

Monitoring Health Impacts of Air Pollution by High-Resolution Data

Tao Xue

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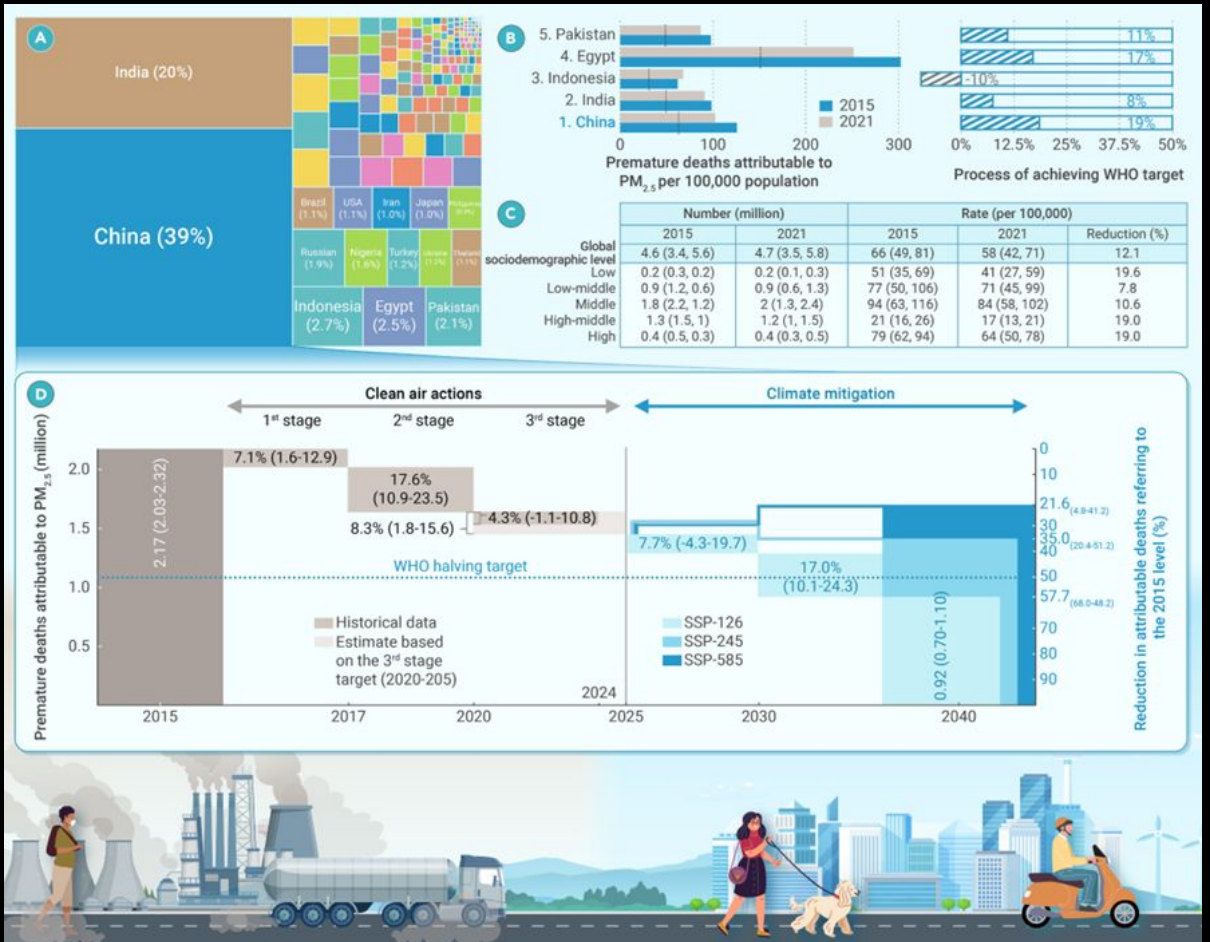
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Background: Benefits from Clean Air Actions

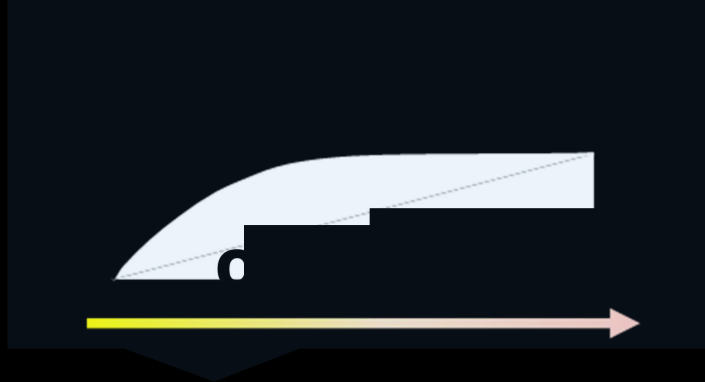
Beyond the halving commitment: China can do more to achieve clean air for global health

Ning Kang,^{1,6} Ruohan Wang,^{1,6} Pengfei Li,² Tao Xue,^{1,*} Jun Liu,⁴ Wei Wan,⁵ Jicheng Gong,³ Shiqiu Zhang,³ and Tong Zhu^{3,*}

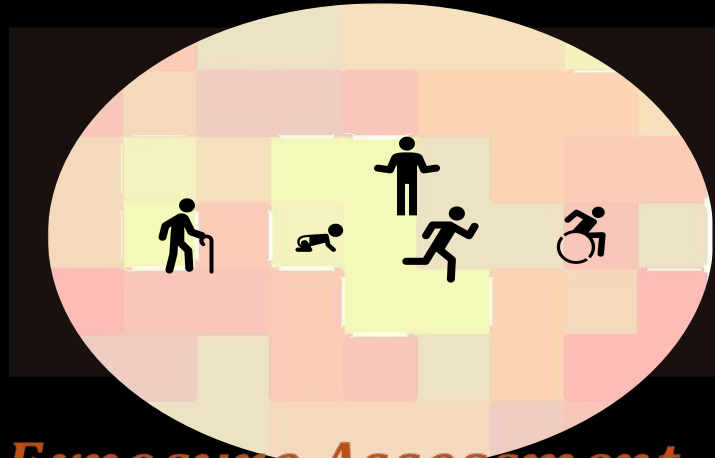


The Innovation

How to Track Benefits by Risk Assessments



f exposure–response function

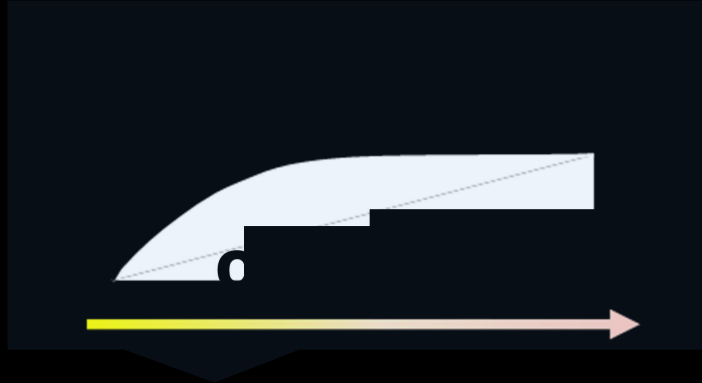


Exposure Assessment

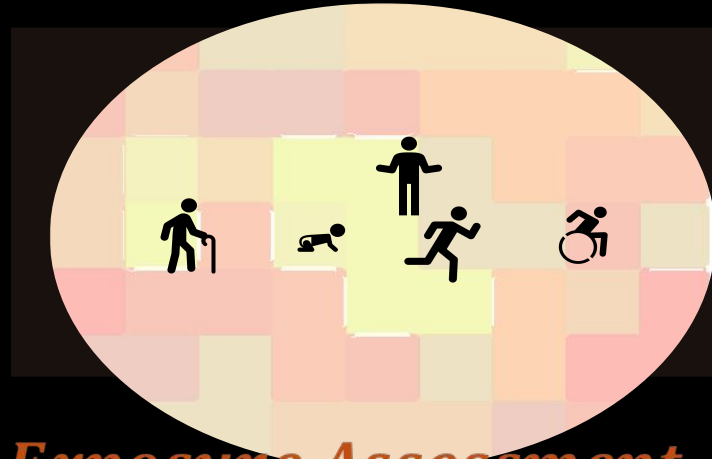


Risk Characterization

Outline: Why High-Resolution?



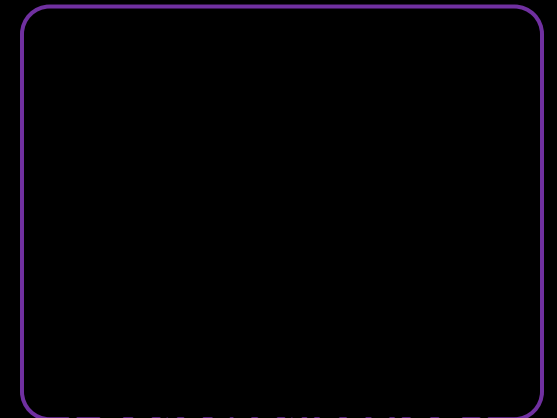
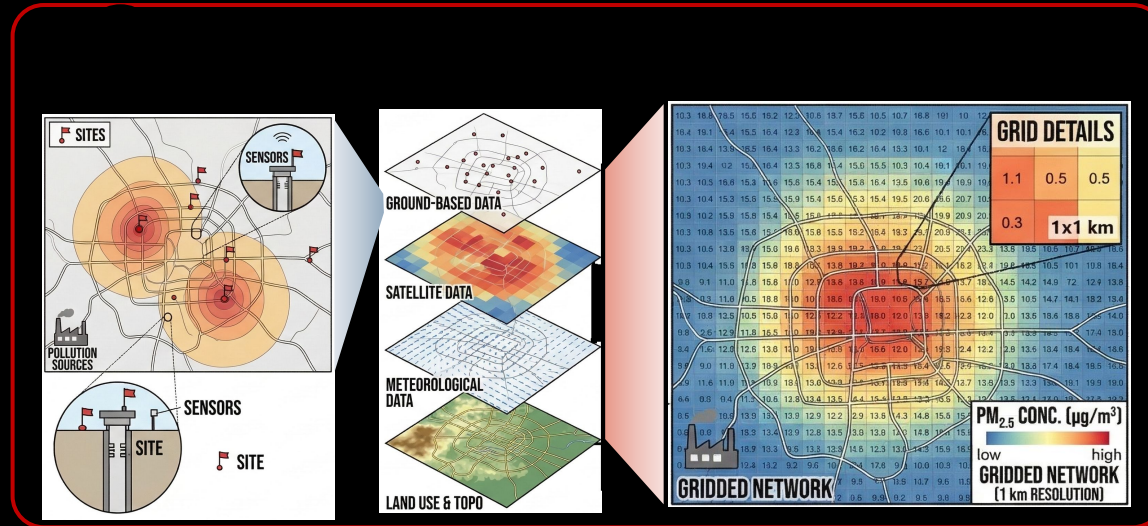
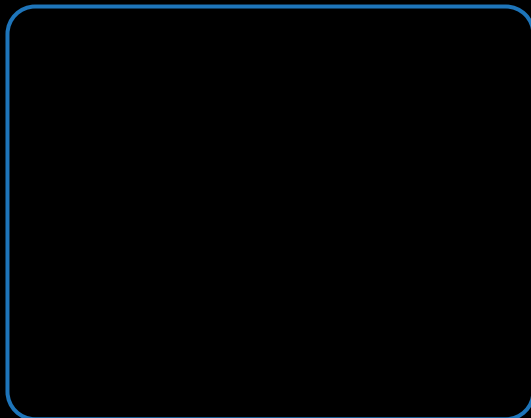
f exposure-response function



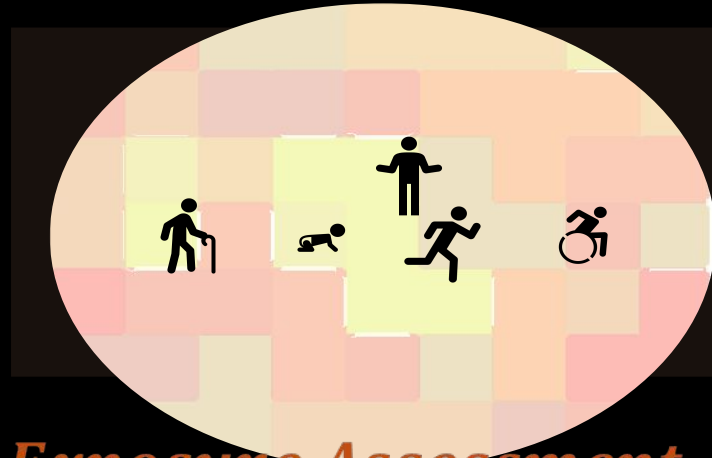
Exposure Assessment



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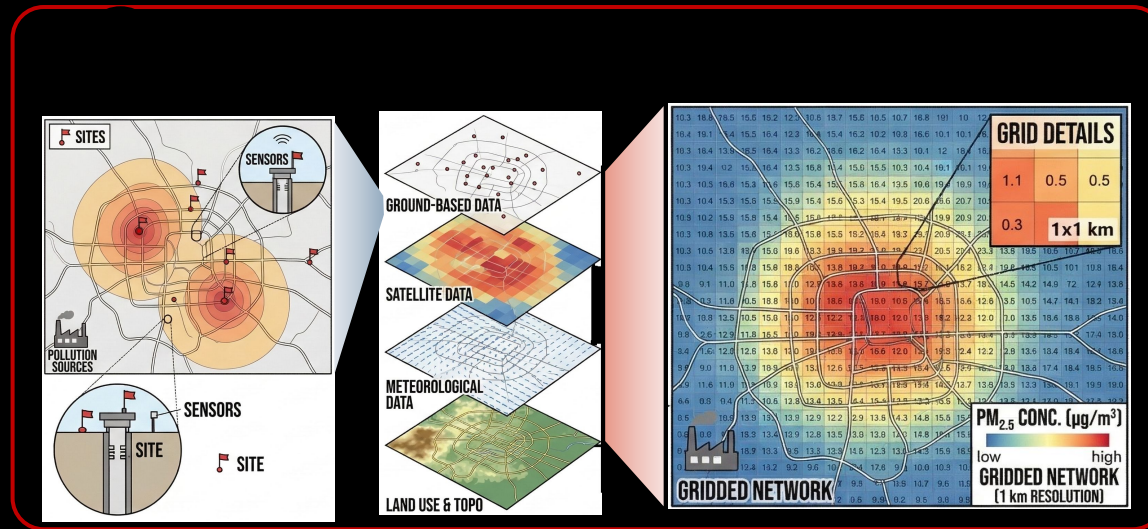


f exposure–response function

Exposure Assessment

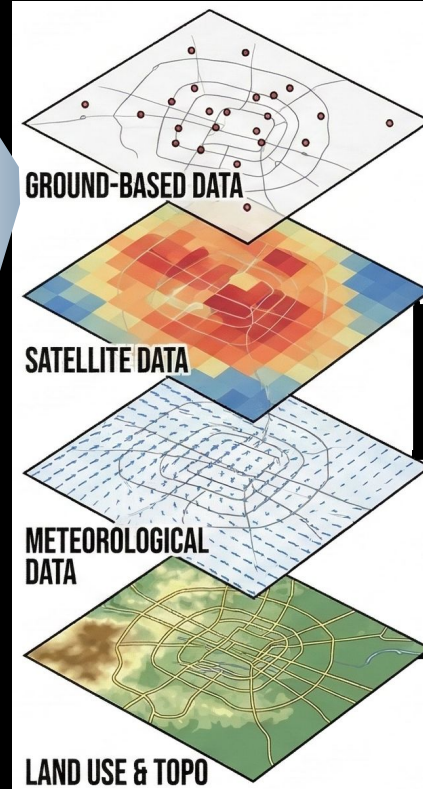
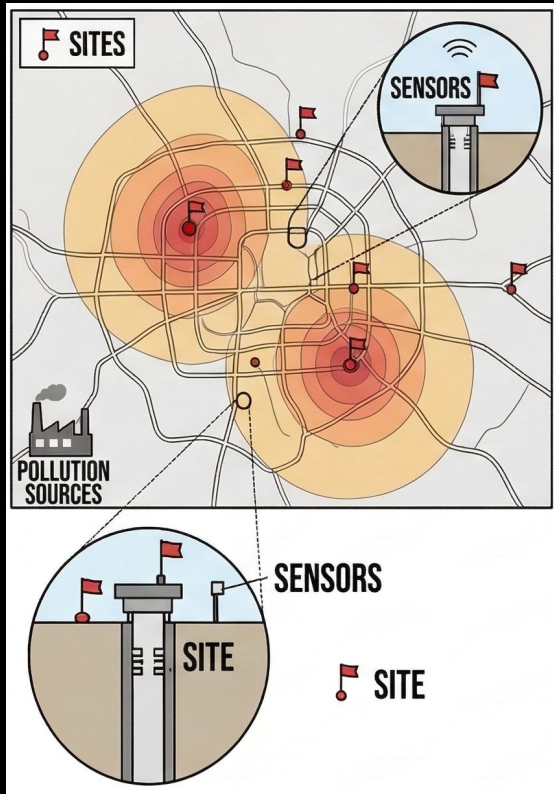
Risk Characterization

② Why the High-Resolution Data is Important to Build an Exposure-Response Function?



③ Why the High-Resolution Data is Important for Better Policy-Oriented Risk Characterization?

Improve Resolution by Data Fusion

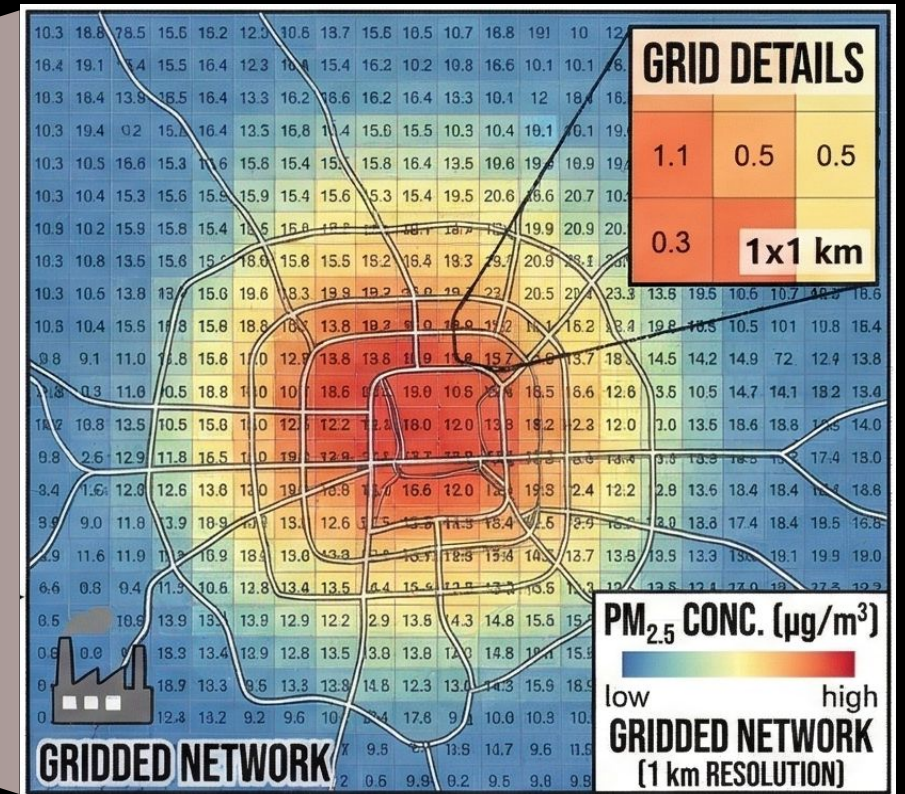


Golden Standard

Spatiotemporal Resolution ++

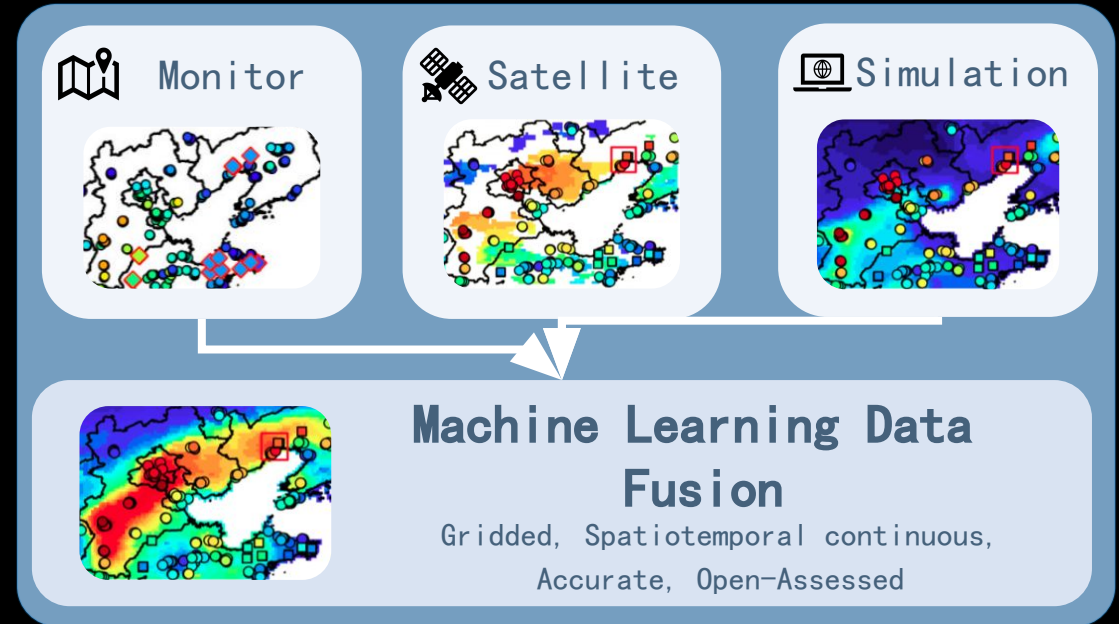
Spatiotemporal Resolution +

Spatial Resolution +++



Improve Resolution by Data Fusion

- A major challenge is that China's air quality monitoring network started since 2013 and has limited spatial coverage.
- As a result, station-based risk assessments are incomplete. According to the first risk assessment regarding the first stage Clean Air Action in China (Huang et al. in The Lancet Planetary Health), this site-based approach ignores about **59%** of the total population, underscoring the need to move beyond just ground-level data.
- By utilizing a machine learning method, we develop spatiotemporally continuous grid exposure data for $PM_{2.5}$ and O_3 . We can conduct assessments covering the whole population.



Products

Spatiotemporal continuous estimates of $PM_{2.5}$ concentrations in China, 2000–2016: A machine learning method with inputs from satellites, chemical transport model, and ground observations^{2*}

Tao Xue^{a,b}, Yixuan Zheng^b, Dan Tong^b, Bo Zheng^c, Xin Li^b, Tong Zhu^a, Qiang Zhang^{b,*}



ENVIRONMENTAL
Science & Technology

pubs.acs.org/est

Estimating Spatiotemporal Variation in Ambient Ozone Exposure during 2013–2017 Using a Data-Fusion Model

Tao Xue, Yixuan Zheng, Guannan Geng, Qingyang Xiao, Xia Meng, Meng Wang, Xin Li, Nana Wu, Qiang Zhang,* and Tong Zhu^a

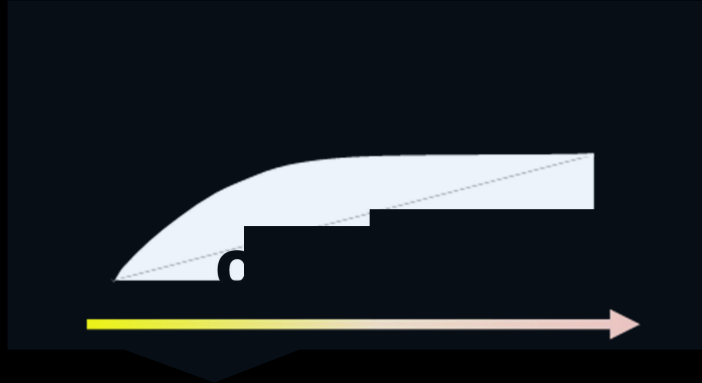
ENVIRONMENTAL
Science & Technology

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Tracking $PM_{2.5}$ and O_3 Pollution and the Related Health Burden in China 2013–2020

Qingyang Xiao, Guannan Geng,^a Tao Xue,^a Shigan Liu, Cilan Cai, Kebin He, and Qiang Zhang

Outline: Why High-Resolution?

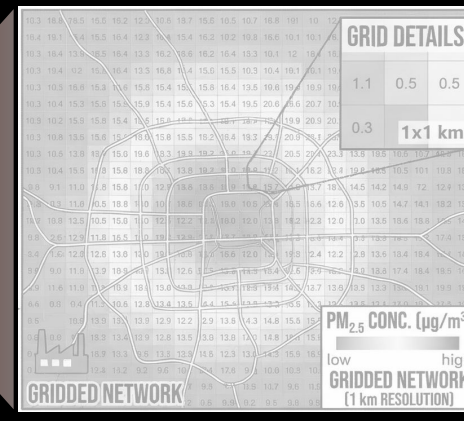
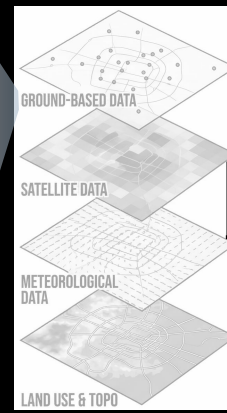
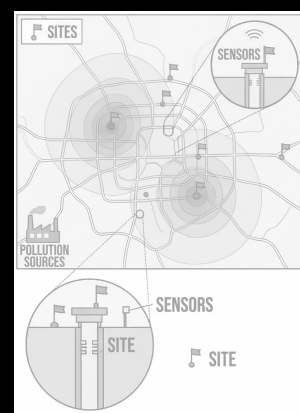


f exposure–response function

Exposure Assessment

Risk Characterization

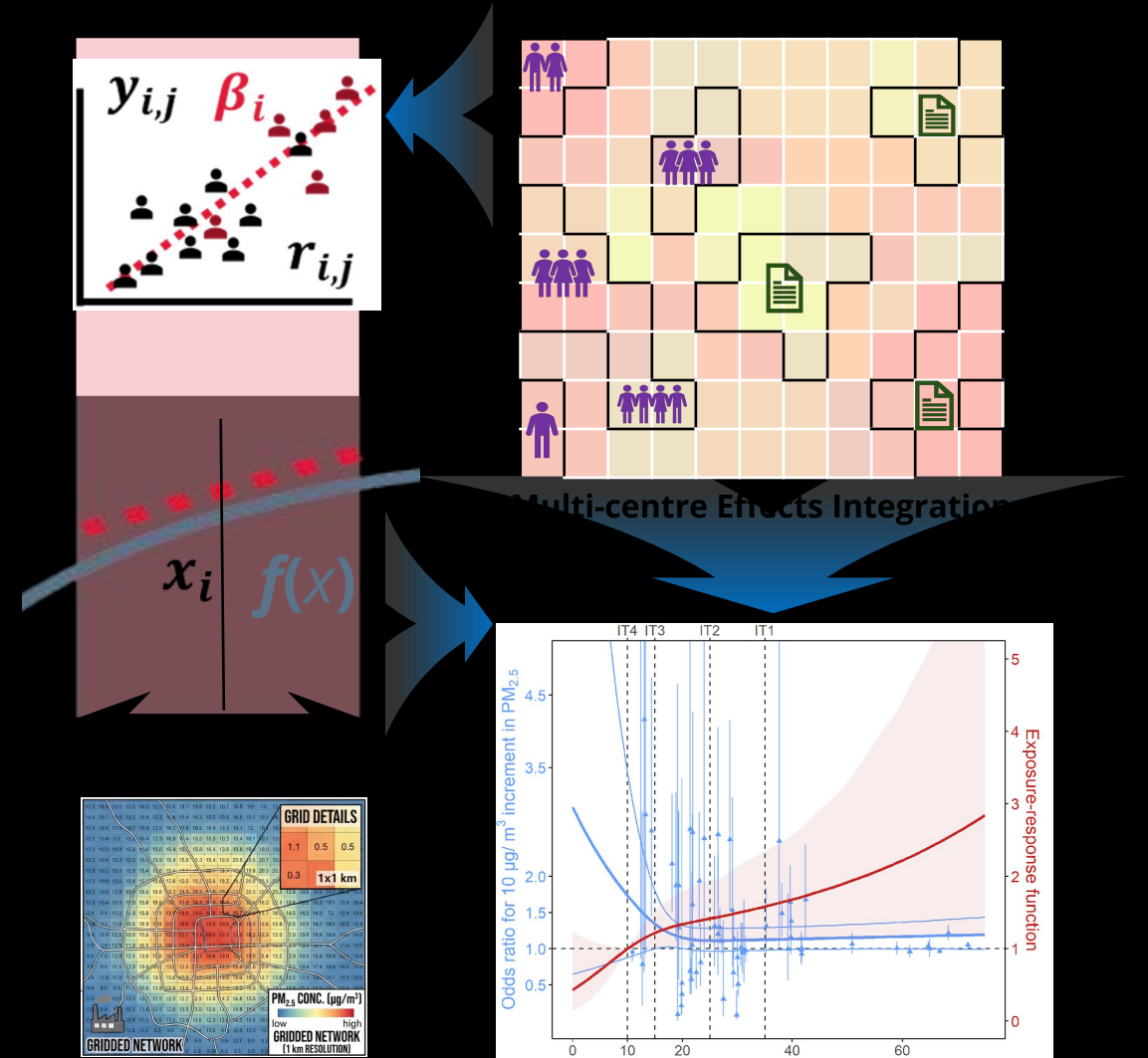
① How to Improve Exposure Resolution?



③ Why the High-Resolution Data is Important for Better Policy-Oriented Risk Characterization?

How to Get an Exposure-Response Function?

- To build a complete exposure-response function across all concentration levels, we integrated findings from multi-center studies.
- The challenge here is that each center only covers a partial concentration range.
- Because of this, our statistical power depends almost entirely on the exposure variation within each specific center.
- Consequently, if our spatial resolution is low, we lose that crucial local variation, which directly reduces our statistical efficiency.



High-Resolution Within-Center Exposure Variation Helps to Show Unbiased Health Effects

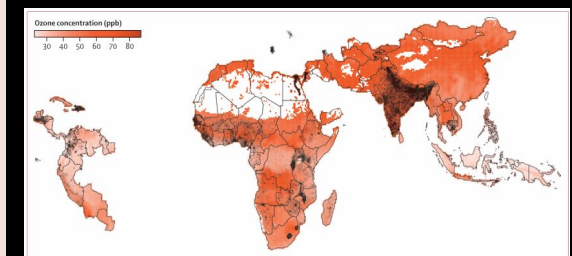
- Looking at the example, the raw data is misleading. It shows that dead cases had slightly lower ozone exposure than controls.
- This happens because directly comparing different regions introduces massive bias from unmeasured confounders.
- To find the true, unbiased health effect, we have to look strictly at the exposure variation within each individual center.
- The within-center variation accounts for only 7.7% of the total data variance. Because of that, having high-resolution spatial data is absolutely critical to capture these local differences and get accurate results.

Lancet Planet Health 2023;

	Overall	Survived and censored	Deceased	p value
All data				
N	1244409	1169949	74460	..
x_{ij}	51.68 (9.53)	51.69 (9.56)	51.49 (9.05)	<0.0001
x_i	51.68 (9.16)	51.69 (9.20)	51.43 (8.40)	<0.0001
r_{ij}	0 (2.65)	0.0041 (2.63)	0.0648 (3.03)	<0.0001

Estimating the exposure–response function between long-term ozone exposure and under-5 mortality in 55 low-income and middle-income countries: a retrospective, multicentre, epidemiological study

Tao Xue, Ruohan Wang, Mingkun Tong, Frank J Kelly, Hengyi Liu, Jijianghui Li, Pengfei Li, Xinghua Qiu, Jicheng Gong, Jing Shang, Tong Zhu



Outline: Why High-Resolution?



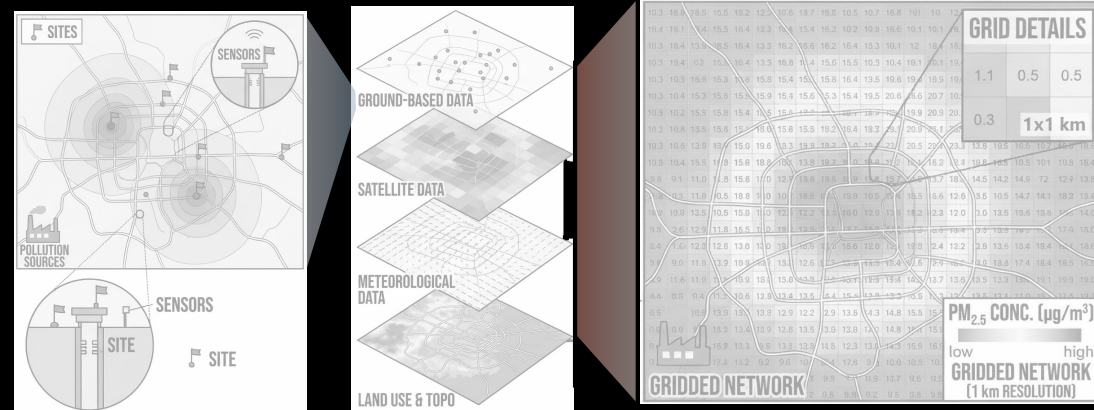
f exposure–response function

Exposure Assessment

Risk Characterization

① How to Improve Exposure Resolution?

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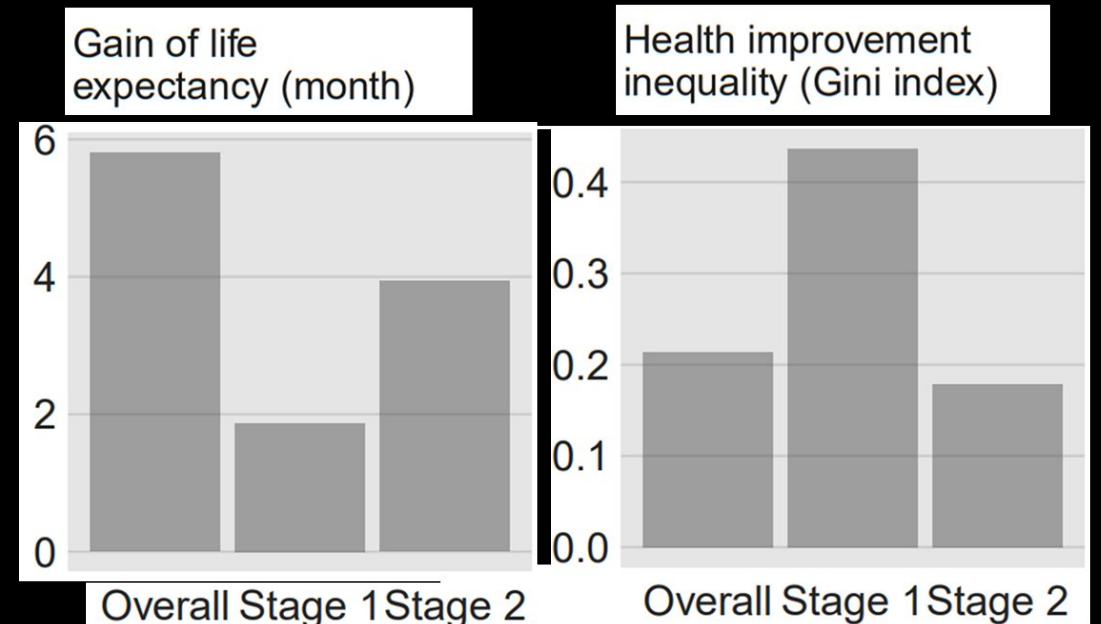
Two Dimensions of Clean Air Actions

- We must ask not only "how much health benefit was generated?" but "who received it?".
- We quantified the two dimensions of health impacts from clean air actions using two metrics: Gain of Life Expectancy (GLE) and the Gini index to measure geographic inequality.
- During the first stage, from 2013 to 2017, the mean GLE was 1.87 months. However, this benefit was highly unequal, with a Gini index of 0.44. Half of all health benefits were concentrated in just 25% of the population.
- The second stage, from 2017 to 2020, tells a very different story. The mean GLE more than doubled to 3.94 months, and the geographic inequality reduced to a Gini index of 0.18.



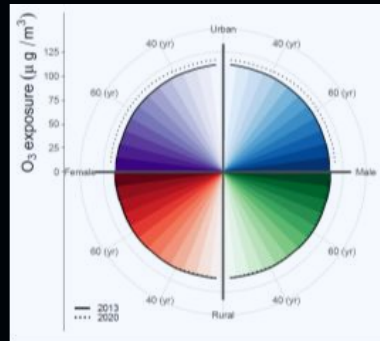
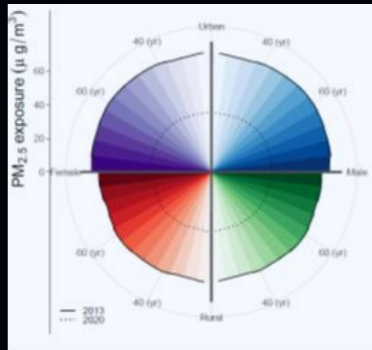
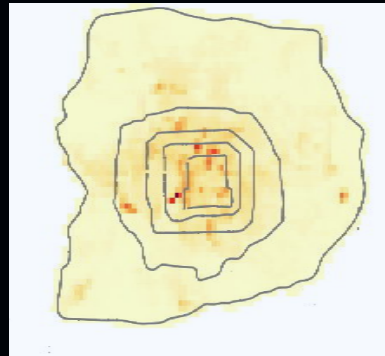
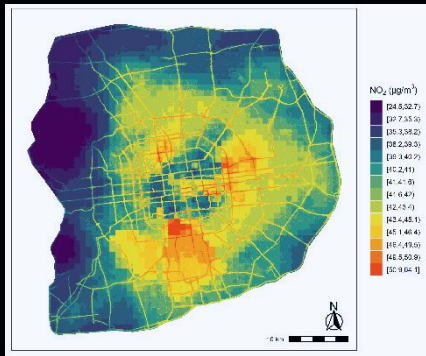
Health benefits from the rapid reduction in ambient exposure to air pollutants after China's clean air actions: progress in efficacy and geographic equality

Tao Xue^{1,2,3,*†}, Ruohan Wang^{1,†}, Meng Wang^{4,†}, Yanying Wang⁵, Dan Tong⁶, Xia Meng⁷, Conghong Huang^{8,9}, Siqi Ai^{5,2}, Fangzhou Li^{5,2}, Jingyuan Cao^{5,2}, Mingkun Tong^{1b}, Xueqiu Ni¹, Hengyi Liu¹, Jianyu Deng¹, Hong Lu¹, Wei Wan¹⁰, Jicheng Gong^{5,2}, Shiqiu Zhang^{5,2} and Tong Zhu^{1b,5,2,*}

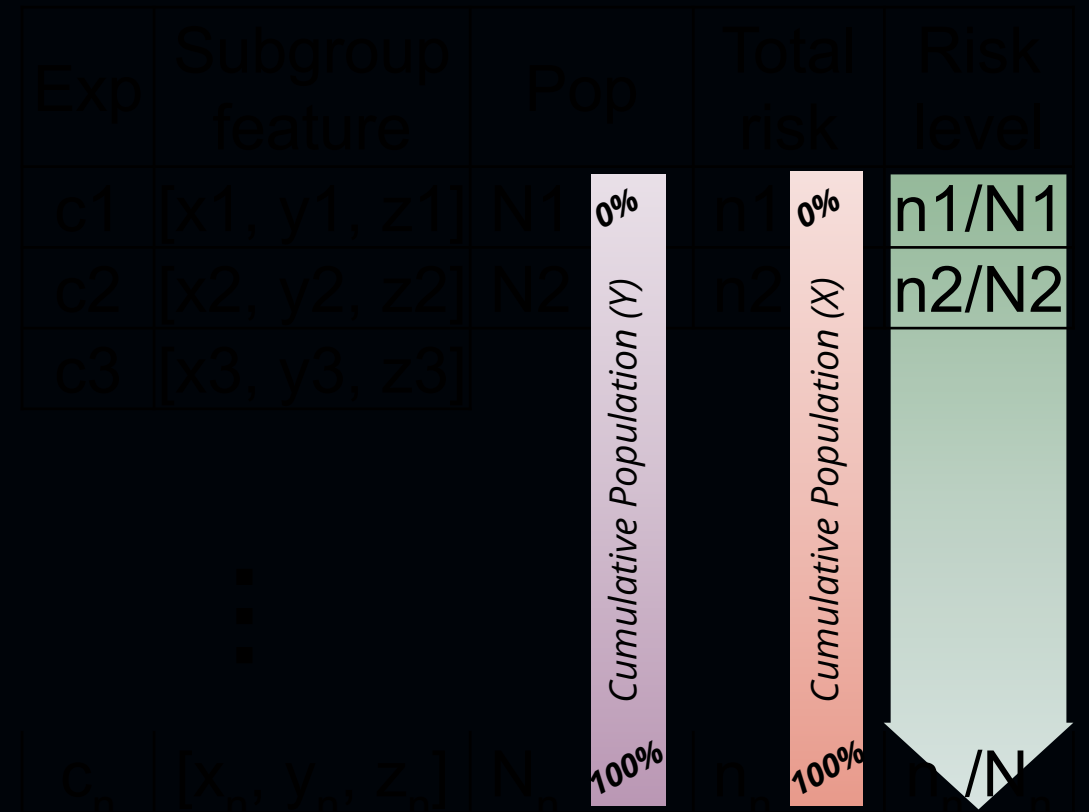


Method: From High-Resolution Risk Assessment to Environmental Inequality (Gini Index)

Inputs by Grid & Subgroups

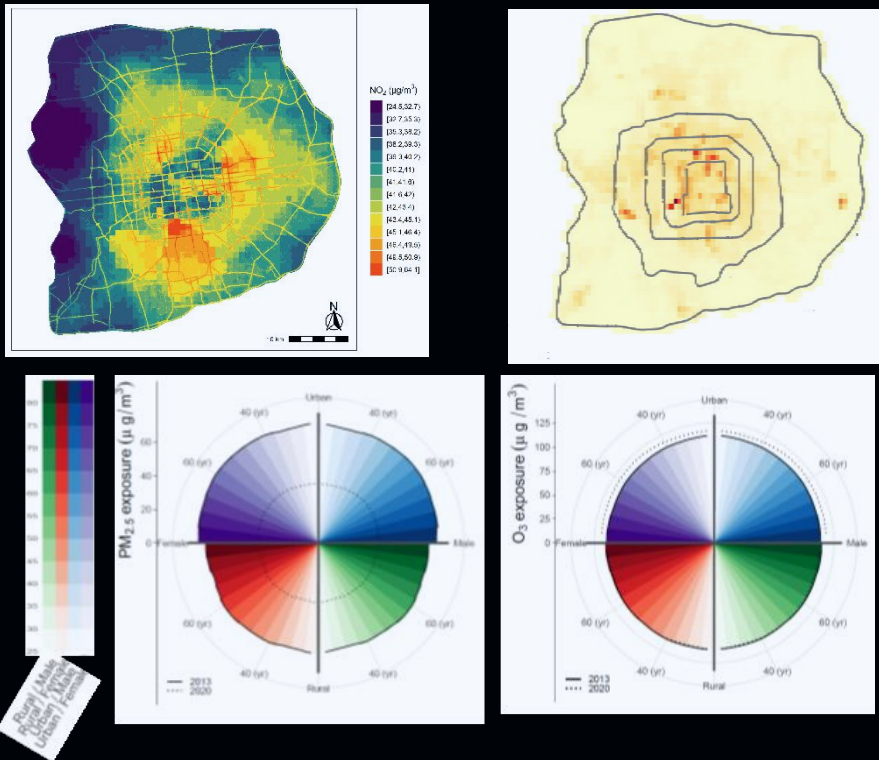


- ① Group of equal risk,
- ② Rank by risk,
- ③ Calculate cumulative probabilities for x/y

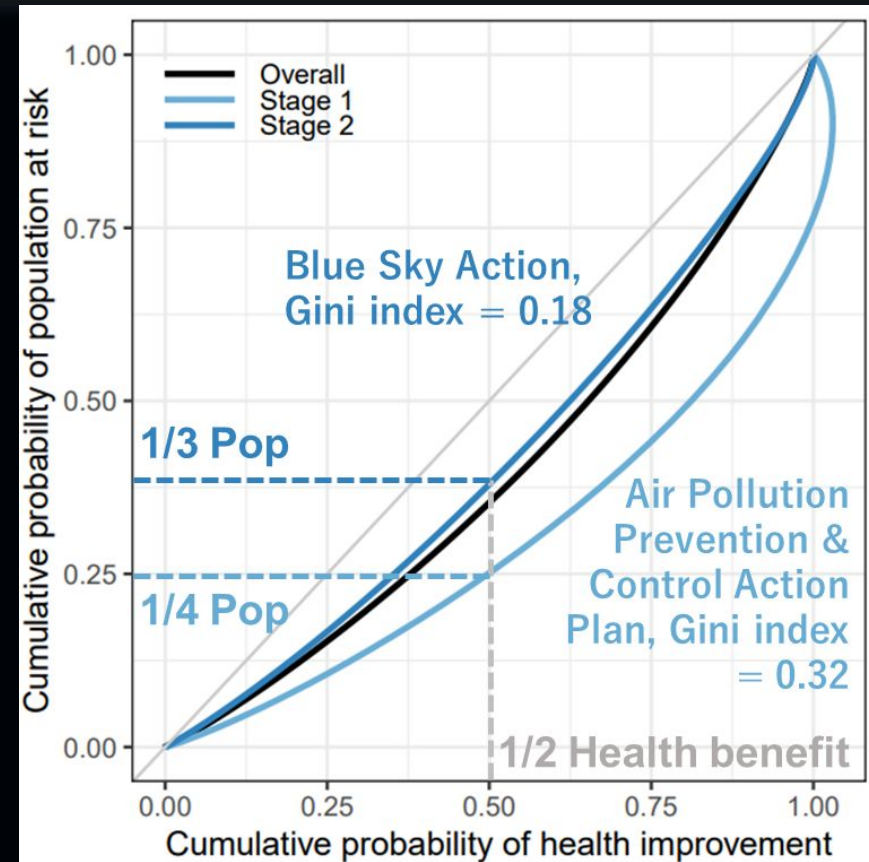


Method: From High-Resolution Risk Assessment to Environmental Inequality (Gini Index)

Inputs by Grid & Subgroups



Lorenz Curve to Measure Inequality



Take-home Messages

- (AI-based) **Data Fusion Models** can help to improve the resolution of data to track air pollution exposure and risk;
- High-resolution Exposure is needed to accurately display **Within-Center Variation** (e.g., city or region) in air pollution exposure, which is critical to develop an exposure-response function;
- High-resolution Exposure and other inputs (e.g., population structure) is necessary to measure **environmental inequality**.

Selected Publications

- Kang, N., Wang, R., Li, P., Xue, T., Liu, J., Wan, W., Gong, J., Zhang, S. and Zhu, T., 2025. Beyond the halving commitment: China can do more to achieve clean air for global health. *The Innovation*, 6(10).
- Xue, T., Zheng, Y., Geng, G., Xiao, Q., Meng, X., Wang, M., Li, X., Wu, N., Zhang, Q. and Zhu, T., 2020. Estimating spatiotemporal variation in ambient ozone exposure during 2013–2017 using a data-fusion model. *Environmental science & technology*, 54(23), pp.14877-14888.
- Xue, T., Wang, R., Tong, M., Kelly, F.J., Liu, H., Li, J., Li, P., Qiu, X., Gong, J., Shang, J. and Zhu, T., 2023. Estimating the exposure–response function between long-term ozone exposure and under-5 mortality in 55 low-income and middle-income countries: a retrospective, multicentre, epidemiological study. *The Lancet Planetary Health*, 7(9), pp.e736-e746.
- Xue, T., Wang, R., Wang, M., Wang, Y., Tong, D., Meng, X., Huang, C., Ai, S., Li, F., Cao, J. and Tong, M., 2024. Health benefits from the rapid reduction in ambient exposure to air pollutants after China's clean air actions: progress in efficacy and geographic equality. *National Science Review*, 11(2), p.nwad263.

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Thank you for attentions

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For any questions, please reach out to
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