

Unlocking Local Emissions Trends

Using Satellite Data to Drive Low-Emission Development



ESA's Sentinel 5P



NASA's OCO-2

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Presentation Outline

1. Research Motivation
2. Source Data and Post Processing
3. Tracking Emissions over time
 - a) Methodology
 - b) Results
4. Scalable Performance Scores for Any Geographic Area
5. Extending the Method to Other Air Pollutants

Low-Emission Growth

A Foundation for Sustainable Development

- **A low-emission growth path across key sectors** is critical for sustainable development, poverty reduction, and a livable planet.
- **Integrating emissions mitigation into development planning** is vital for long-term environmental and economic resilience.
- **Need for metrics to inform global policy dialogue** by enabling transparent and comparable emissions assessments.
- **Need for identification of emissions hotspots** to support policymakers at national and subnational levels in developing targeted mitigation strategies aligned with global climate objectives.

Satellite-Based Metrics to Close the Data Gap

Closing the Data Gap with Satellite- Based Metrics

Source Data:

1. NASA's (OCO-2) georeferenced XCO₂ measurements at a resolution of 1.29 × 2.25 kilometers.
2. ESA's (Sentinel-5P) georeferenced XCH₄ measurements at a resolution of 5.5 × 3.5 kilometers.

Making Satellite Estimates Comparable Across Space and Time

- Local CO₂ and CH₄ anomalies are estimated using the methodology of Hakkarainen et al. 2019.
- Our dataset includes average anomalies by month for each 5 km grid cell to produce a consistent, high-resolution dataset.

Tracking CO₂ and CH₄ Emissions Over Time

Data Quality

We use only satellite observations that meet or exceed NASA/ESA quality thresholds to ensure reliability.

Emission Indicators (5 km Grid Cells)

1. Long-term monthly trend : (2014–2025 for CO₂; 2018–2025 for CH₄)
2. Short-term shift : difference between the past 12-month average and earlier values

Adaptive Grid Approach

- Instead of uniformly coarsening the grid, we expand the observation area around each cell until it meets a minimum data threshold.
- Preserves small, data-rich areas while ensuring statistical robustness across the study area.

Aggregating Trends Across Areas

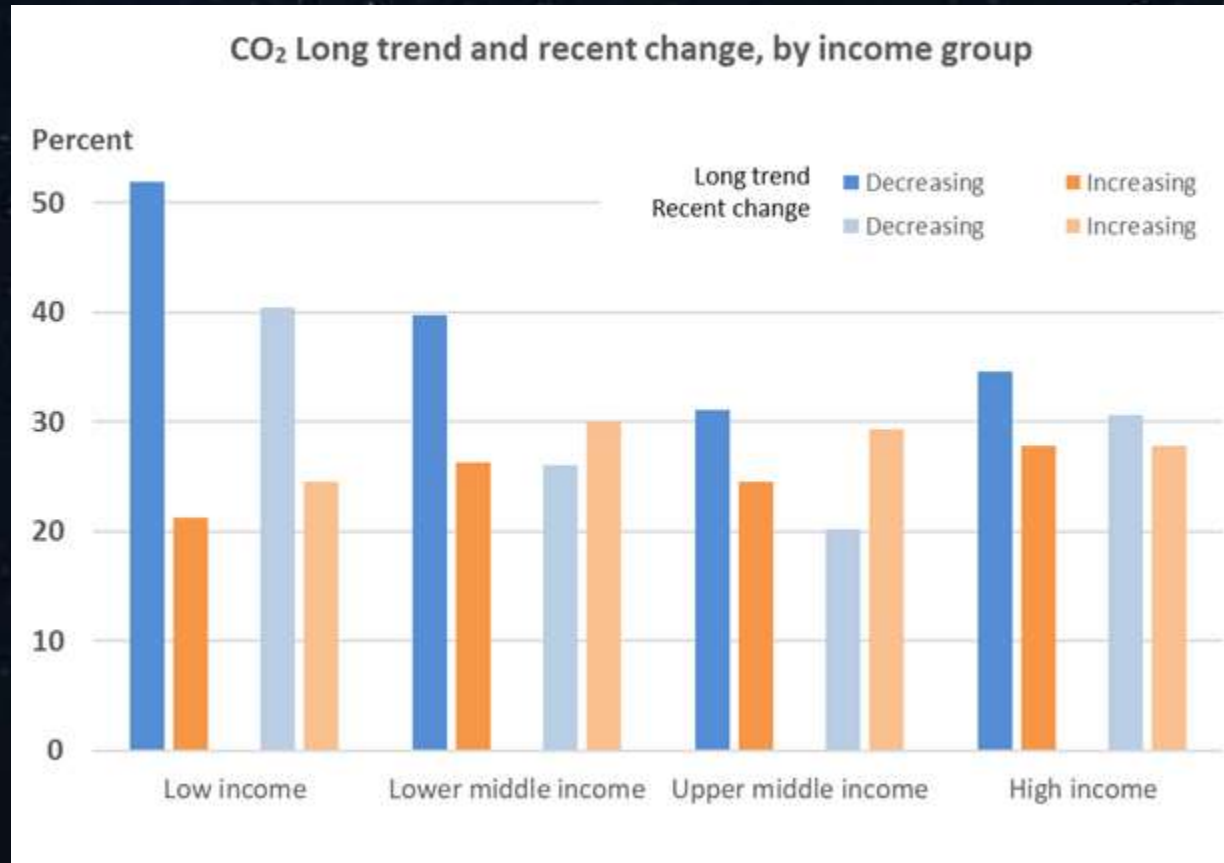
Trend Summarization Approaches

1. **Unweighted** – all grid cells treated equally
 - Score = % increasing – % decreasing
2. **Weighted (Emissions Database for Global Atmospheric Research)** – cells weighted by emissions
 - Higher-emission areas influence the score more

Normalization for Comparisons

- Scores normalized to account for the share of statistically significant trends
- Final scores range from **-100** (all significant decreases) to **+100** (all significant increases)

Global Sub-Provincial CO₂ Trends & Recent Changes by World Bank Income Groups



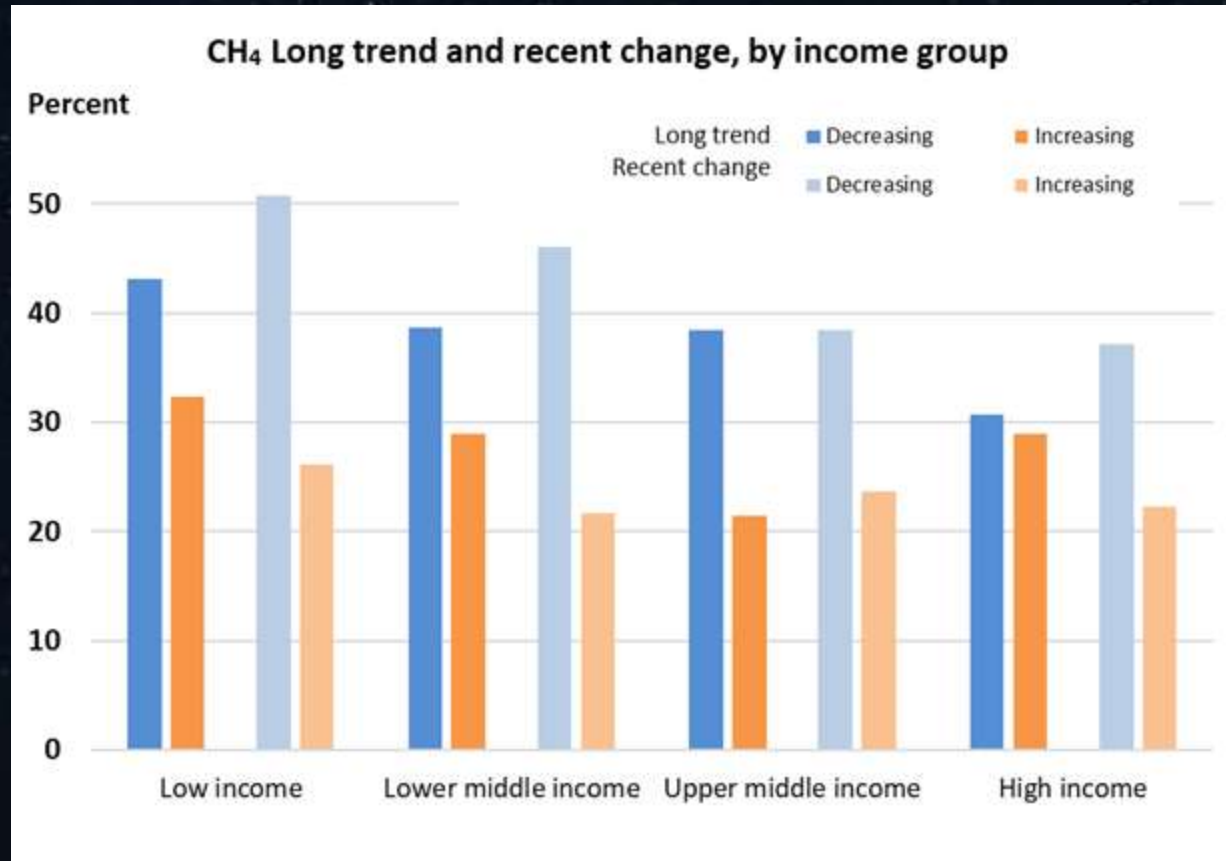
Long-term trend

- Decreasing in **13,179** sub-national units
- Increasing in **9,616** sub-national units

Most recent Change

- Decreasing in **9,663** sub-national units
- Increasing in **10,790** sub-national units

Global Sub-Provincial CH₄ Trends & Recent Changes by World Bank Income Groups



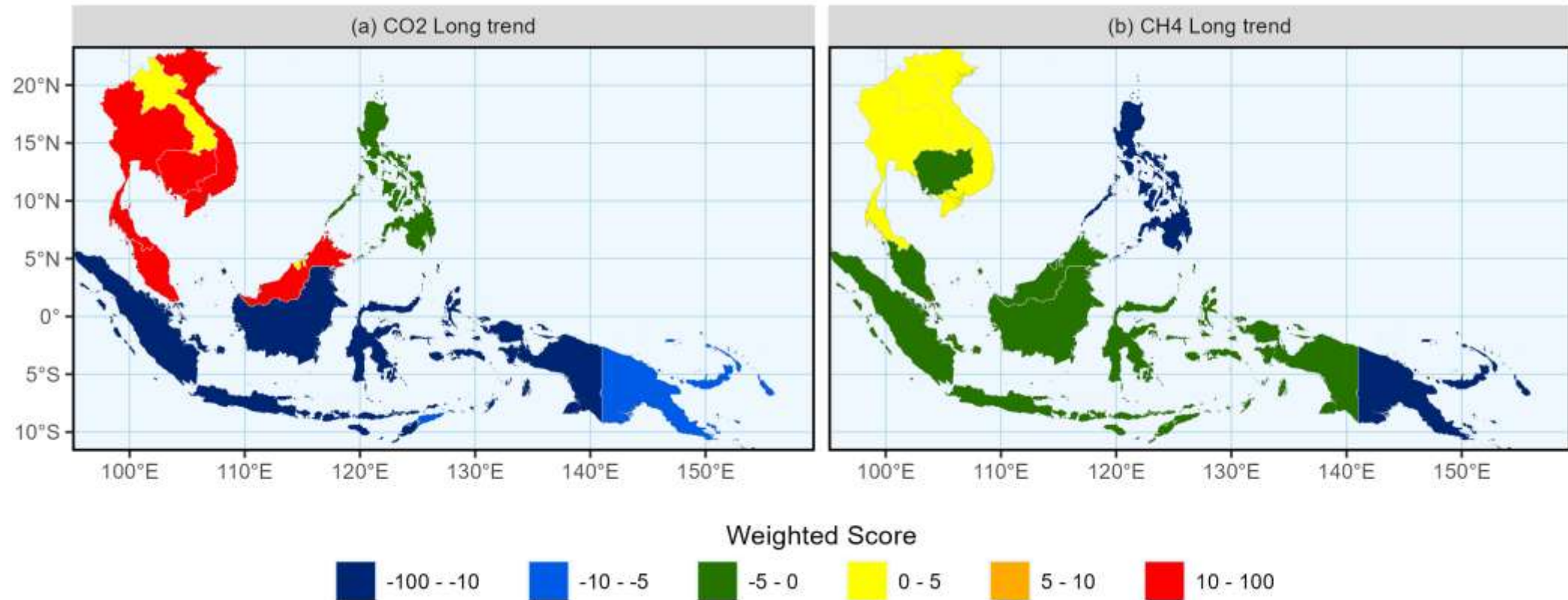
Long-term trend

- Decreasing in **13,734** sub-national units
- Increasing in **9,675** sub-national units

Most recent Change

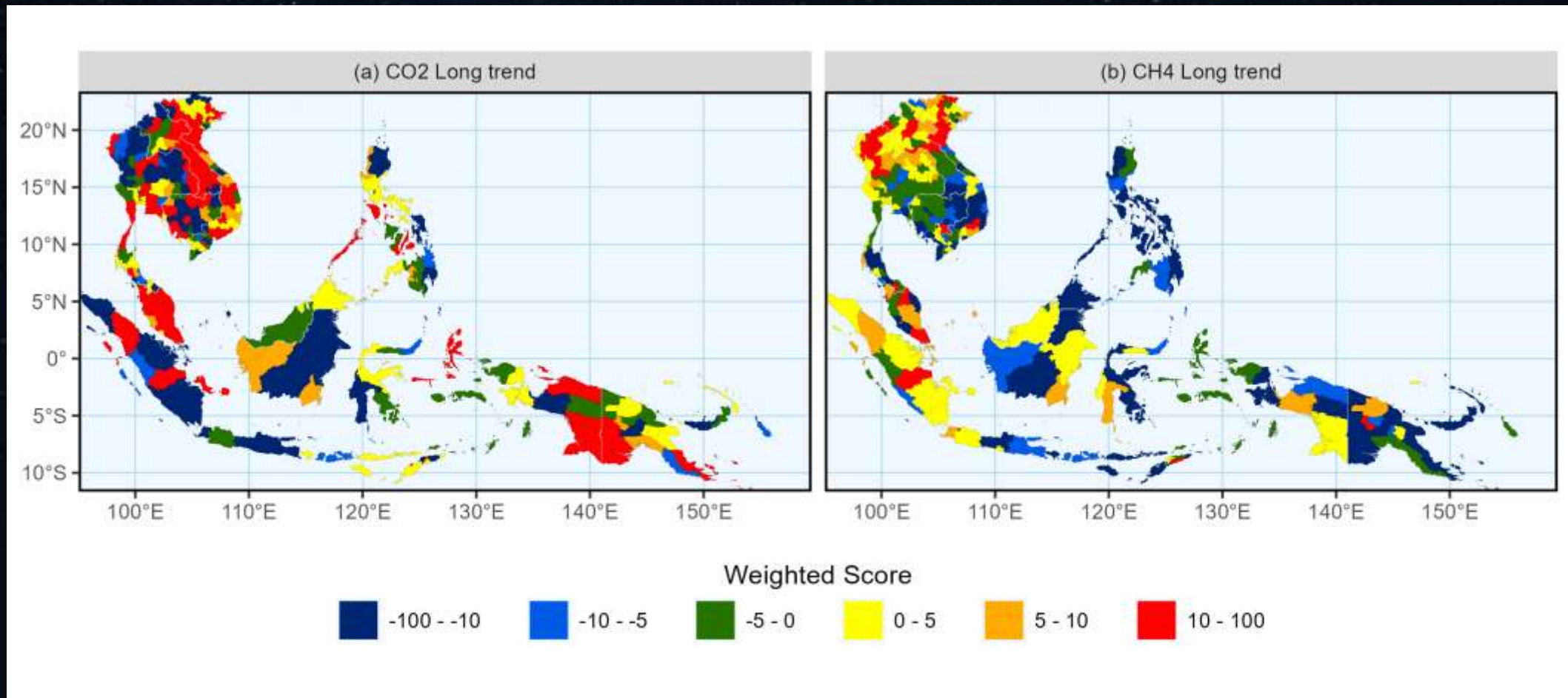
- Decreasing in **15,143** sub-national units
- Increasing in **8,689** sub-national units

Southeast Asia Country Level Map



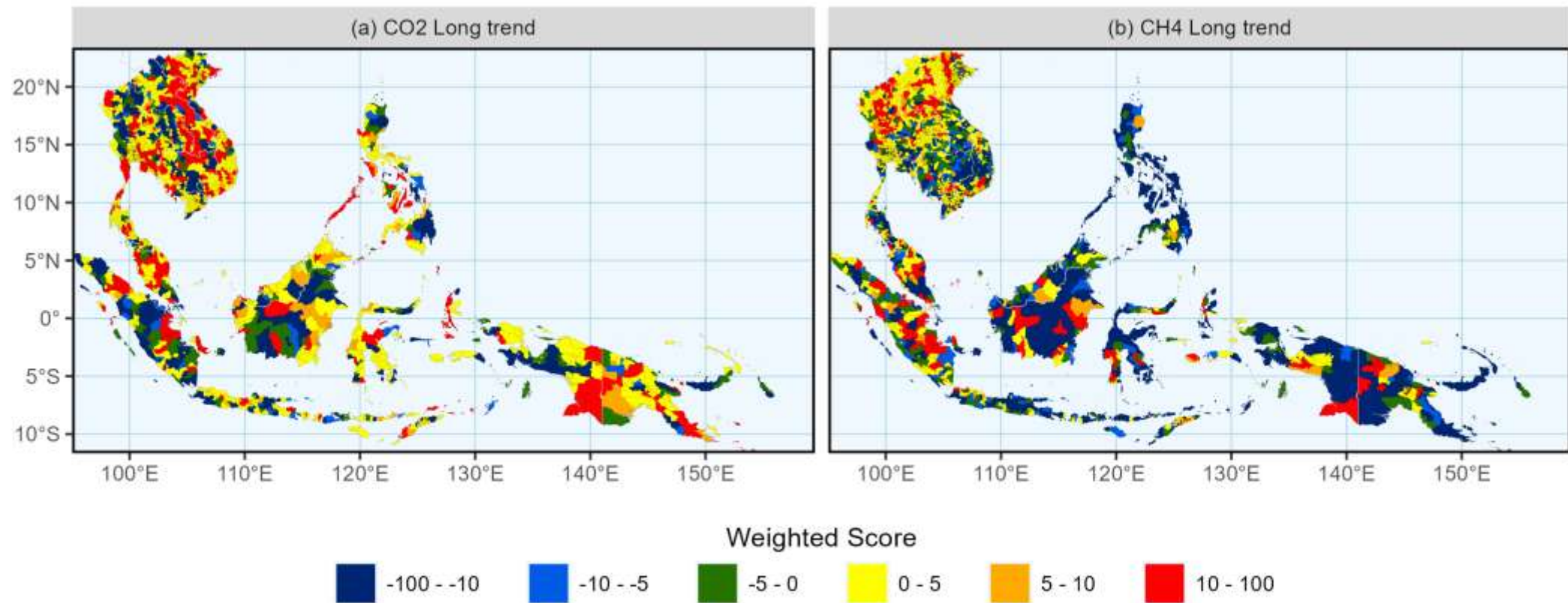
From a policy perspective, comparative scores at the national level provide useful information for international resource allocation, offering a clear view of overall country performance.

Southeast Asia Inter-Province Level Map



Within countries, comparative scores at the inter-provincial level support evidence-based decisions on how resources can be distributed across provinces.

Southeast Asia Sub-Provincial Level Map



At a finer scale, sub-provincial comparisons help identify priority areas and inform local targeting of emissions reduction efforts.

Urbanization and Emissions Data Needs

Urbanization and Emissions

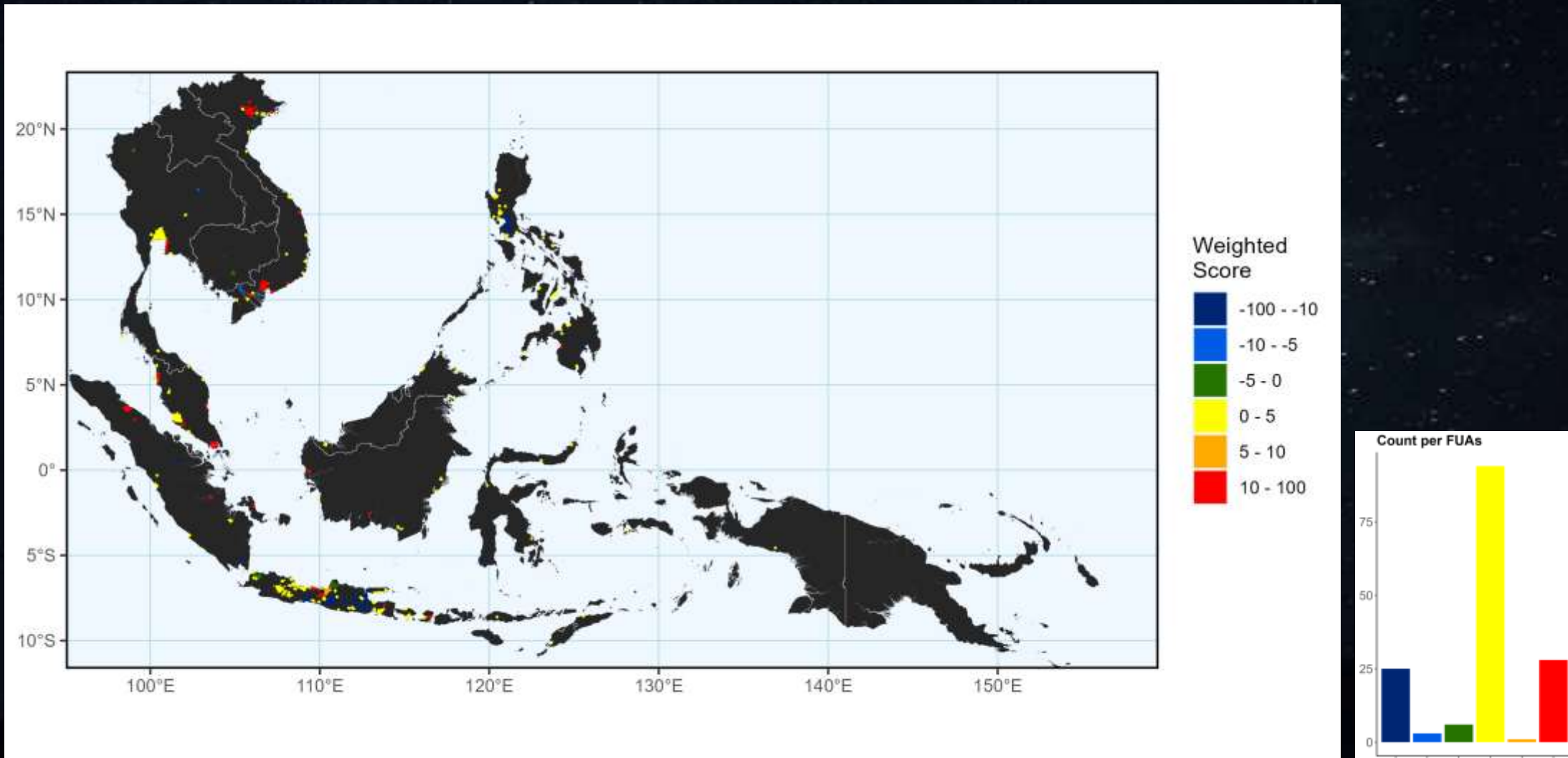
- Cities drive ~70% of global CO₂ and significant CH₄ emissions
- Key sources: transport, energy, industry, landfills
- Rapid urbanization, especially in developing countries, makes cities central to the low-emission growth agenda. Cities will remain central to job creation, given their longstanding role as engines of economic growth, employment generation, and poverty alleviation

Data Gaps

- Location-specific urban emissions data are scarce, especially in the Global South
- High-resolution data needed for tracking trends and guiding low-emission growth

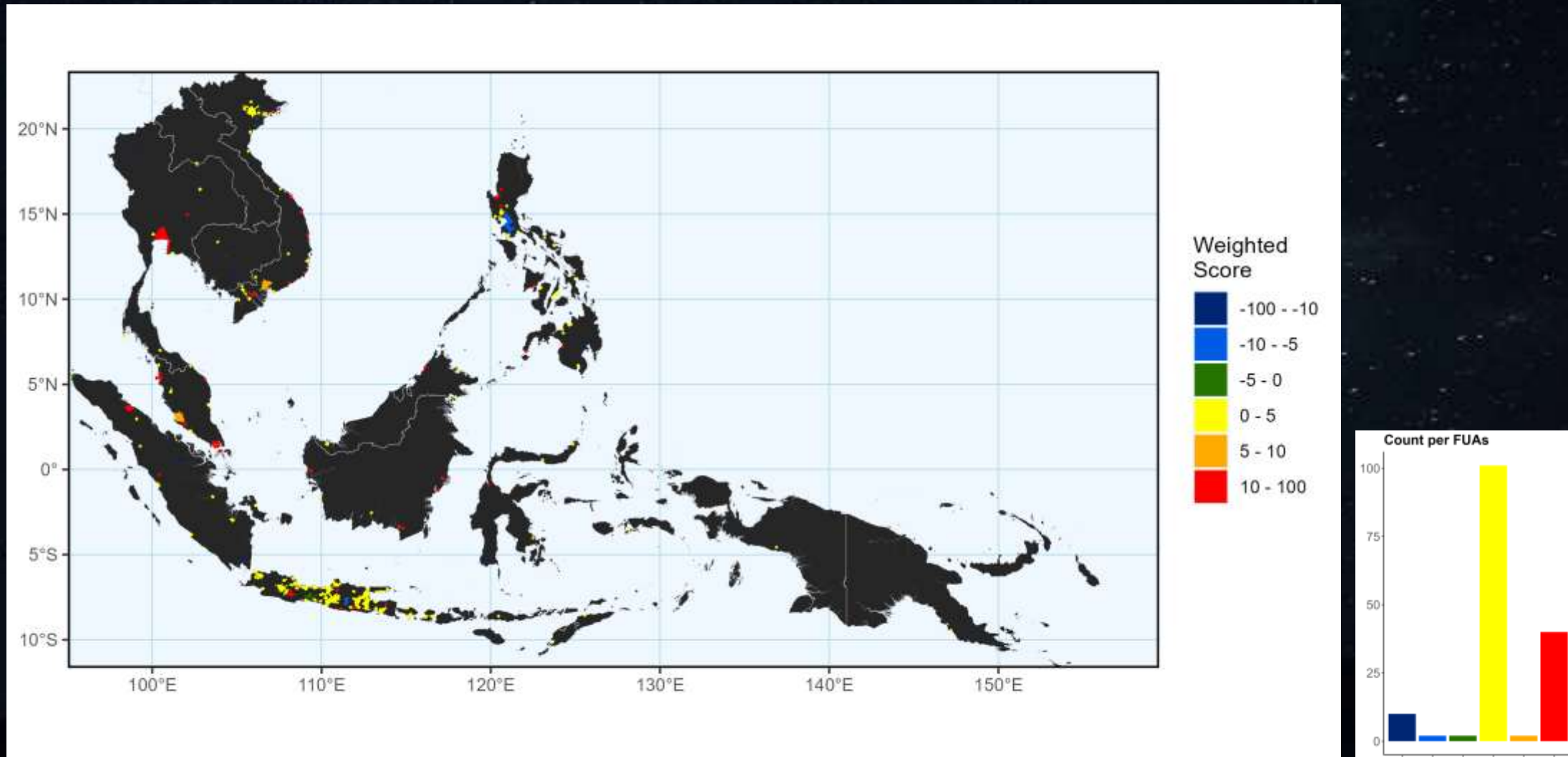
Tracking Long term trend of Urban CO₂ Emissions

Illustrative Example: 157 Urban Areas (>250,000 Population) in Southeast Asia



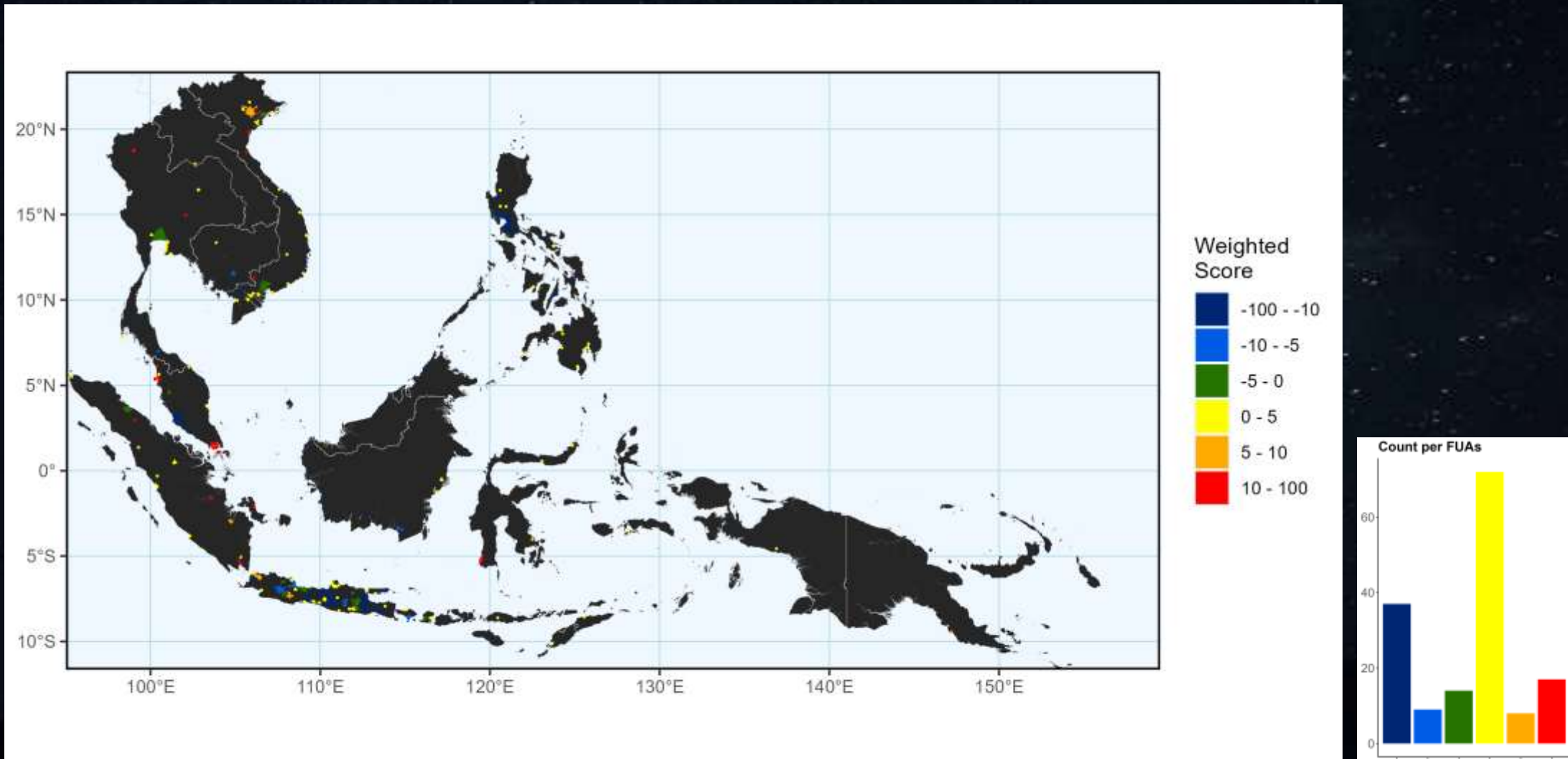
Tracking Recent Changes in Urban CO₂ Emissions

Illustrative Example: 157 Urban Areas (>250,000 Population) in Southeast Asia



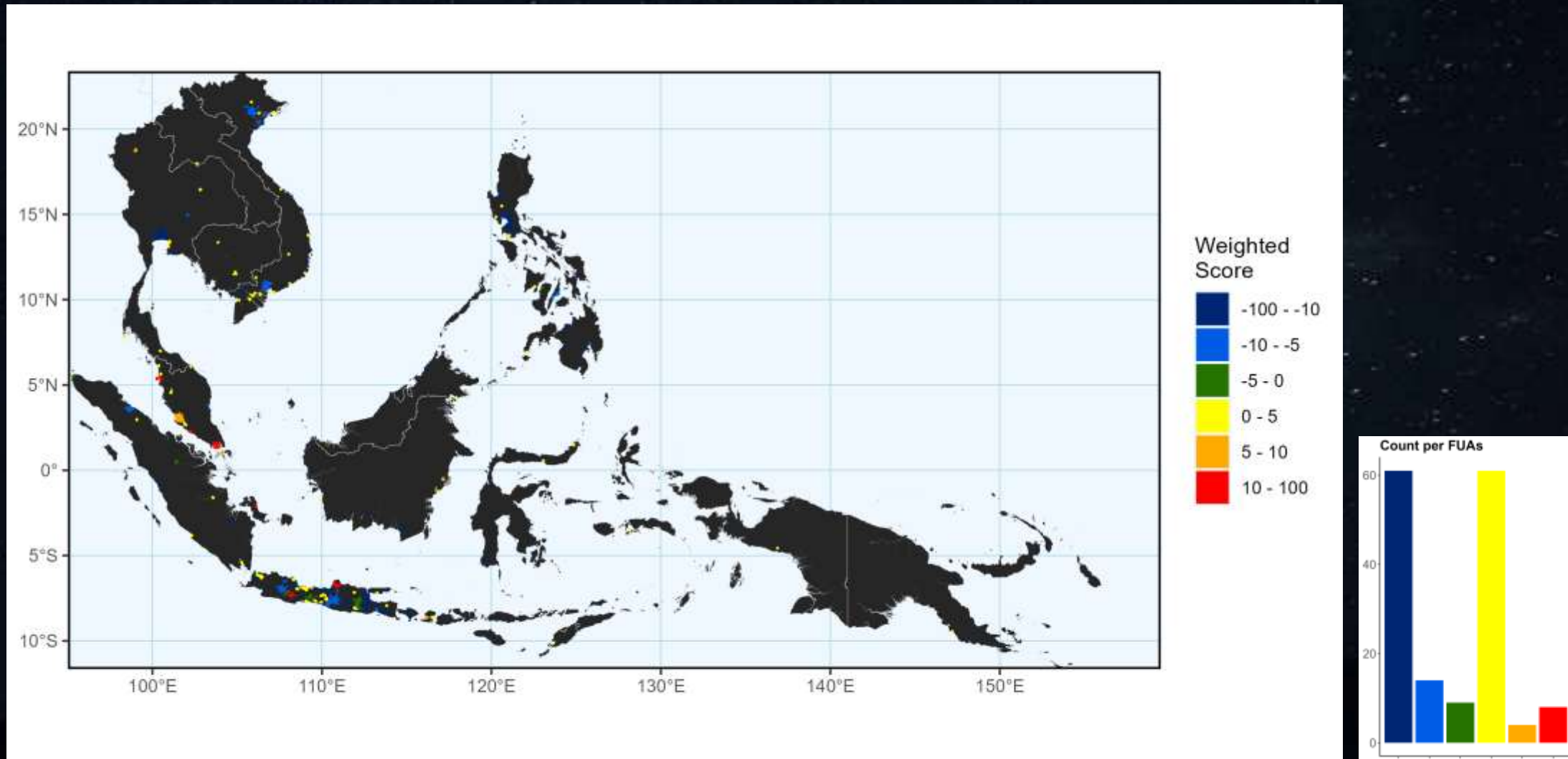
Tracking Long term trend of Urban CH₄ Emissions

Illustrative Example: 157 Urban Areas (>250,000 Population) in Southeast Asia



Tracking Recent Changes in Urban CH₄ Emissions

Illustrative Example: 157 Urban Areas (>250,000 Population) in Southeast Asia



Tracking Urban Emissions in 6,672 Functional Urban Areas Worldwide

Key Findings

- Cities show diverse CO₂ and CH₄ trends
- Increases and decreases often occur within the same country
- Underlines the need for local monitoring and tailored interventions

Why This Matters

- First detailed, comparable emissions data for thousands of cities
- Open access supports policymakers, researchers, and the public
- Helps track progress, identify problem areas, and guide interventions

Multi-Scale Assessment for Any Geographic Area

Flexible, High-Resolution Approach

- 5 km grid-level trend tracking enables emissions performance scores at any geographic scale
- Supports both long-term and short-term CO₂ and CH₄ assessments

Comprehensive Coverage

- 242 countries & non determined legal status areas
- 3,242 provinces (Level-1)
- 36,563 sub-provinces (Level-2)
- 6,672 Functional Urban Areas > 250,000
- 13,636 Functional Urban Areas > 50,000
- 670 offshore oil & gas zones within national EEZs

Open and Updatable

- Open-access code allows integration of new satellite observations
- Facilitates continuous monitoring and policy-relevant insights
- Publicly available datasets summarized at the Development Data Hub

Output

[World Bank Policy Research Working Paper](#)

- [Satellite-Based Measures for Tracking Atmospheric CO₂ and CH₄ At National, Subnational and Urban Scales \(DOI: 10.1596/1813-9450-11237\)](#)

[Blogs](#)

- [From Space to Strategy: Using Satellite Data to Drive Low-Emission Development](#)
- [New Global Dataset Tracks Urban Emissions from Space](#)

[Publicly available datasets:](#) (at [World Bank Development Data Hub](#))

- Regression results:
 - CH₄ regression results of long trends and recent changes
 - CO₂ regression results of long trends and recent changes
- Geographic summary of the trends:
 - National
 - Sub-national
 - Functional Urban Areas



Thank You

We gratefully acknowledge funding from the Global Data Facility