Tampereen yliopisto
Tampere University

INSTITUTO DE CIENCIAS DE LA ATMÓSFERA Y CAMBIO CLIMÁTICO

Multi-scale drivers of PM2.5 and PM10 extremes in the Valley of Mexico:
Synoptic regimes, boundary-layer stability, and ENSO modulation

stage one

summary

MSc Thesis

February 3, 2026

RICO ESPARZA Erick

Data & Methodology

- **Reanalysis:** Z500 + winds (daily), anomalies via daily climatology (rolling smooth).
- **Branch A (daily city-mean, 2012–2024):** events = p90 (high tail) and p10 (low tail) computed within each month-year.
- **Branch B (RAMA hourly, PM10 1995–2023; PM2.5 2003–2023):** compute NowCast12h and classify events using NOM-172 (2026 thresholds).
- **Branch C (PCAA exceedance days):** 24h moving average ≥ Phase I / Phase II thresholds.

Branch A

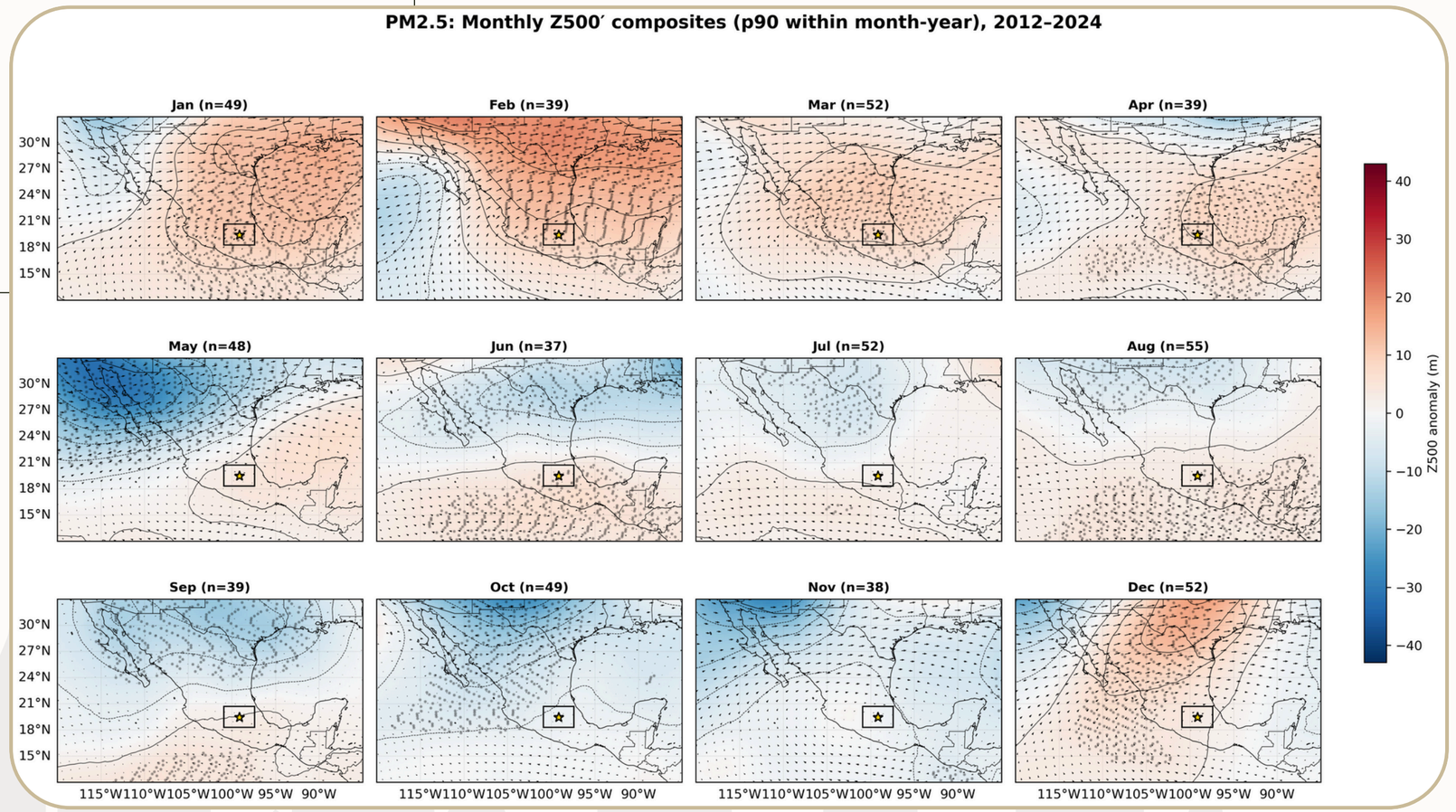
Monthly composites: p90 + p10

- Goal: compare “high-pollution days” (p90) vs “low-pollution days” (p10) to see if circulation signals are consistent and season-dependent.
- Method reminder: events defined within each month-year (controls for seasonality and long-term changes), then Z500′ composites computed over those event dates.
- Interpretation scope: these are pattern-screening maps; use them to decide active months + best event definition for Stage 2.

p90 high-pollution events

p90 (PM2.5): Z500′ monthly composites

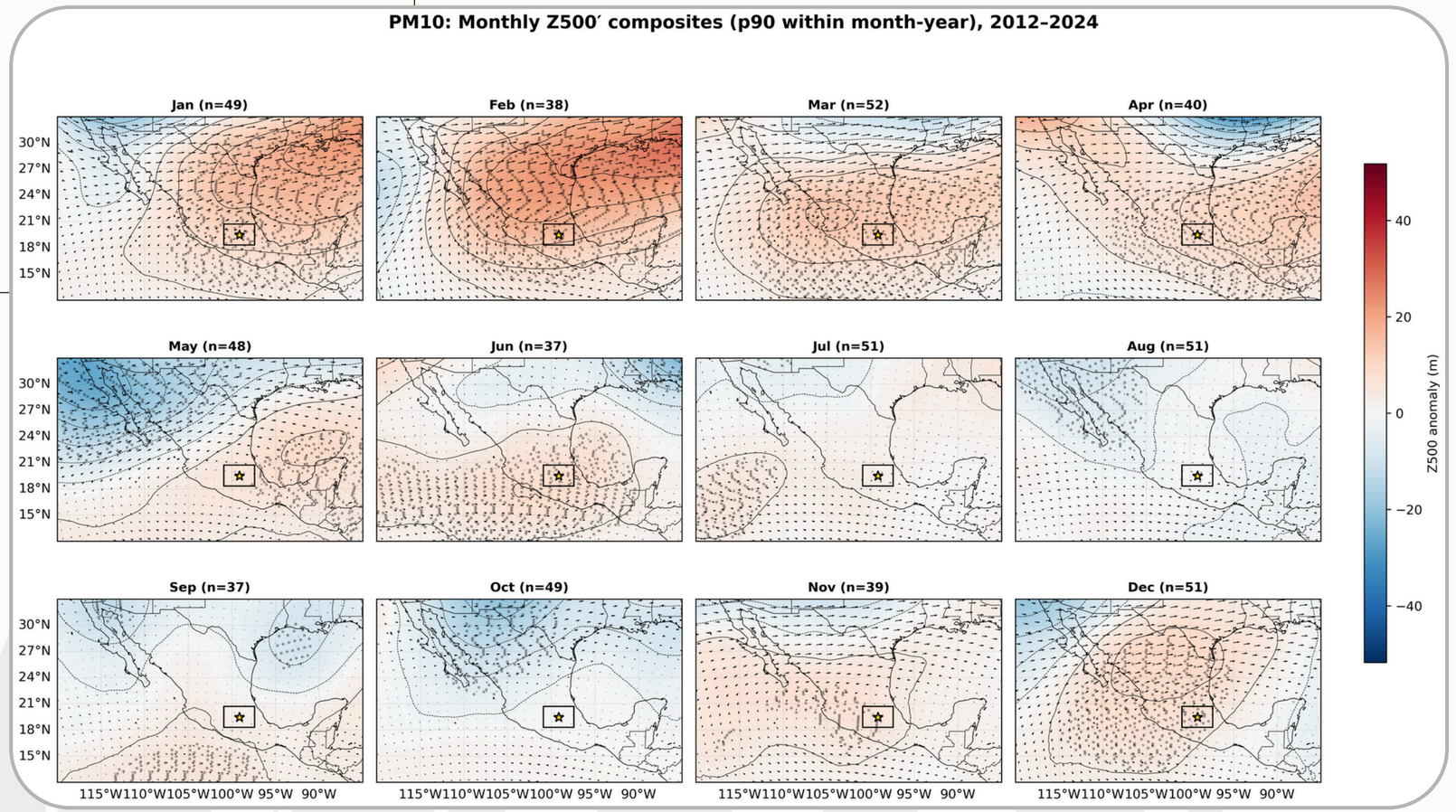
- Winter–spring (DJF–AM): persistent positive Z500′ / ridging over N–central Mexico and adjacent regions → more stable, weaker ventilation conditions.
- Flow implication: circulation favors subsidence and stagnation, consistent with accumulation rather than rapid dispersion.
- Seasonal structure: the p90 signal is strongest in dry-season months, weakening toward summer when mixing/precipitation dominate.



p90 high-pollution events

p90 (PM10): Z500′ monthly composites

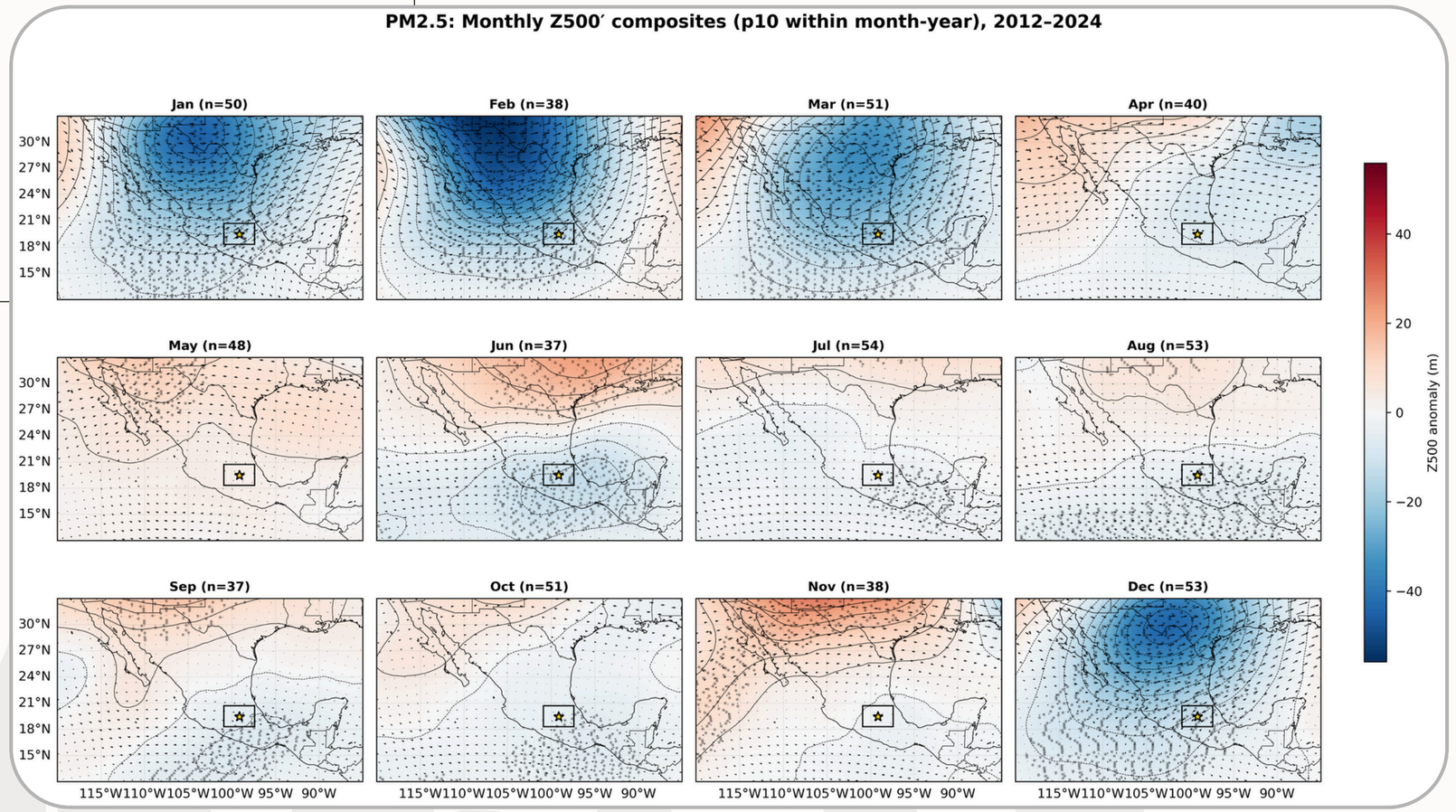
- Dry-season dominance: p90 PM10 also aligns with ridging / higher Z500′ patterns → reduced dispersion is a common ingredient.
- Compared to PM2.5: PM10 shows more month-to-month variability, suggesting stronger sensitivity to local resuspension + regional transport.
- Takeaway: high PM10 episodes still look synoptically “stagnation-like”, but with a less uniform signature than PM2.5.



p10 low-pollution events

p10 (PM2.5): Z500′ monthly composites

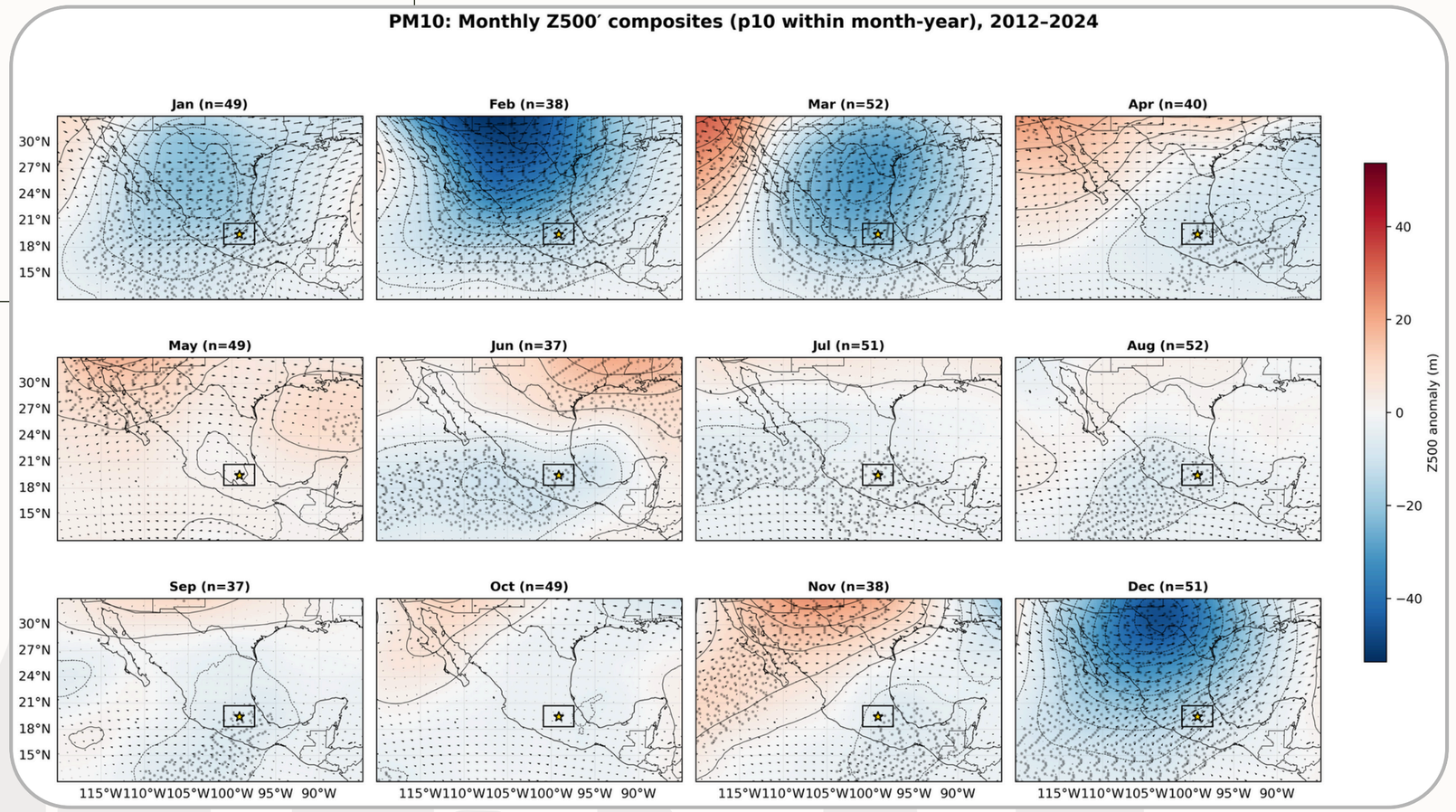
- Opposite regime to p90: many months show negative Z500′ / troughing patterns → enhanced ventilation and less stable conditions.
- Flow implication: stronger synoptic forcing tends to support mixing/advection, consistent with cleaner PM2.5 days.
- Usefulness: p10 acts as a contrast baseline, helping confirm that p90 patterns are not just “monthly climatology noise.”



p10 low-pollution events

p10 (PM10): Z500′ monthly composites

- Ventilation signature: p10 PM10 commonly aligns with lower Z500′ and more dynamic flow → conditions favoring dispersion.
- Seasonal contrast: the p10 vs p90 difference is clearest in winter–spring, when synoptic control on PM is strongest.
- Takeaway: PM10 “clean days” may reflect both meteorology and reduced resuspension/transport, so the pattern can vary by month.



Branch B

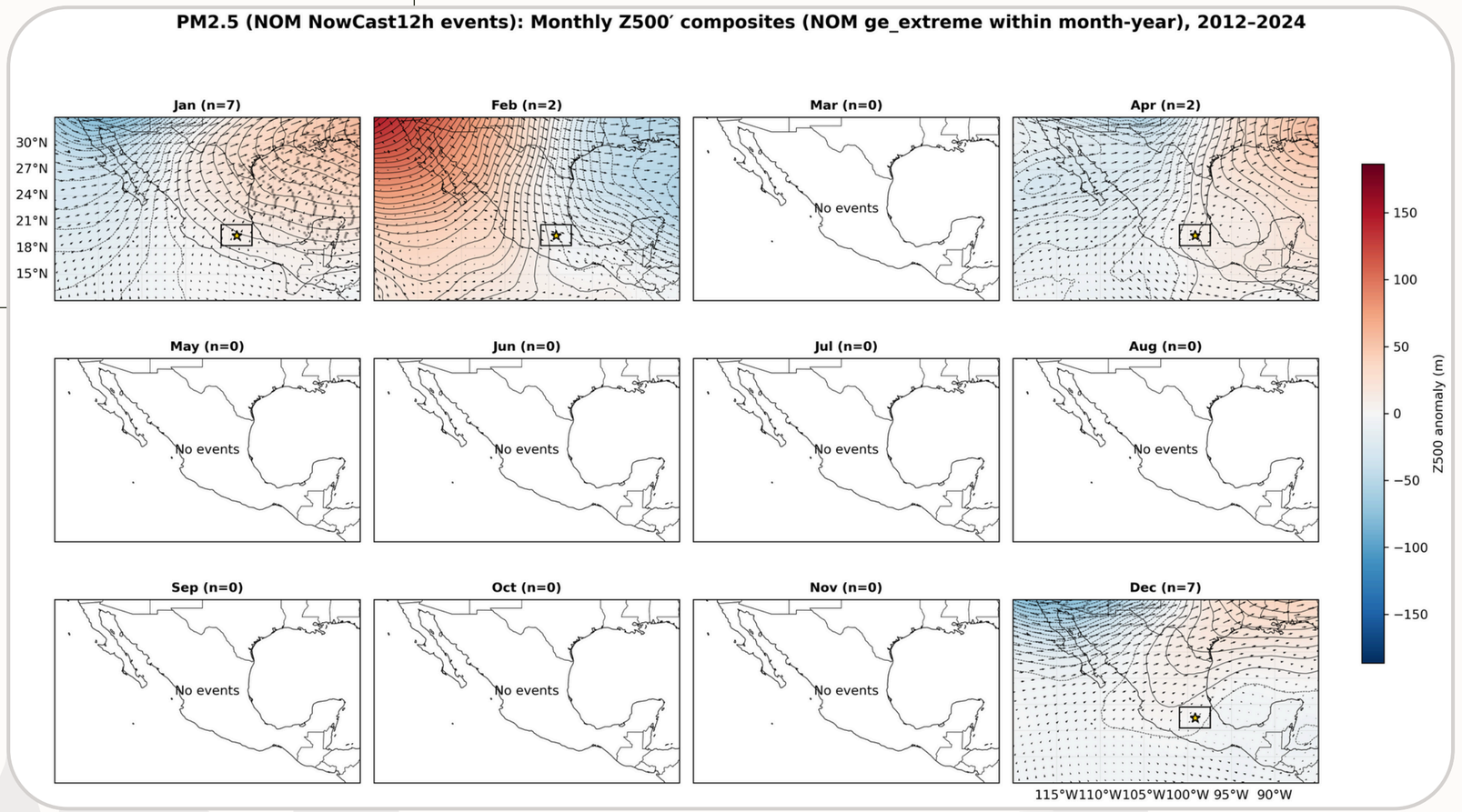
NOM-172 NowCast12h thresholds (event definition from RAMA hourly)

- Why NowCast: 24 h averages are “late”; NowCast provides a preventive, near-real-time approximation using the last 12 hours.
- Core math (Anexo A idea): compute a weighted 12 h moving average where weights depend on recent variability (stable → weights similar; rapidly changing → recent hours get more weight).
- Workflow here: compute NowCast12h → assign 2026 categories → export event-day CSVs → feed directly into monthly composites + event counts.

NOM composites

(PM2.5, ≥ Extremely Poor)

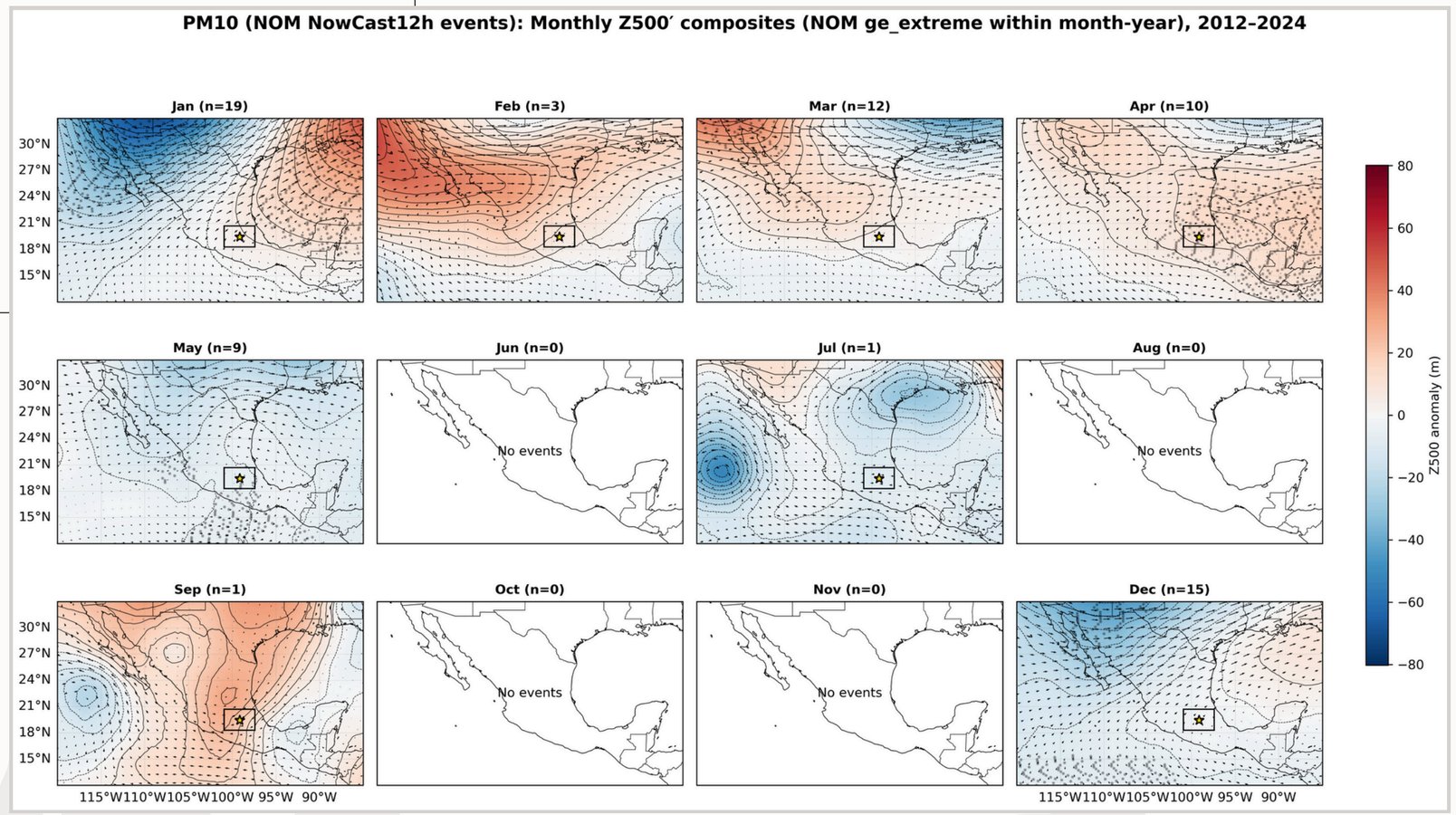
- Very sparse sampling: signal is concentrated in Jan/Feb/Apr/Dec → interpretation should be month-specific (n is small).
- Winter patterns dominate: composites suggest extremes occur under dry-season synoptic backgrounds that limit dispersion.
- Usefulness: helps identify which months are even feasible for threshold-based synoptic analysis.



NOM composites

(PM10, ≥ Extremely Poor)

- More events than PM2.5: still seasonal, but PM10 provides enough winter cases to see structured patterns.
- Mixed synoptic flavors: some months look ridge/stagnation-like, others reflect regional flow anomalies, consistent with PM10's broader sensitivity.
- Note: months with n≈0–1 are illustrative only, not stable composites.



BRANCH C

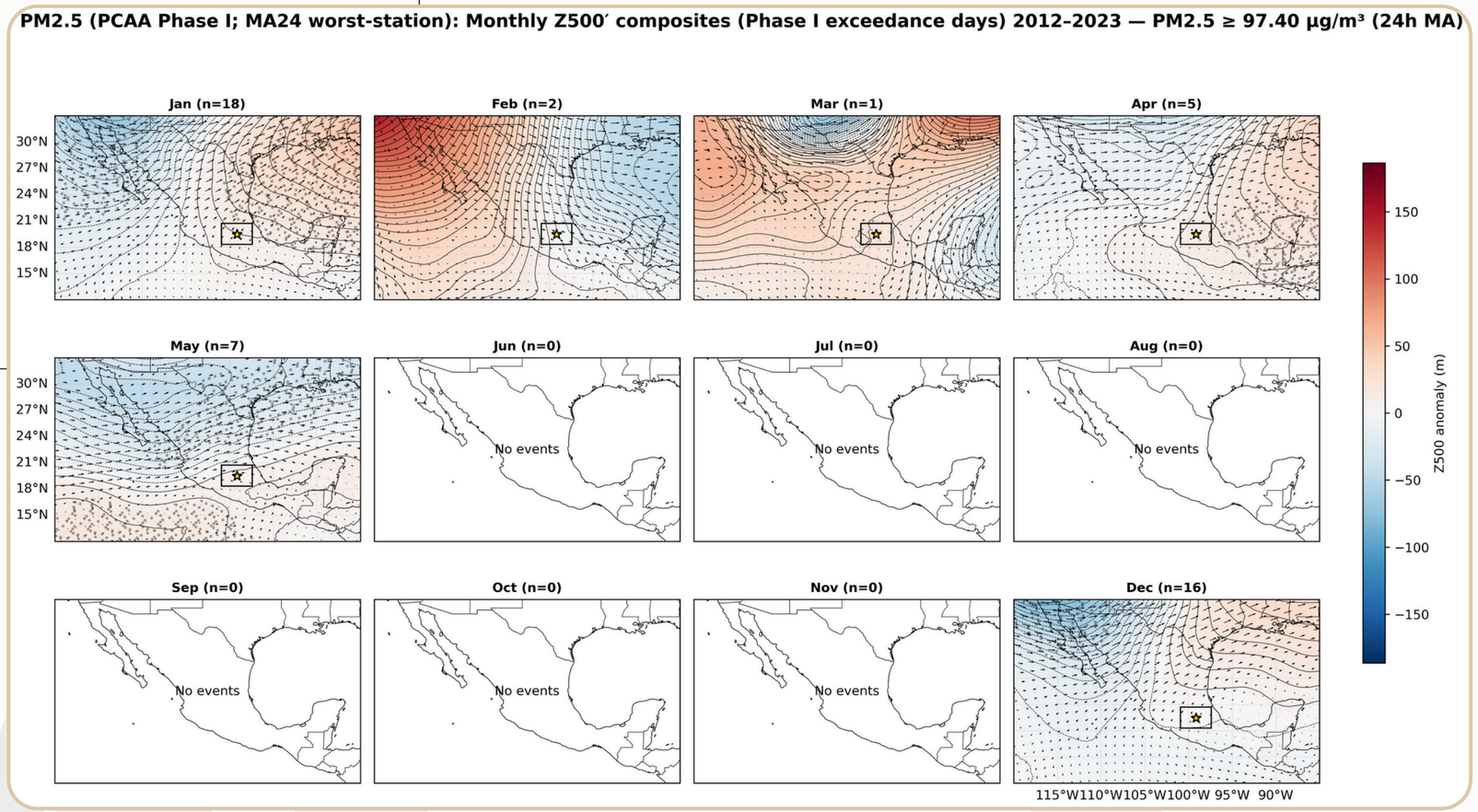
PCAA Phases 1 & II composites (MA24 ≥ Phase I / II threshold)

- 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).
- 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 I composite

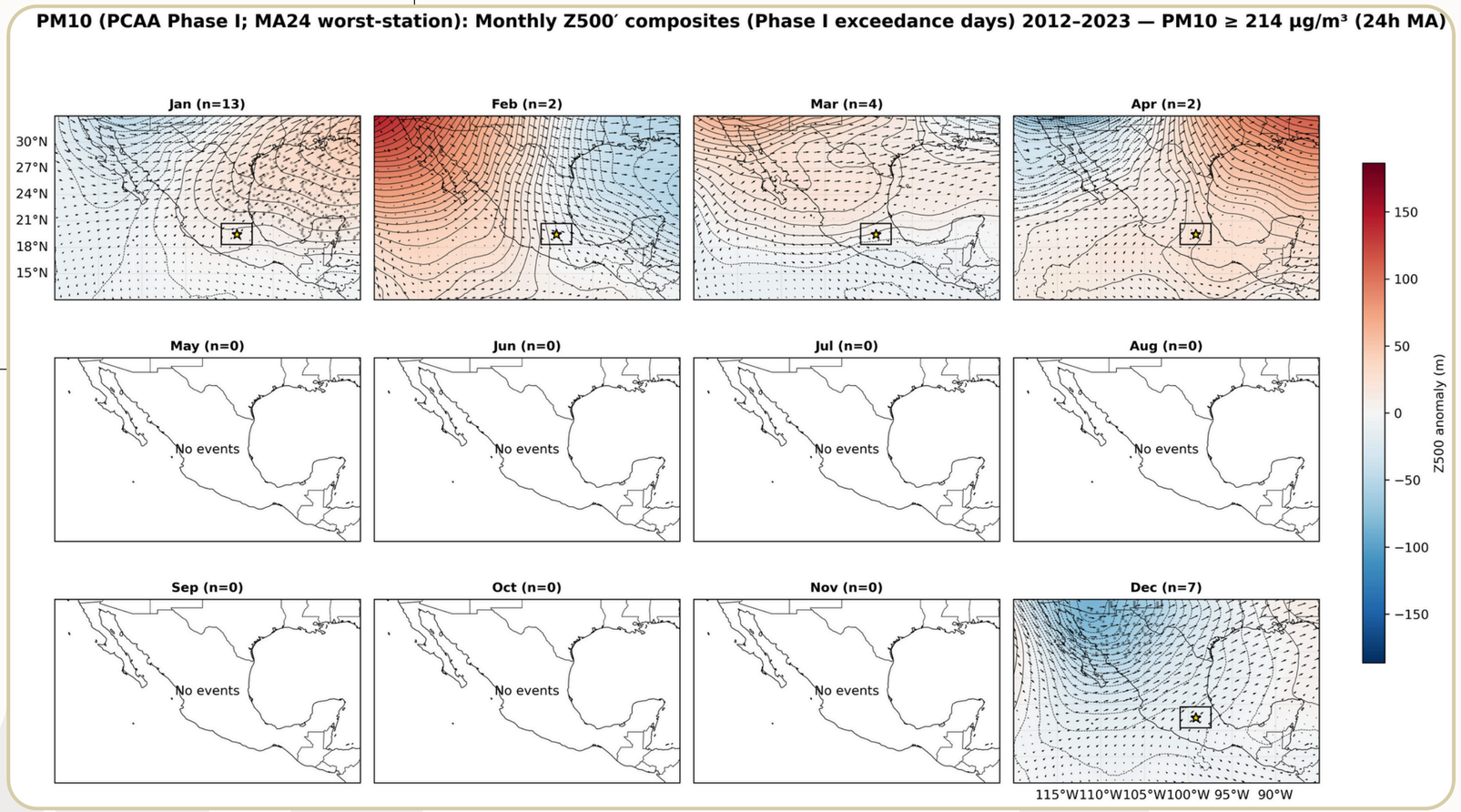
- More frequent than PM10; seasonality includes winter + spring shoulder (Apr–May).
- Winter signal consistent with stagnation/ridge-like configurations favoring accumulation.
- Spring occurrences suggest additional role of radiative/chemical environment under weak ventilation.



PM10

Phase I composite

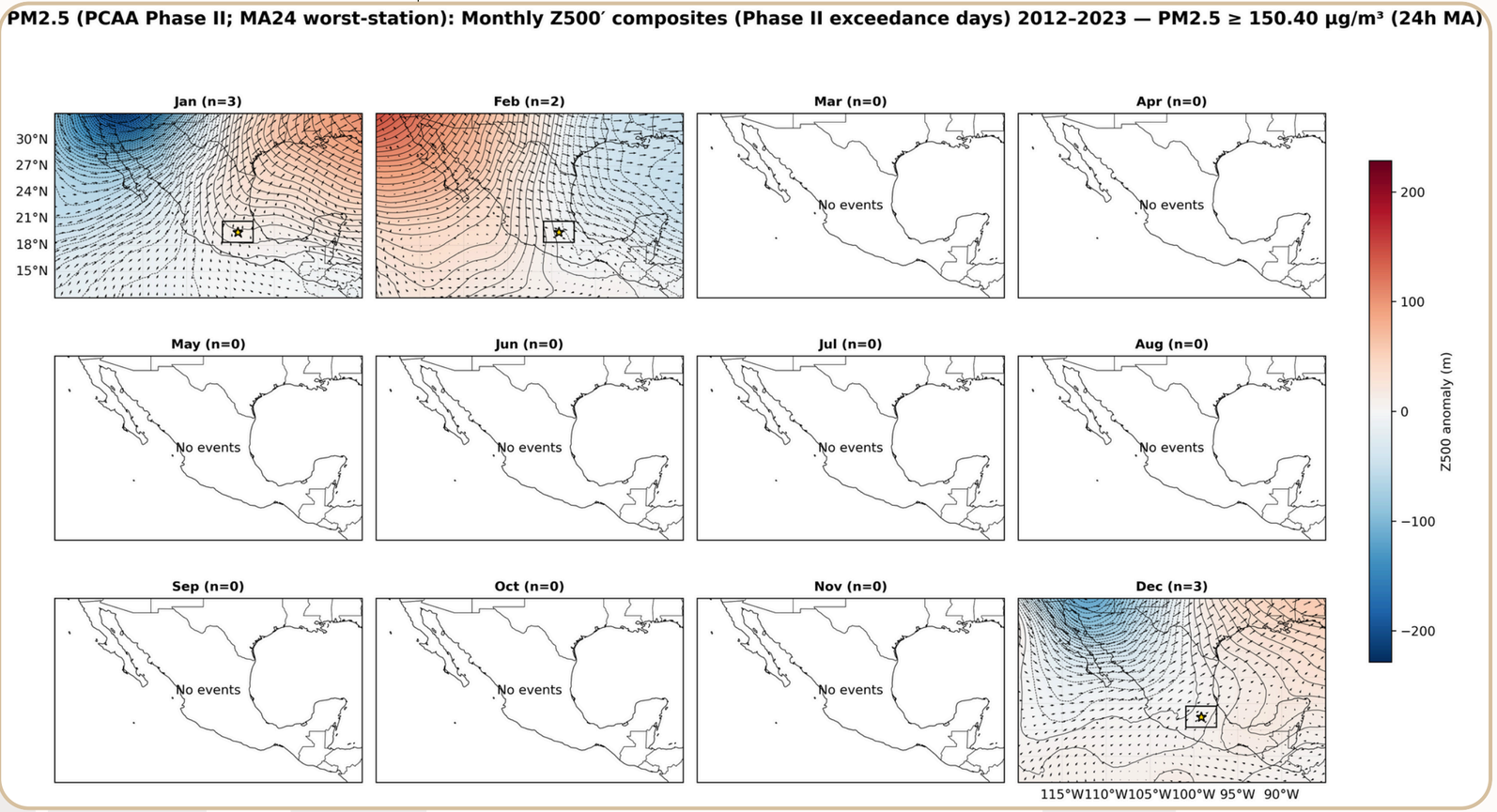
- Concentrated in cold-dry season (Jan/Dec), absent in rainy months.
- Signals indicate episodic stagnant conditions, but small-N months limit robustness.
- Suggests Phase I for PM10 captures very rare extremes → complements percentile-based definitions.



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.



Discussion + Next Steps

(Stage 1.3 → Stage 2)

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

- 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.

Tampereen yliopisto
Tampere University

INSTITUTO DE CIENCIAS DE LA
ATMÓSFERA
Y CAMBIO CLIMÁTICO

thank you!