The Integrated Triad Model: Beijing's Path to Precision Air Quality Governance

Xiu'e Shen

Beijing Municipal Ecological and Environmental Monitoring Center

11 March 2026 | Bangkok, Thailand

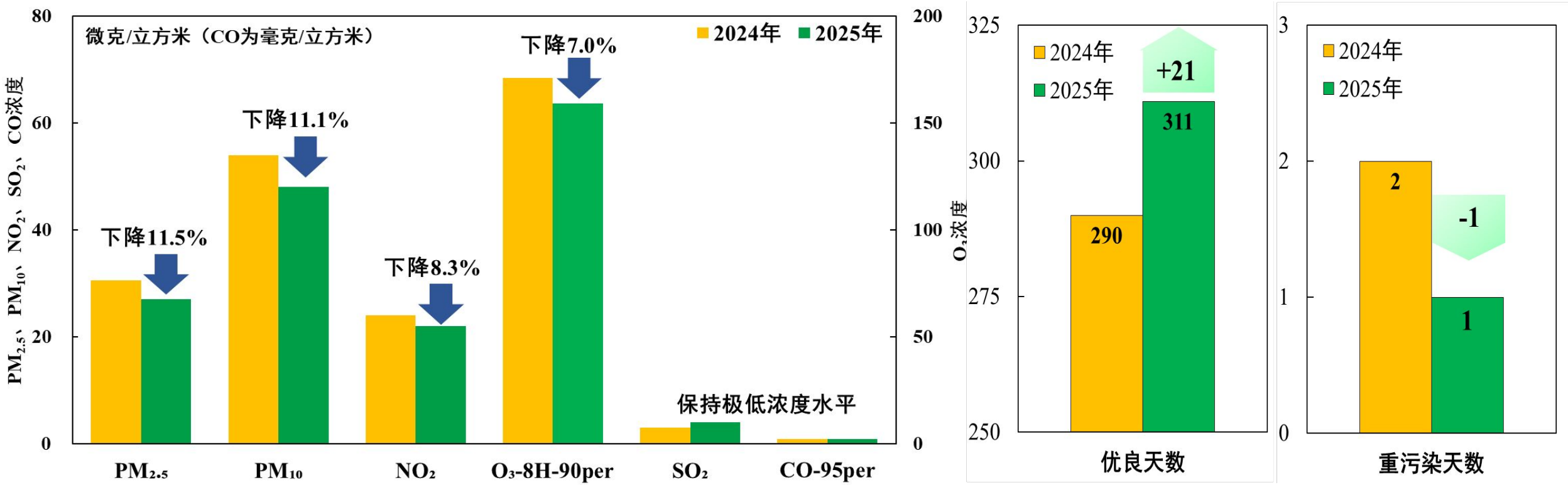
主要内容
Contents

2025年，北京市空气质量全面达标

Beijing's air quality achieved full compliance with national standards

2025年，6项主要污染物实现全面达标，$PM_{2.5}$年均浓度是27.0，同比下降11.5%。全年优良天数是311天，重污染天仅有1天。

In 2025, all six major air pollutants in Beijing met the national standards. PM2.5 concentration dropped to 27.0 μg/m³, a decrease of 11.5%. The city achieved 311 days of good air quality, with only one day of heavy pollution. Beijing has made remarkable achievements in air quality improvement.

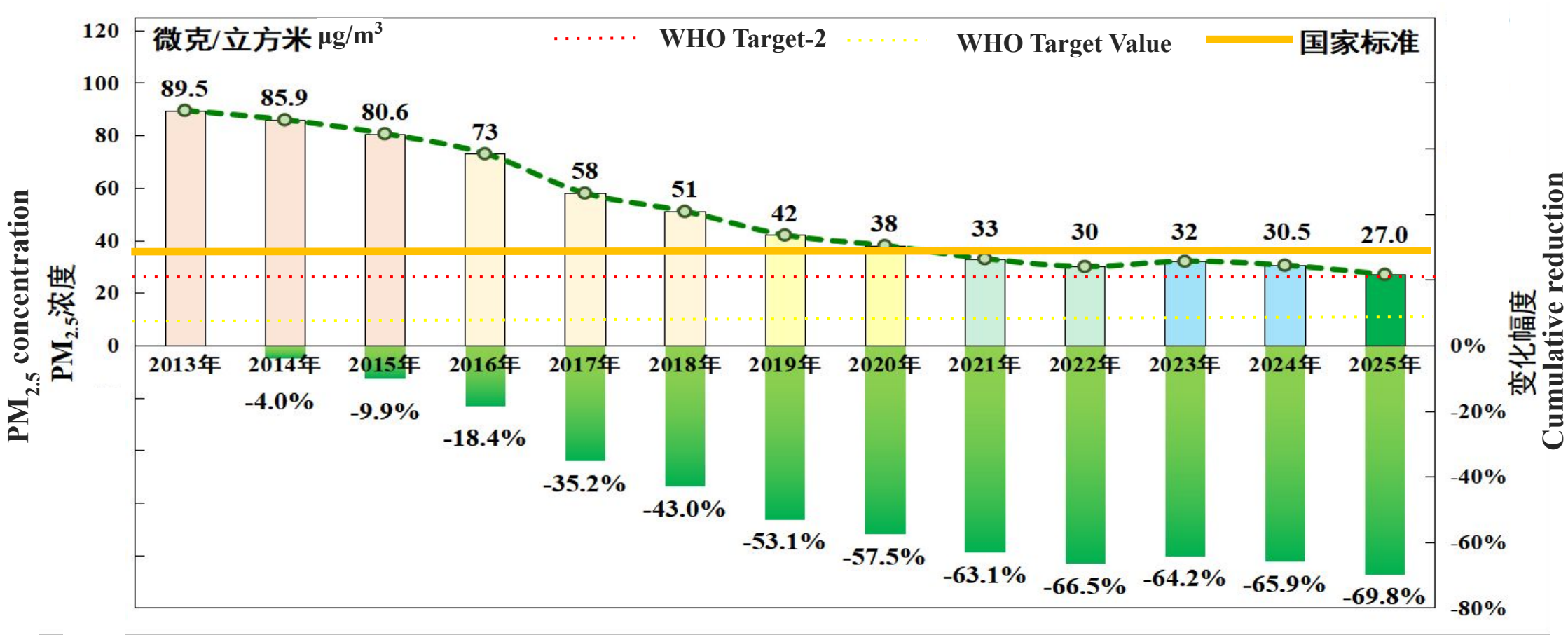


空气质量取得里程碑式突破

A Landmark Transformation in Air Quality

北京市$PM_{2.5}$从2013年89.5微克/立方米下降至2025年27.0微克/立方米，降幅达到69.8%。但与国际先进水平相比仍有差距，重污染天时有发生，大气污染治理任重道远.

Since 2013, $PM_{2.5}$ has dropped from 89.5 to 27.0 μg/m³—a 69.8% reduction. Yet challenges remain. Current pollutant concentrations still exceed WHO guidelines, and heavy pollution episodes still occur in autumn and winter. We still have a long way to go.

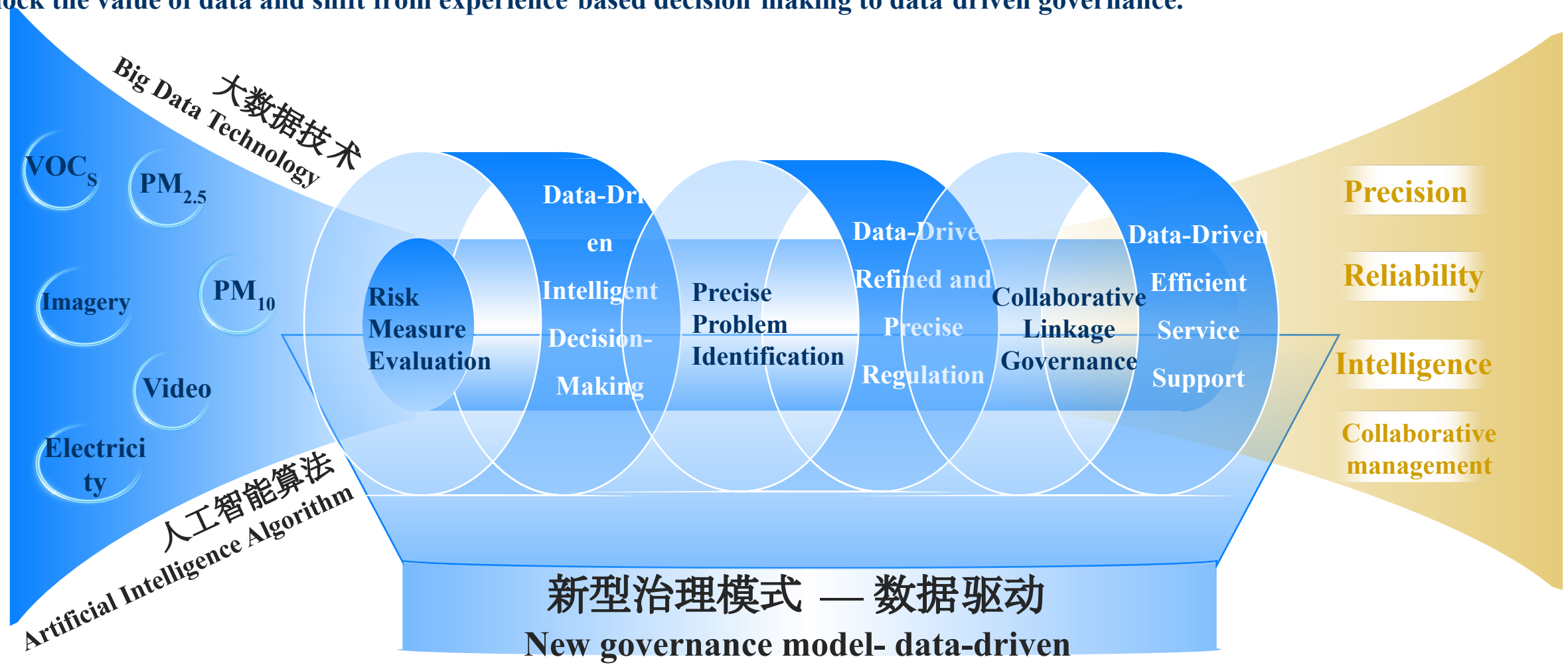


以“数据驱动”推动数据价值实现，探索精准治污技术之路

Unlocking Data Value: Exploring the Path to Precision Pollution Control

利用现代信息技术手段，充分挖掘数据价值，用数据决策、监管、服务，从“经验驱动”向“数据驱动”转变，推动环境治理向 “精准、可信、智能、共治”的方向迈进

To tackle these challenges, Beijing has applied big data analytics and artificial intelligence to air quality governance. Our goal is to unlock the value of data and shift from experience-based decision-making to data-driven governance.

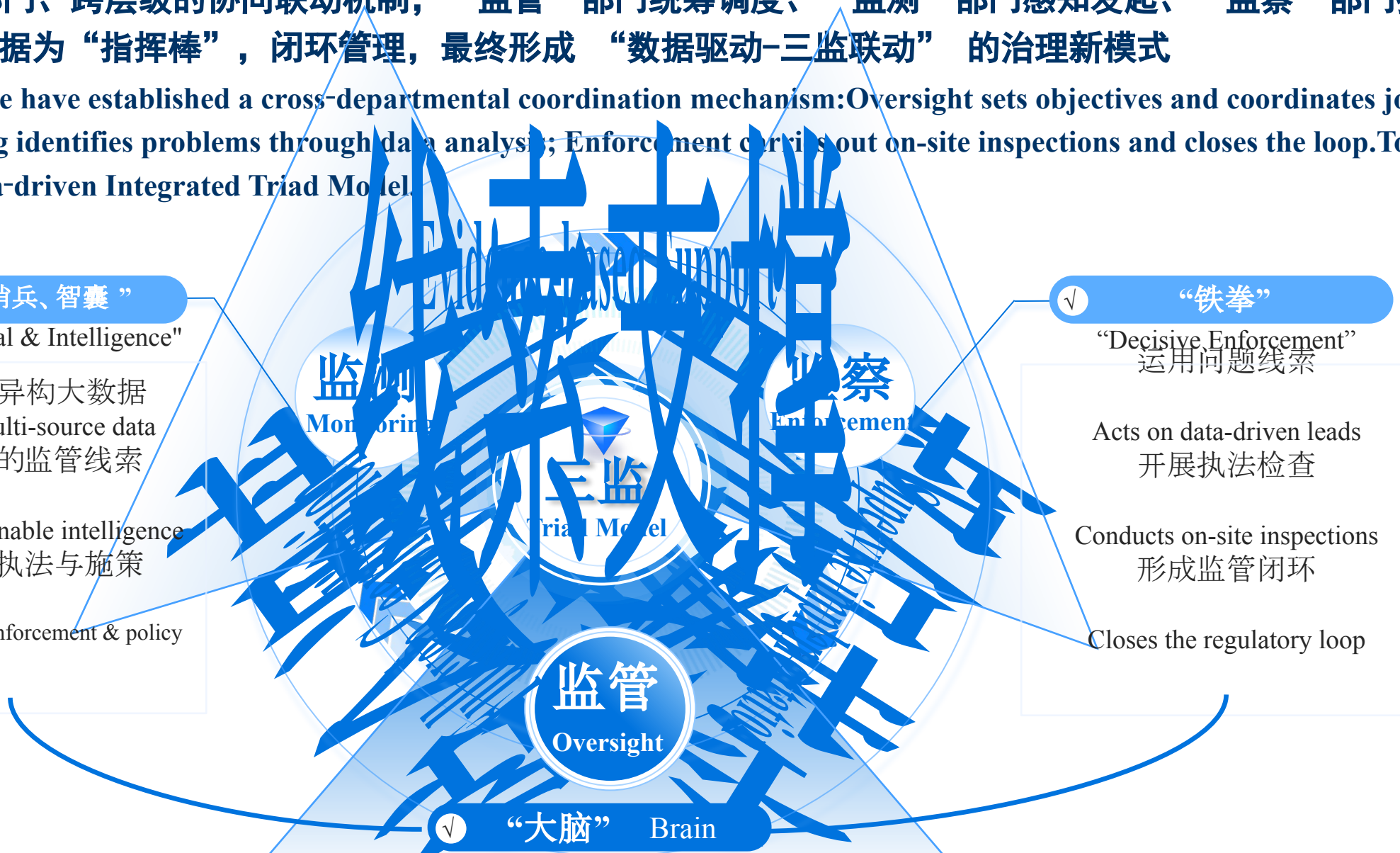


以“三监联动”破解协同治理难题，形成治理机制新模式

The Integrated Triad Model: A New Governance Mechanism for Coordinated Air Quality Management

探索跨部门、跨层级的协同联动机制，“监管”部门统筹调度、“监测”部门感知发起、“监察”部门执法检查，以精准数据为“指挥棒”，闭环管理，最终形成 “数据驱动-三监联动” 的治理新模式

Meanwhile, we have established a cross-departmental coordination mechanism:Oversight sets objectives and coordinates joint actions;Monitoring identifies problems through data analysis; Enforcement carries out on-site inspections and closes the loop.Together, they form our data-driven Integrated Triad Model.



√ “耳目、哨兵、智囊 ”

"Sensor, Signal & Intelligence"

统筹多源异构大数据

Integrates multi-source data

提供精准的监管线索

Generates actionable intelligence

指引精准执法与施策

Directs targeted enforcement & policy

√ “铁拳”

“Decisive Enforcement”

运用问题线索

Acts on data-driven leads

开展执法检查

Conducts on-site inspections

形成监管闭环

Closes the regulatory loop

主要内容
Contents

建成“智能感知–精准管控–智慧调度”的三监联动技术体系

From Data to Action: The Integrated Triad Workflow

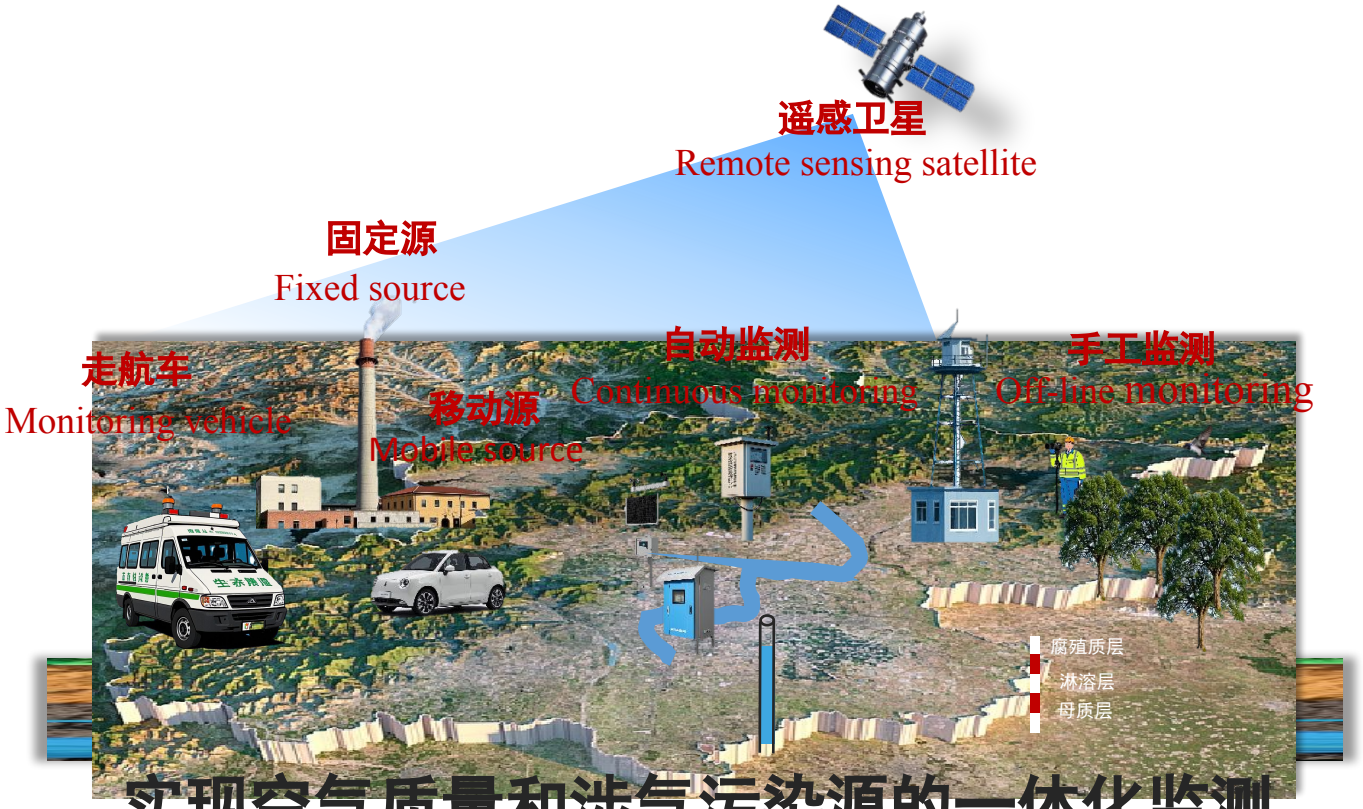
We have built a complete three-layer technical system:Intelligent Monitoring, Precision Management, and Smart Dispatching.

Intelligent Monitoring focuses on data acquisition; Precision Management focuses on data Utilization；Smart Dispatching focuses on AI-Driven Dispatching.

一、智能感知：“天空地移智”一体化监测网络

1. Intelligent Monitoring: The Integrated "Sky-Space-Ground-Mobile-AI" Monitoring Network

We have integrated satellites, monitoring towers, ground sensors, and mobile inspection vehicles to realize unified monitoring of air quality and pollution sources.



实现空气质量和涉气污染源的一体化监测

Achieving Integrated Monitoring Across Air Quality and Pollution Sources

天 Sky

- 柱浓度反演 Vertical profile
- 气体污染物高值筛选 High value screening
- 扬尘源识别 Dust source identification

空 Radar

- 雷达探测 Radar detection
- 高塔监测 Tower monitoring

地 Ground

- 空气质量监测 Air quality monitoring
- 污染源监测 Pollution source monitoring

移 Mobile

- 环境污染物走航 Mobile Pollutant Survey
- 面源走航 Area Source Mobile Survey

智 AI

- 用电感知 Power Consumption
- 图像识别 Image recognition
- OBD监测 OBD monitoring .....

1. 污染源：建立全链条动态感知能力

1. Intelligent Monitoring:Pollution Sources-Full-Chain Dynamic Sensing Capability

We have established a multi-dimensional sensing network covering point, line, and area sources—including CEMS and power-consumption monitoring for stationary sources, OBD and remote sensing for over 200,000 vehicles, and AI-powered video inspections for construction dust.

过程监测“产和治”

Process Sensing — "Generation and Treatment"

生产设施电量感知
power-consumption Monitoring

末端监测“排”

End-of-Pipe Monitoring — "Discharge"

企业在线监测
CEMS (Continuous Emission Monitoring Systems)

远程监控
Remote monitoring

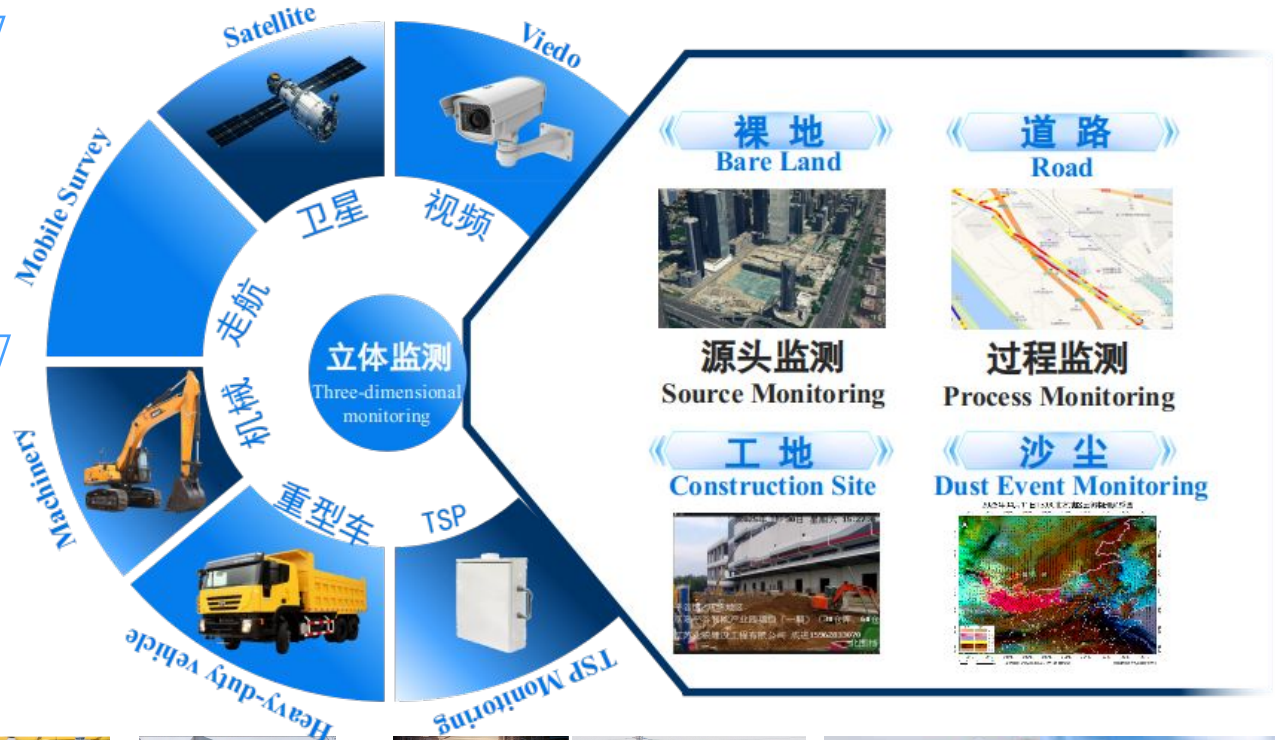
定位监控
GPS-based monitoring

车 Vehicle

尾气遥测
On-road Remote Sensing

黑烟抓拍
Black Smoke Detection

路



固定源“一张网” Fixed Sources

移动源“车企路油云” Mobile Sources

扬尘源“四尘”共治 Dust Sources

二、精准管控：“事前-事中-事后”全流程管控体系

2.Precision Management: A Full-Process “Before–During–After” Control Framework

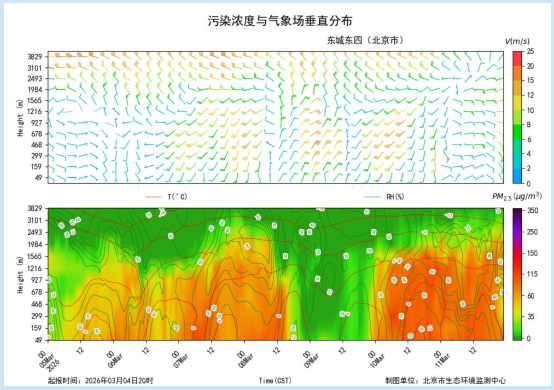
在智能感知网络的支撑下，构建事前风险预警、事中解析溯源、事后动态评估的全流程精准管控体系

Building on intelligent monitoring, we implemented full-cycle precision management

风险预警
Risk Warning

空间覆盖城市、区县、站点3级尺度，时间分辨率由逐日精细至逐小时

We established a forecasting system covering medium-to-long term down to hourly forecasts.



解析溯源
Source Analysis & Tracing

从成因解析、网格溯源到问题追踪，实现了到污染对象的溯源追因

We developed multi-scale source apportionment technologies for real-time analysis of pollution formation and rapid source localization.

高值点位识别

High-concentration Site Identification

污染来源溯源

Pollution Source Tracing

动态评估
Dynamic assessment

秒级、小时级监控移动、工业、扬尘源活动水平，逐日开展动态的效果评估

We use multi-source data to track emission changes, evaluate the effectiveness of control measures, and quantify emission reductions.

Enabling rapid daily assessment across mobile, industrial, and dust sources

事前—精准研判
Pre-event — Precise Forecasting & Assessment

事中—精准溯源
In-event — Precise Source Tracing

事后—精准评估
Post-event — Precise Effectiveness Evaluation

三. 智慧调度：建成平急两用的联动调度机制

3.Smart Dispatching: Routine and Intensive Operations

We built a dual-mode dispatch system: weekly for routine operations, daily for heavy pollution. Multiple departments collaborate to ensure every problem is tracked and resolved.

三监联动

Tri-agency Coordination

监管统筹调度-监测感知发起-监察执法检查

Regulatory Coordination & Dispatch — Monitoring-triggered Initiation — Inspection & Enforcement

平急两用

Routine-Intensive Dual-mode Operation

应急场景 Intensive Mode

2小时响应 2-hour response time

4小时反馈 4-hour feedback

常态化场景 Routine Mode

周推送、周反馈 Weekly Reporting, Weekly Feedback

月调度、月总结 Monthly Dispatch, Monthly Review

闭环整改

Closed-loop Corrective Action

反馈率 Feedback rate

核查率 Verification rate

查实率 Issue Confirmation Rate

三. 智慧调度：建成支撑三监联动的系列平台工具

3.Smart Dispatching: Developing a Suite of Platform Tools to Support Triad Model

建立了集成大模型的调度大屏、业务平台及APP，支撑“三监”联动体系下的智慧调度

We have also built an operational dashboard, a unified management platform, and a mobile app to ensure the efficient and effective operation of the Triad Model.

调度大屏

Operational Dashboard

业务平台

Operational Platform

APP

主要内容
Contents

应用成效：支撑了大气污染的治理效能的不断提升

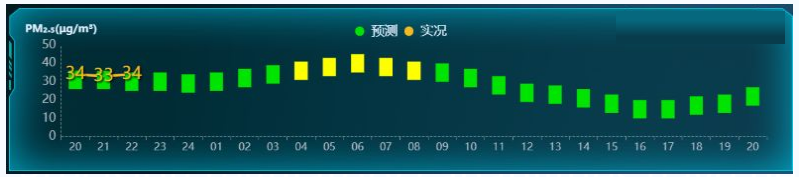
Application Outcomes: Faster, Smarter, More Targeted

With this system, our problem-detection capability has been upgraded to hourly response. More than 17,000 problem leads have been resolved through closed-loop management.The proportion of off-site supervision has increased from 10% to 70%, providing strong support for precise pollution control.

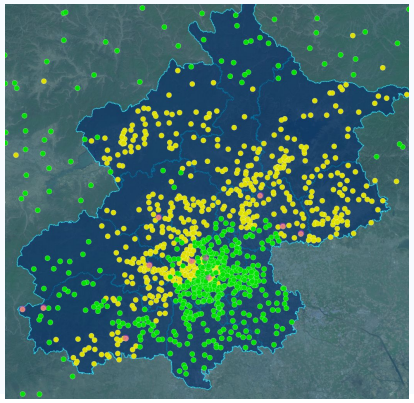
精准监管能力提升至小 时级

Precision regulatory capabilities have been upgraded to the hour level

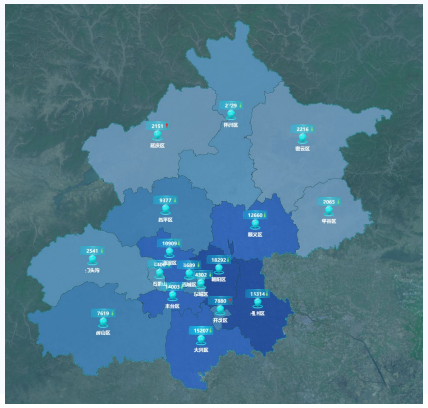
小时预报风险 Hourly risk forecasting



小时识别问题 Hourly problem identification



小时追踪落实 Hourly follow-up and implementation



非现场执 法比例大幅提升

The proportion of off-site law enforcement has increased significantly

线索数 1. 7万+

Number of problem clues

办结率 100%

Resolution rate

Intelligent Management

Precision 问题现场核实准确率超过70%

On-site verification accuracy for issues exceeds 70%

Reliability 环境大数据可信存储共享

Secure and trusted storage and sharing of environmental big data

Intelligence 20余类问题智能算法

Smart algorithms covering more than 20 problem categories

Collaborative management 三监联动协同治理

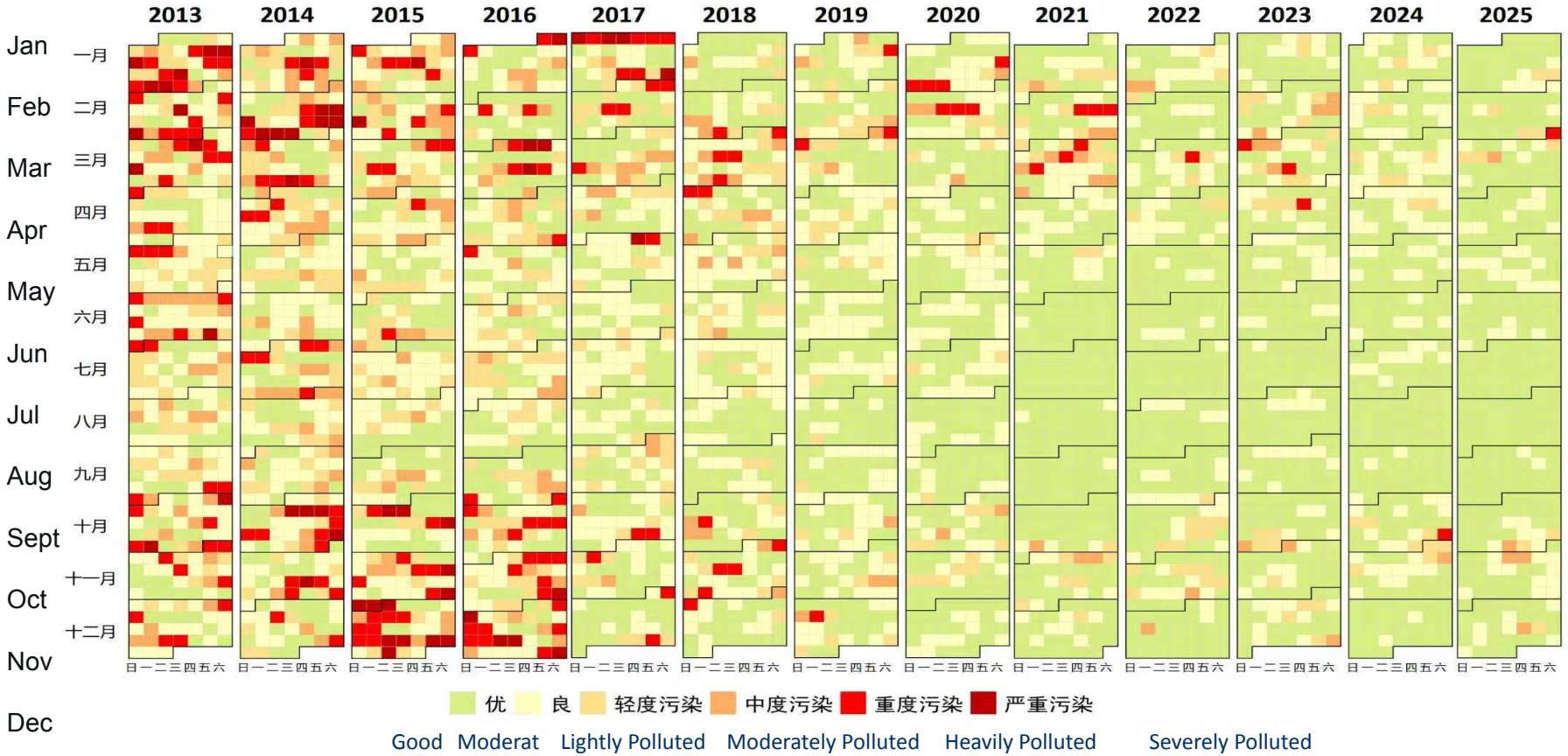
“Regulation-monitoring-inspection" linkage

应用成效：“北京蓝”走向“常态蓝”

Application Outcomes: From "Beijing Blue" to "Permanent Blue"

昔日繁星难见、重污染频发的困扰已成过往，北京从 “APEC 蓝” 迈向常态蓝，蓝天白云抬头可见，群众蓝天获得感、幸福感显著提升

This system has helped consolidate and sustain Beijing’s air quality improvements. Today, blue skies and white clouds have become a regular part of daily life in Beijing.



2013-2025年$PM_{2.5}$日历图 $PM_{2.5}$ Calendar (2013-2025)

Better Air Quality calls for joint efforts—let's move forward together!
Thank you for your attention!

沈秀娥

XIU-E SHEN

北京市生态环境监测中心

Beijing Municipal Ecological and Environmental Monitoring Center

2026. 03