How to Build a Scientific Base for Clean Air Policy in China: Program on the Causes and Mechanisms to Address PR China's Air Pollution Complex

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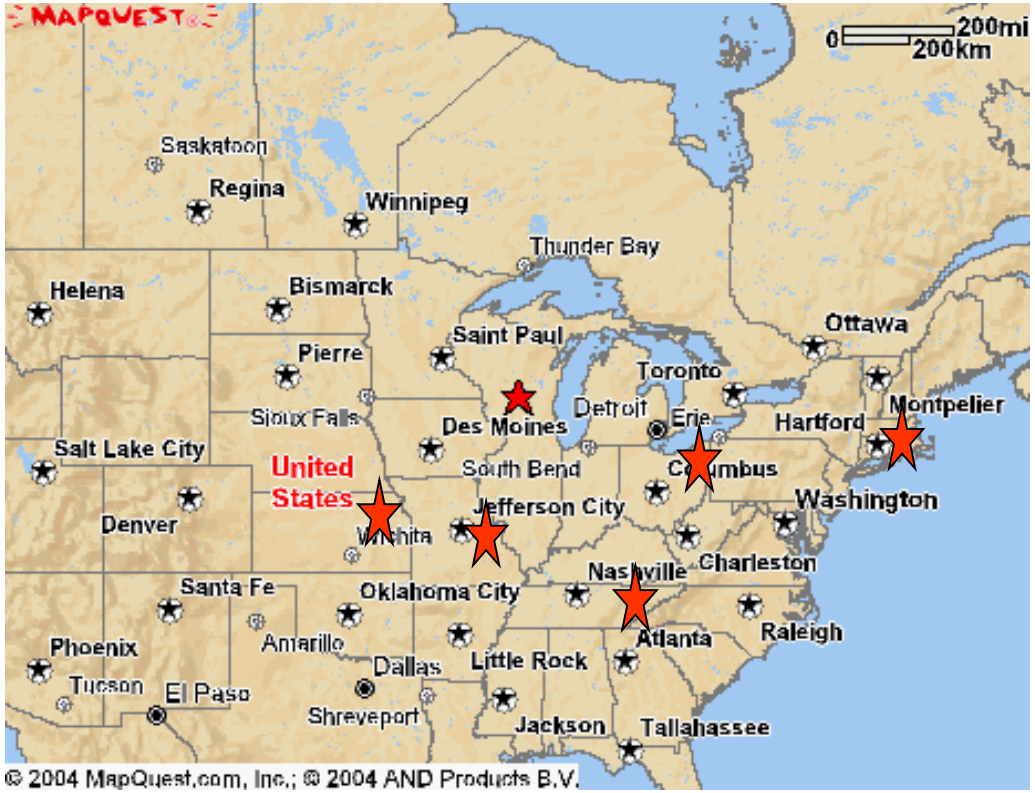
Six cities study by Harvard University: the evidence that fine particles ($PM_{2.5}$) associated with mortality

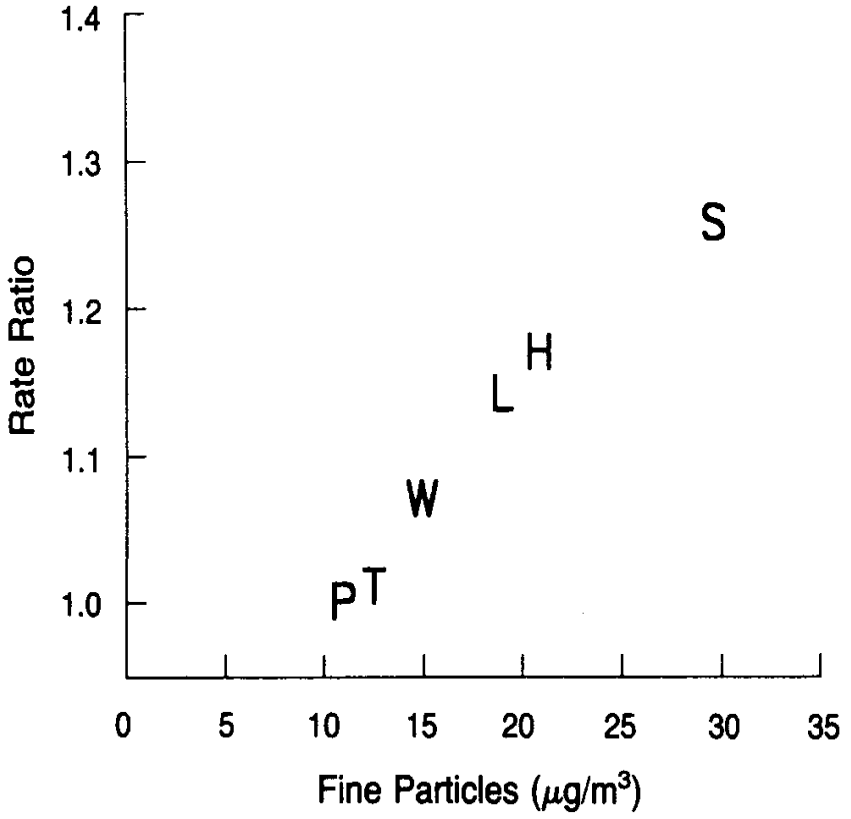
An Association between Air Pollution and Mortality in Six U.S. Cities

The NEW ENGLAND JOURNAL of MEDICINE
1993; 329: 1753-1759

Douglas W. Dockery,
C. Arden Pope,
Xiping Xu,
John D. Spengler,
James H. Ware,
Martha E. Fay,
Benjamin G. Ferris,
Frank E. Speizer



Exposure-response relationship



World Health Organization (WHO) released Global Air Quality Guidelines (AQG) in 2005

In 1958, air pollution for the first time appeared in WHO report
Technical Report Series, No. 157

Health effects of SO_2, photochemical pollution

1987, 1st AQG (Europe)

Set long term and short term AQG for SO_2 and PM

2005, Renewed AQG (Global)

Includes PM, O_3, NO_2, SO_2
IT-1, IT-2, IT-3

Pre-AQGs | **European AQG period** | **Global AQG period**

Criteria、Guides first appeared in WHO 1972, Nr. 506 report
Technical Reports 271 and 506，(Barker et al., 1961; Katz, 1969; Lawther, Martin & Wilkins, 1962; WHO, 1963a; 1963b; 1968; 1970).

Long term goals for S compounds, TSP, CO, photochemical pollutants

2000, 2nd AQG (Europe)

Indoor air separately listed

Table 1. Air quality guideline and interim targets for particulate matter: annual mean

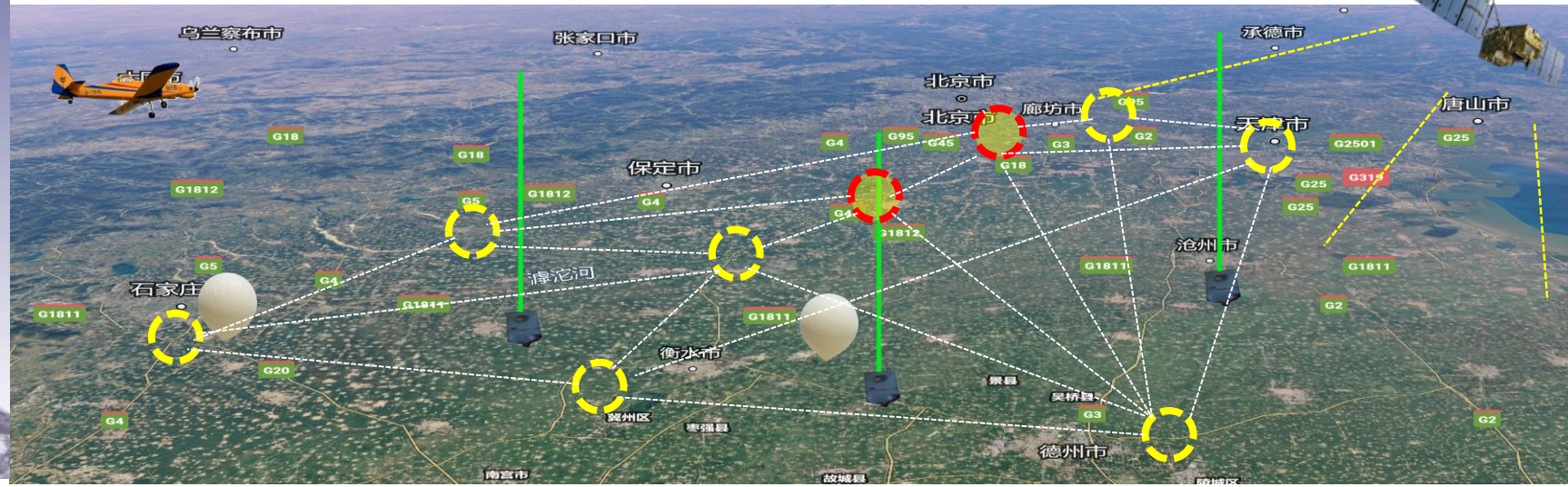
Annual mean level	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	Basis for the selected level
WHO interim target-1 (IT-1)	70	35	These levels are estimated to be associated with about 15% higher long-term mortality than at AQG
WHO interim target-2 (IT-2)	50	25	In addition to other health benefits, these levels lower risk of premature mortality by approximately 6% [2-11%] compared to WHO-IT1
WHO interim target-3 (IT-3)	30	15	In addition to other health benefits, these levels reduce mortality risk by another approximately 6% [2-11%] compared to WHO-IT2 levels.
WHO Air quality guidelines (AQG)	**20**	**10**	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to $PM_{2.5}$ in the ACS study (Pope et al., 2002). The use of $PM_{2.5}$ guideline is preferred.

Successful Story: scientific research to support Air Quality Protection for the 2008 Beijing Olympics Games

CAREBeijing (Campaigns of Air Quality Research in Beijing and Surrounding Region) 2006-2007-2008

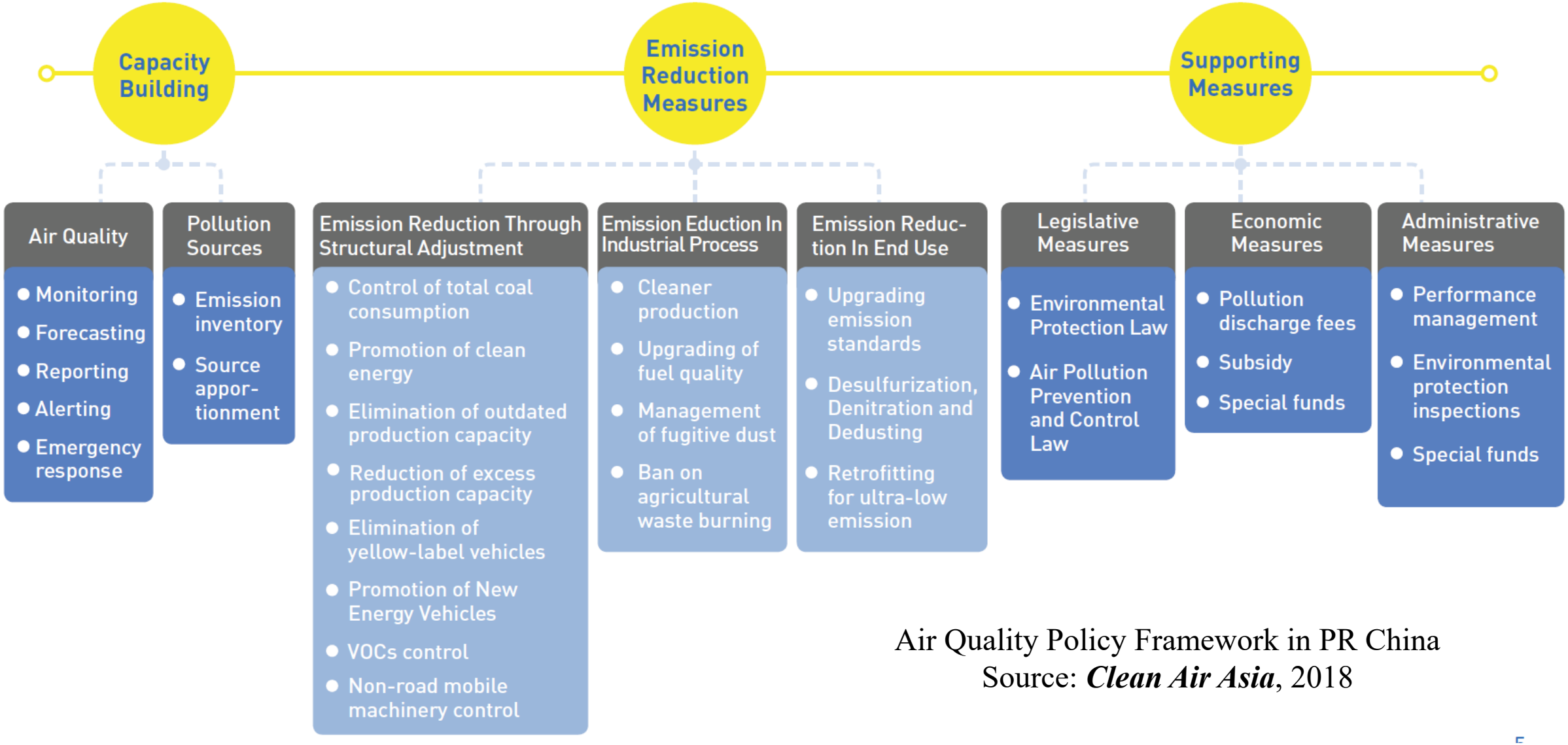
> 200 participants, ~20 research institutes, 3 special issues

1. Evaluate emission inventory;
2. Regional transport and chemical transformation processes;
3. Integrated regional air quality management;
4. Policy suggestion for air quality attainment during 2008 Beijing Olympic game and beyond.



PR China Introduced $PM_{2.5}$ NAAQS in 2012, = WHO-IT1

National Action Plan on Air Pollution Prevention and Control 2013-2017



Air Quality Policy Framework in PR China
Source: ***Clean Air Asia***, 2018

The Challenges of Air Pollution Researches in PR China:

Air Pollution Complex –Prof. Xiaoyan Tang，1997

population growth

energy consumption increase

coal combustion

motor vehicles

air pollution complex

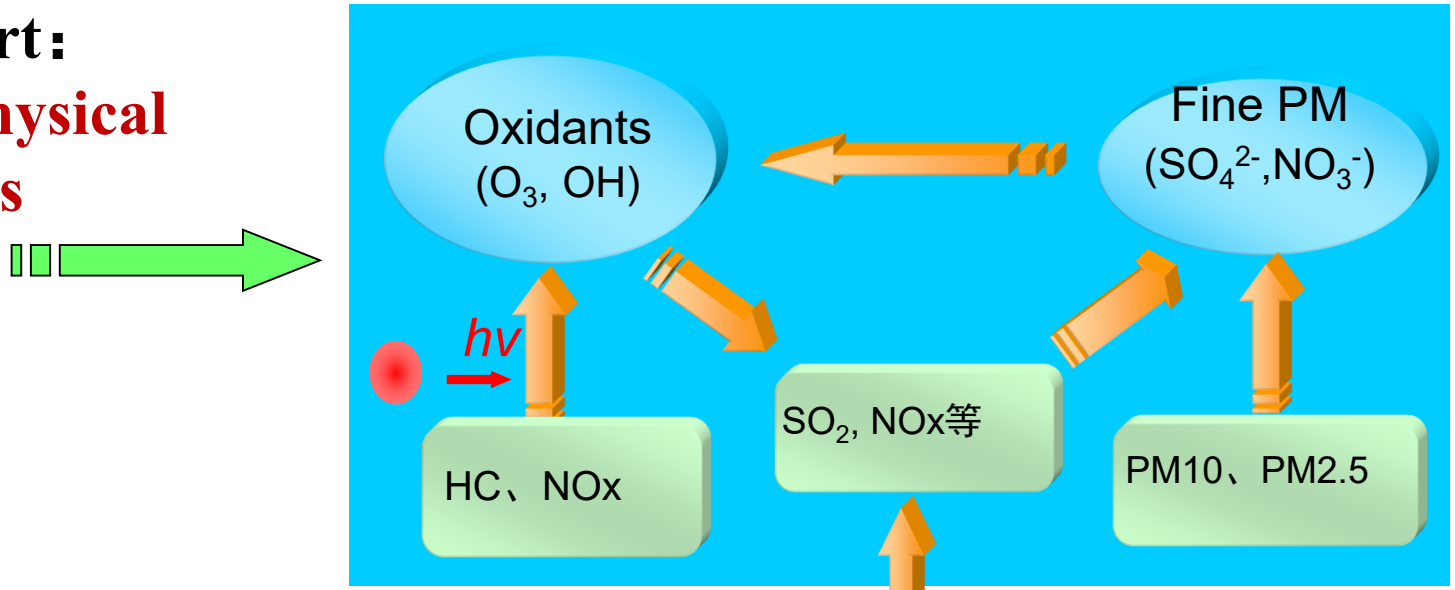
Beijing: 2000-

Air Pollution Complex Conceptual Framework

Air pollutants: where do they come from, how are they formed, accumulated, and what are their impacts?

Chemical Transformation: Multi Scales/Phases

Transport:
Multi-Physical Processes



Higher fine PM, O_3

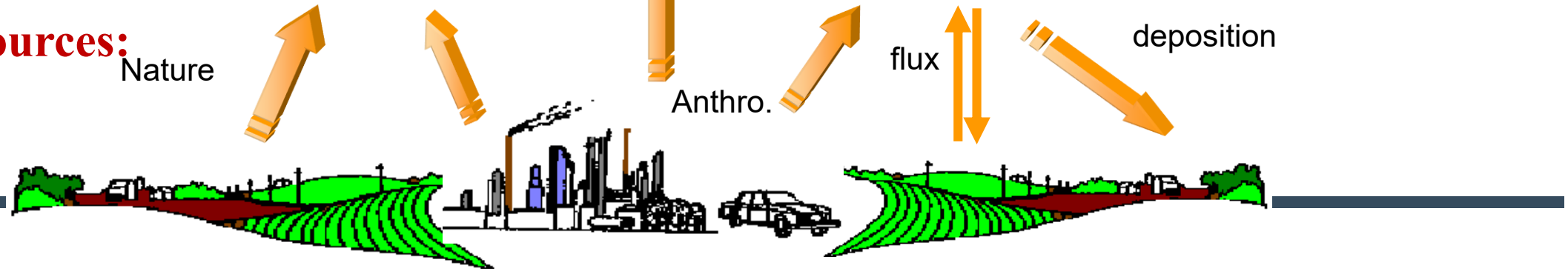
Multi-Impacts:

Health

Ecosystem

Climate

Multi-Sources:



Major Research Projects on Air Pollution Funded by PR China's Government in the last 10 years

National Natural Science Foundation Committee

- Joint Major Program: "The formation processes, health impacts, and response mechanism of **air pollution complex** in PR China", 400 million RMB, 2015-2020/2022

Ministry of Science and Technology

- Key Research Development Plan: "Air Pollution Formation Mechanisms and Control Technology", 2.5 billion RMB, 2015-2020

Founding of the Prime Minister of PR China

- Formation Mechanisms and Controlling Policy of Heavy Air Pollution in Beijing, Tianjin, Hebei", ~800 million RMB, 2017.9-2019.9

Fundamental Researches on the Formation and Response Mechanism of the Air Pollution Complex in PR China

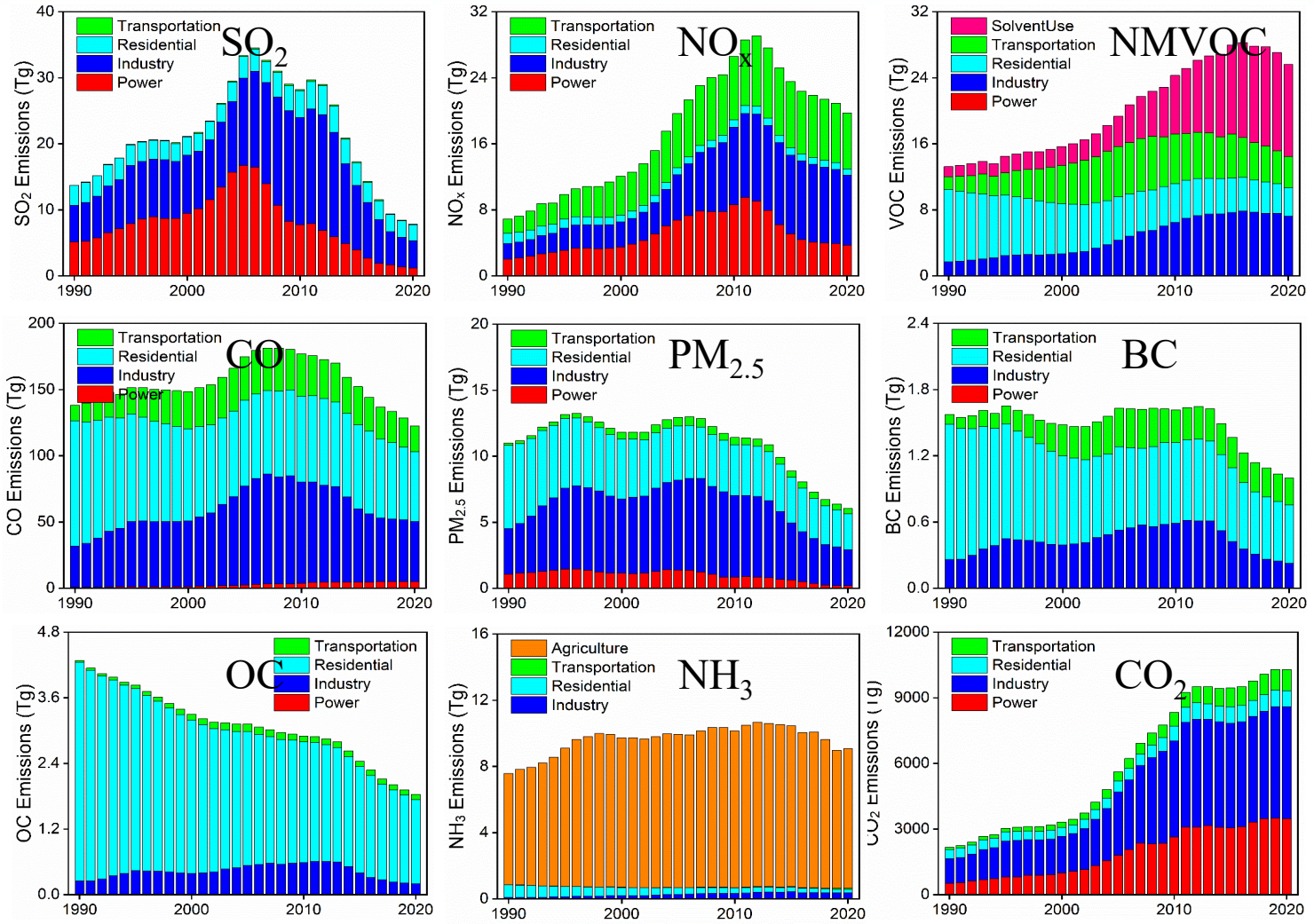
Objectives：

1. to elucidate the **chemical and physical processes** critical to the formation of air pollution complexes, to reveal the formation mechanisms of air pollution complexes, and to construct an **air pollution complex theoretical framework**;
2. to develop new theories and methodologies for the surveillance, source appointment and decision-making analysis of air pollution complexes, and to propose **innovative ideas for controlling air pollution complexes in PR China**.

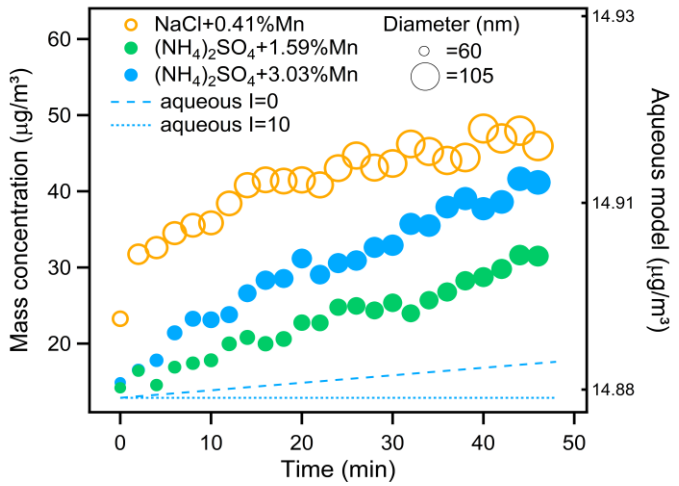
Time：2016-2023; Founding：240 million RMB

76 projects, 30 universities/institutes, >700 researches

Major Achievements 1: developed the most comprehensive emission inventory in PR China, with high resolution (3km)



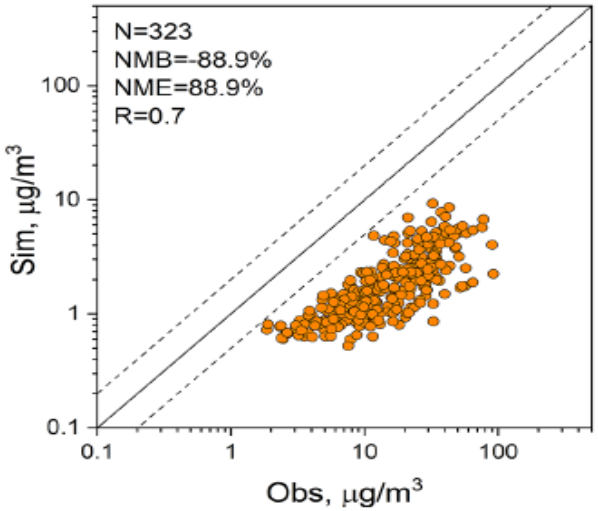
Major Achievements 2: comprehensively elucidated chemical processes, from radical reactions to new particle formation and heterogeneous reactions

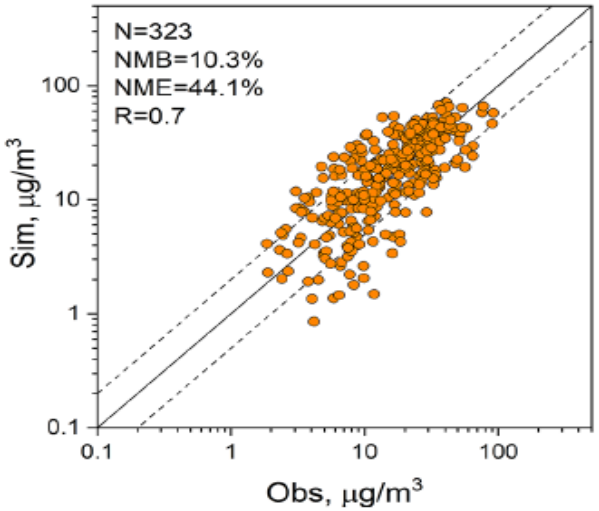


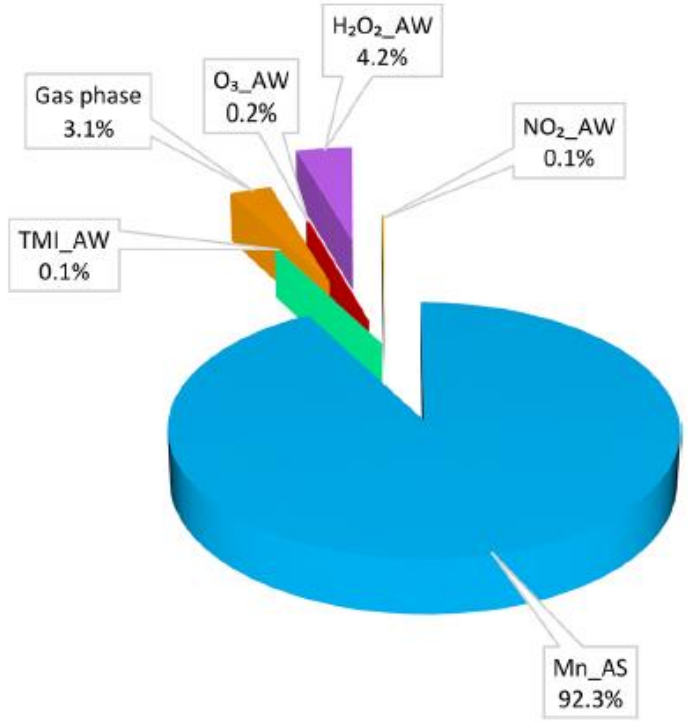
Fund new mechanism to explain fast sulfate formation during winter haze period

Mn^{2+} catalytic oxidation of SO_2 on surface **92%**

1. Chamber Study
2. Field measurements
3. WRF-Chem model simulation

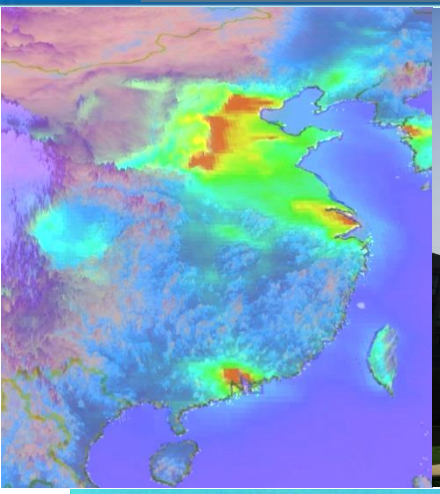


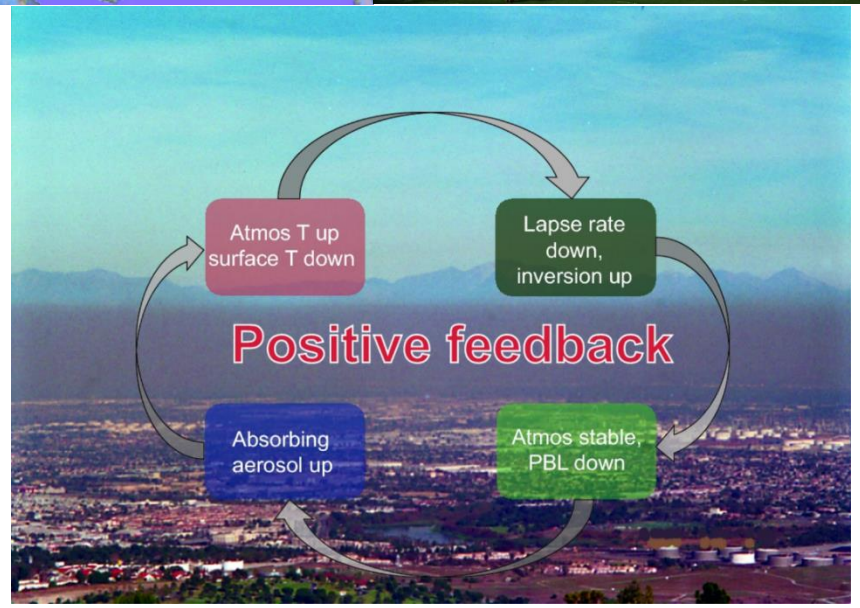


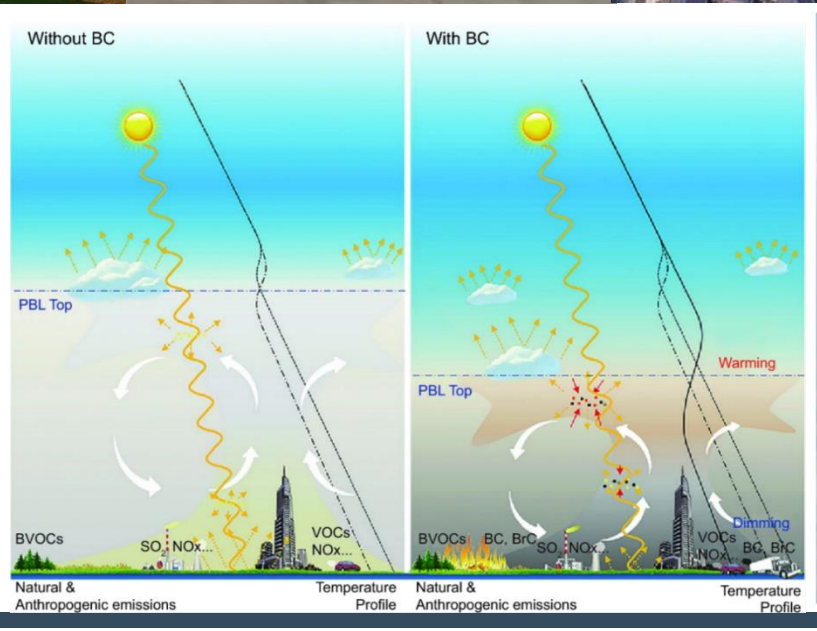


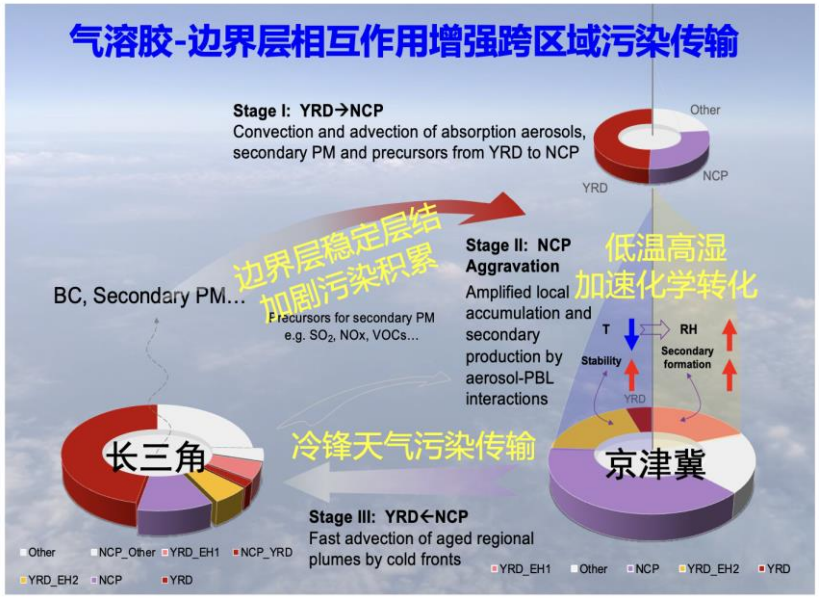
Wang et al., Nature Communications, 2021

Major Achievements 2: revealed interactions between air pollution and multi-scale physical processes: aerosol-cloud-radiation, boundary, weather, climate









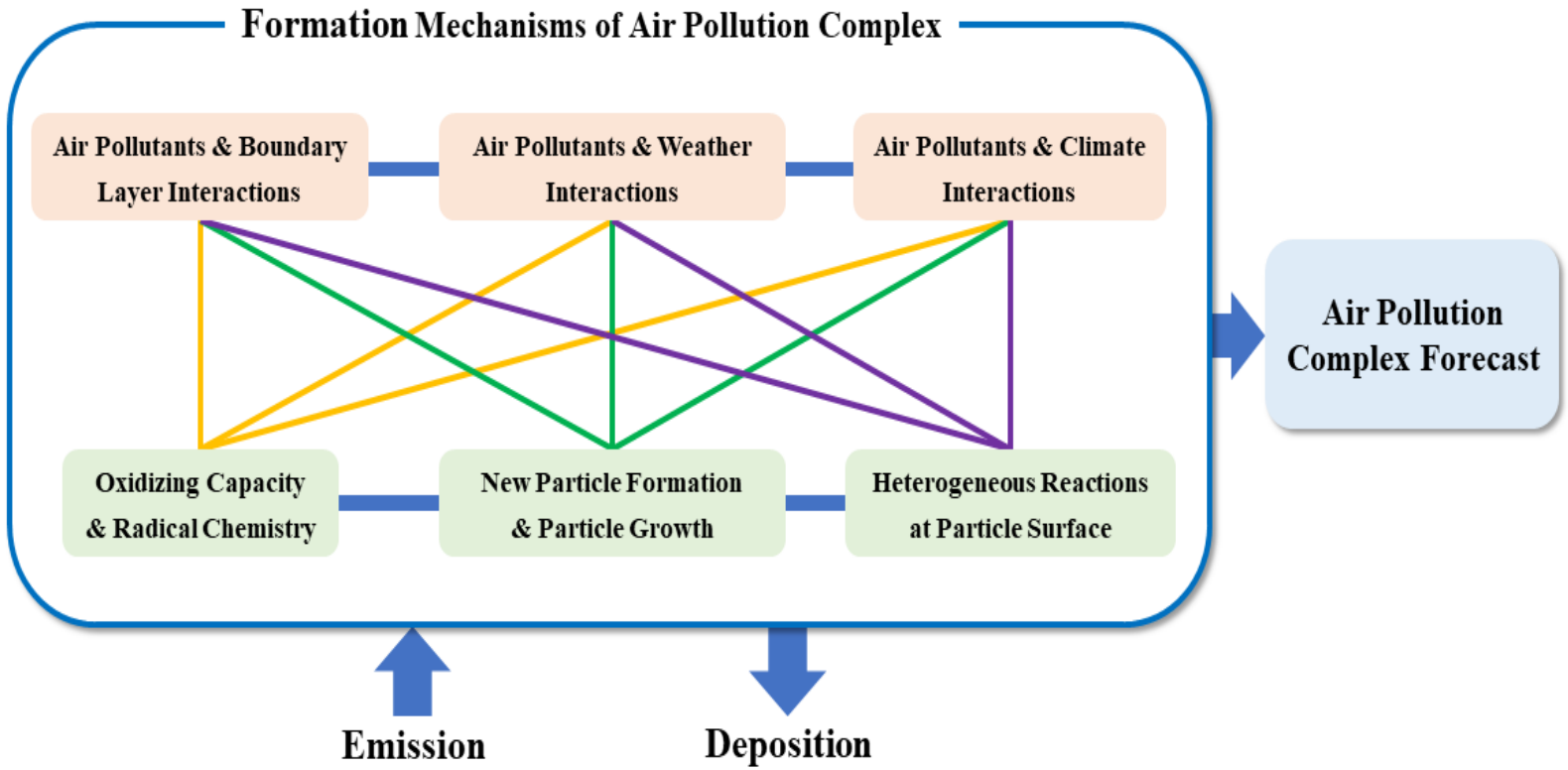
Li et al., Natl Sci Rev. 2017

Ding et al., GRL, 2016

Major Achievements 2: established a theoretical framework of air pollution complex

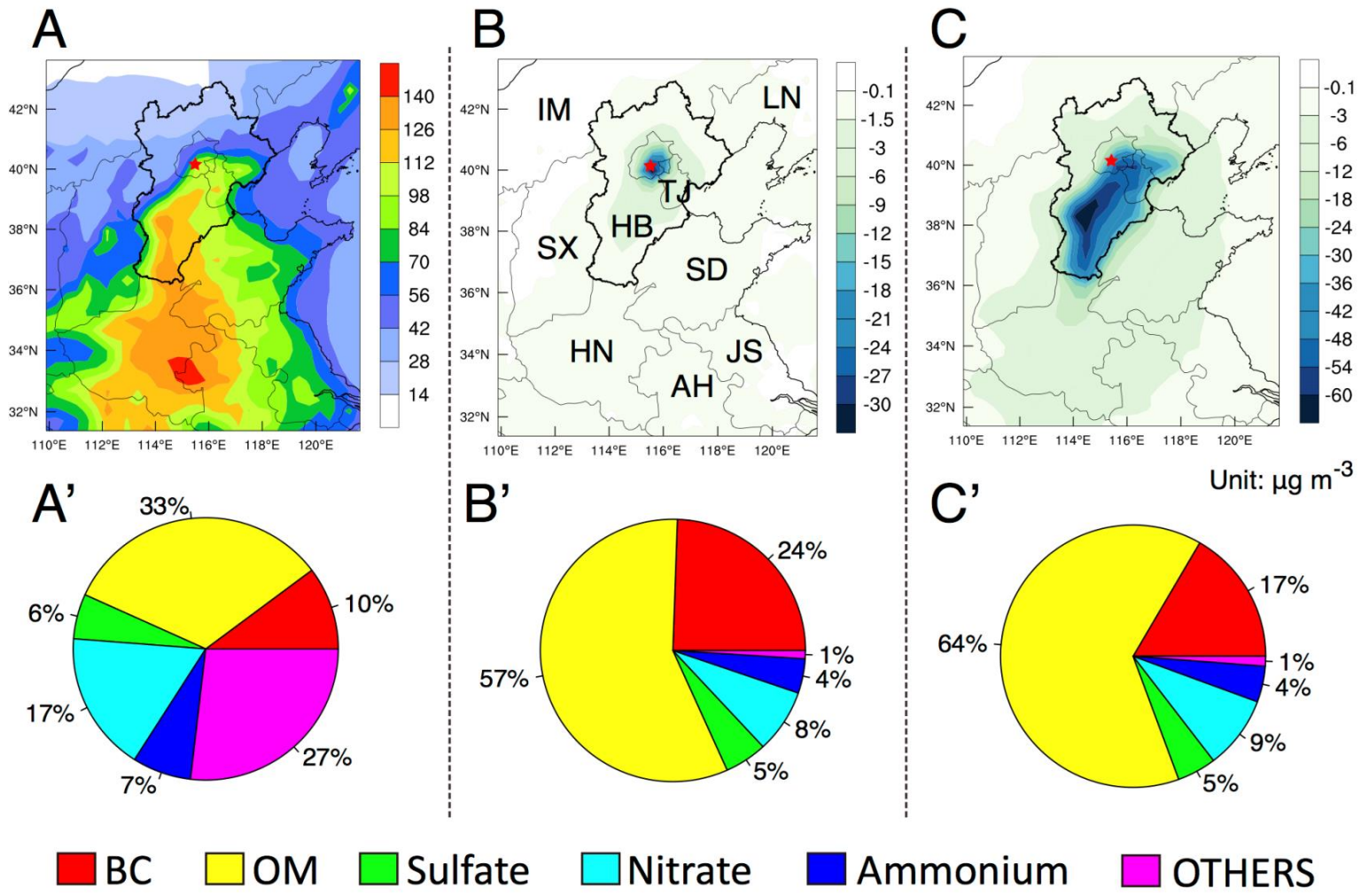
$$\rho(t) = f\{E(t, P), P(t, \rho, C), C(t, E, \rho, P)\}$$

E: emission P: physical C: chemical



Zhu et al., ***AAS,*** 2023

Major Achievements 3: identified households solid fuel is a major air pollution source — policy for coal use control in rural area

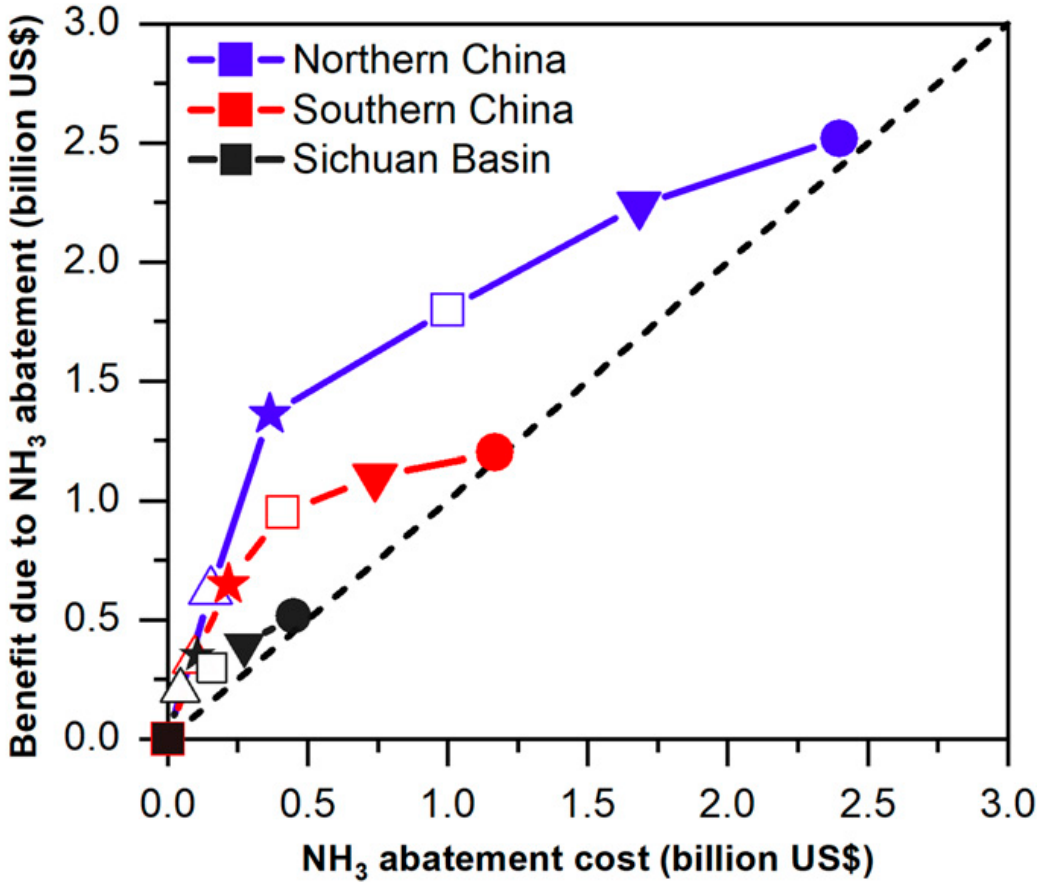


1. In winter, household emission from Beijing contributes up to 20% $PM_{2.5}$ in Beijing,
2. While those from Beijing, Tianjin, and Hebei (BTH) in total contributes up to 40% $PM_{2.5}$ in Beijing.

Controlling action on coal use in rural area in BTH.

Liu et al., ***PNAS***, 2016

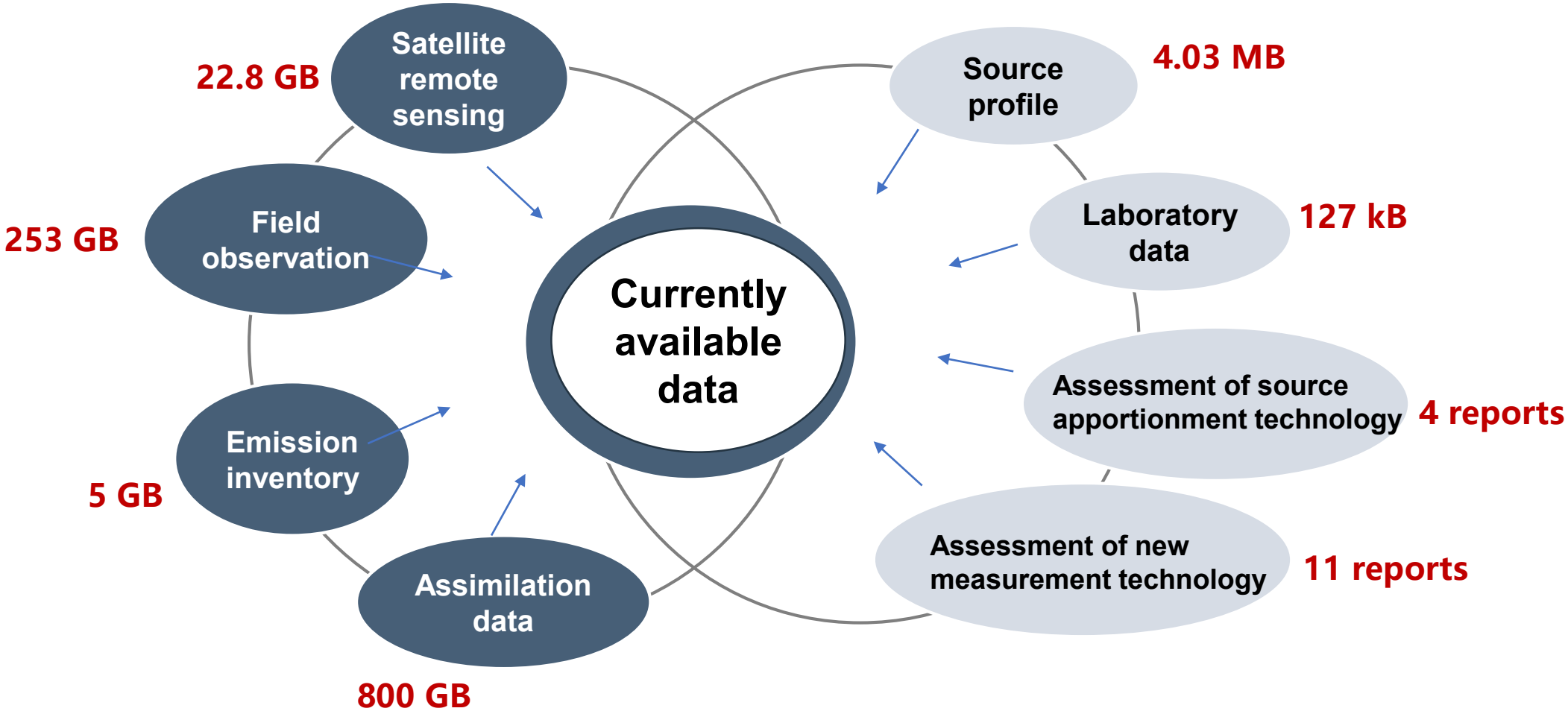
Major Achievements 3: ammonia emission control would mitigate haze pollution, but worsening acid rain! Regional based integrated policy



NH_3 emission reductions of 0 (■), 10% (Δ), 20% (★), 30% (□), 40% (▼), and 50% (●)

Liu et al., ***PNAS***, 2019

> 1 TB of data/knowledge for download will be available by the end of 2023

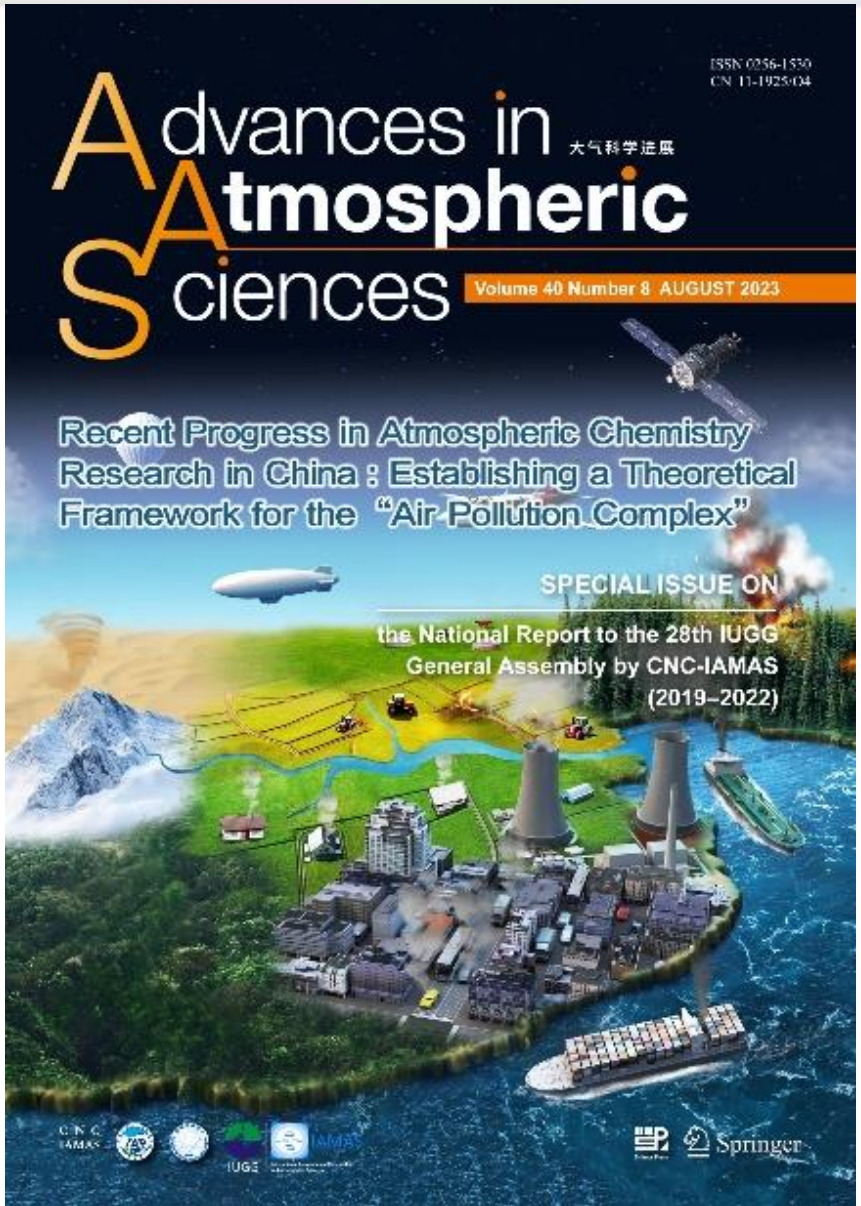


More Major Achievements

- Multi-resolution **emission inventory** for PR China and applications in policy
  Qiang Zhang, Department of Earth System Science, Tsinghua University
- Atmospheric chemical processes: **monitoring, modeling and data assimilation**
  Zifa Wang, Professor/Director, Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry, Institute of Atmospheric Physics, Chinese Academy of Sciences
- **Interactions of air pollution with meteorology, weather and climate in Asia**
  Aijun Ding/ Wei Nie, Professor, School of Atmospheric Sciences, Nanjing University

Asian countries have the most mortality associated with air pollution

Science-Based Policy Making and Action for Clean Air: Asia Experience Sharing and Exchange!



Thank you!

Zhu et al., Recent progress in atmospheric chemistry research in China: Establishing a theoretical framework for the "air pollution complex", ***Adv. Atmos. Sci.,*** 2023

https://doi.org/10.1007/s00376-023-2379-0