional synoptic-scale circulation patterns.

Sensitivity / policy-oriented pathways:

- Sensitivity A (data source): derive a daily-equivalent series from RAMA hourly data (2012–2023) and recompute percentiles to test robustness of event counts and composite patterns.
- Sensitivity B (policy benchmark): use PCAA Phase I/II exceedances (MA24) to contrast statistical extremes versus official contingency criteria.

Decision rule

- Differences across sensitivities will be interpreted as metric-dependent effects (regional mean vs worst-station / MA24),
- not as justification to restart or redefine the main pipeline.

Next Steps

(Stage 1.3 → Stage 2)

- • Confirm dataset and episode definition this week to keep Stage 2 on schedule (Feb 1–Feb 22).
• Transition from exploratory diagnostics to focused monthly and seasonal composites, followed by synoptic regime classification.



thank you!

