Global Burden of Disease – Major Air Pollution Sources (GBD – MAPS)

中国燃煤和其他主要大气污染源所致的疾病负担

Disease Burden from Coal Combustion and Other Major Sources in China

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Tsinghua University | IHME | University of Washington | Health Effects Institute | UBC a place of mind The University of British Columbia | Institute for Health Metrics and Evaluation

Background: All causes attributable to ambient PM pollution in 2013, DALYs per 100,000

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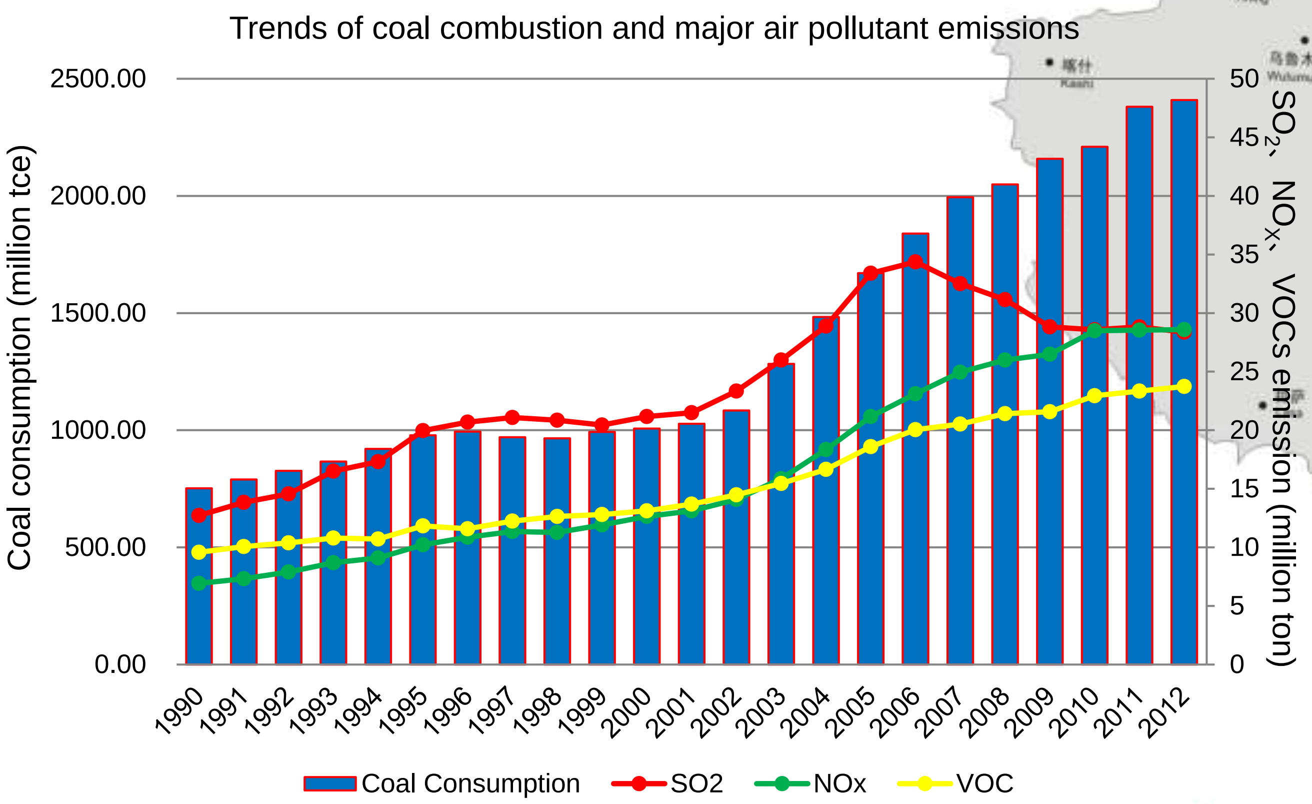
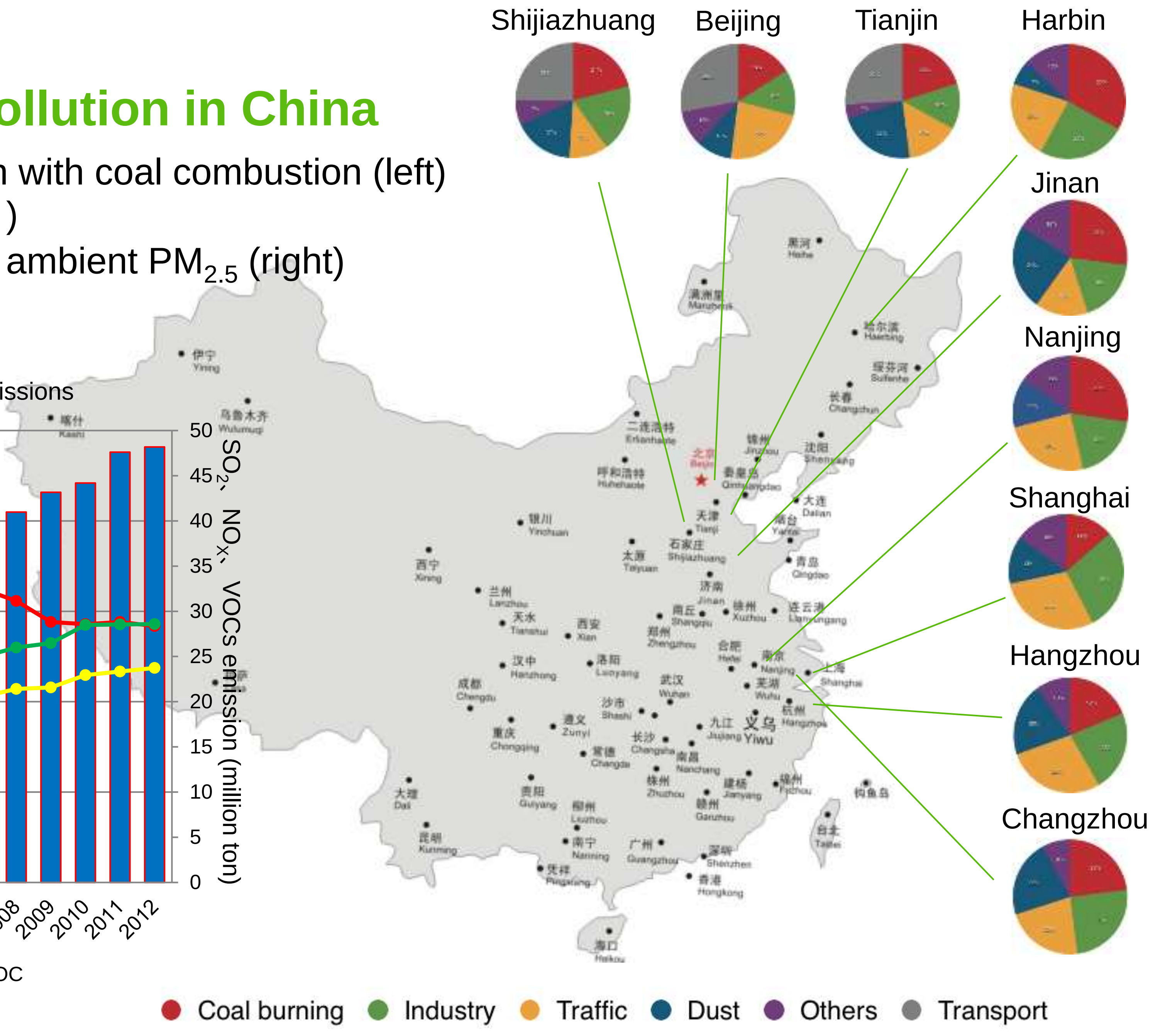
燃煤是空气污染的一个重要来源

Coal - A major source of air pollution in China

- Air pollutant emission has a close relation with coal combustion (left)
  主要大气污染物和煤炭消费关系密切（左）
- Coal combustion is a dominant source of ambient $PM_{2.5}$ (right)
  燃煤是大气PM2.5的一个主要来源（右）





GBD-MAPS总体研究方法 General methodology

f_{coal}

- 用大气化学模型计算燃煤及其他主要大气污染源对大气 $PM_{2.5}$的贡献比例
- Calculate fraction of ambient $PM_{2.5}$ attributable to each source using atmospheric model

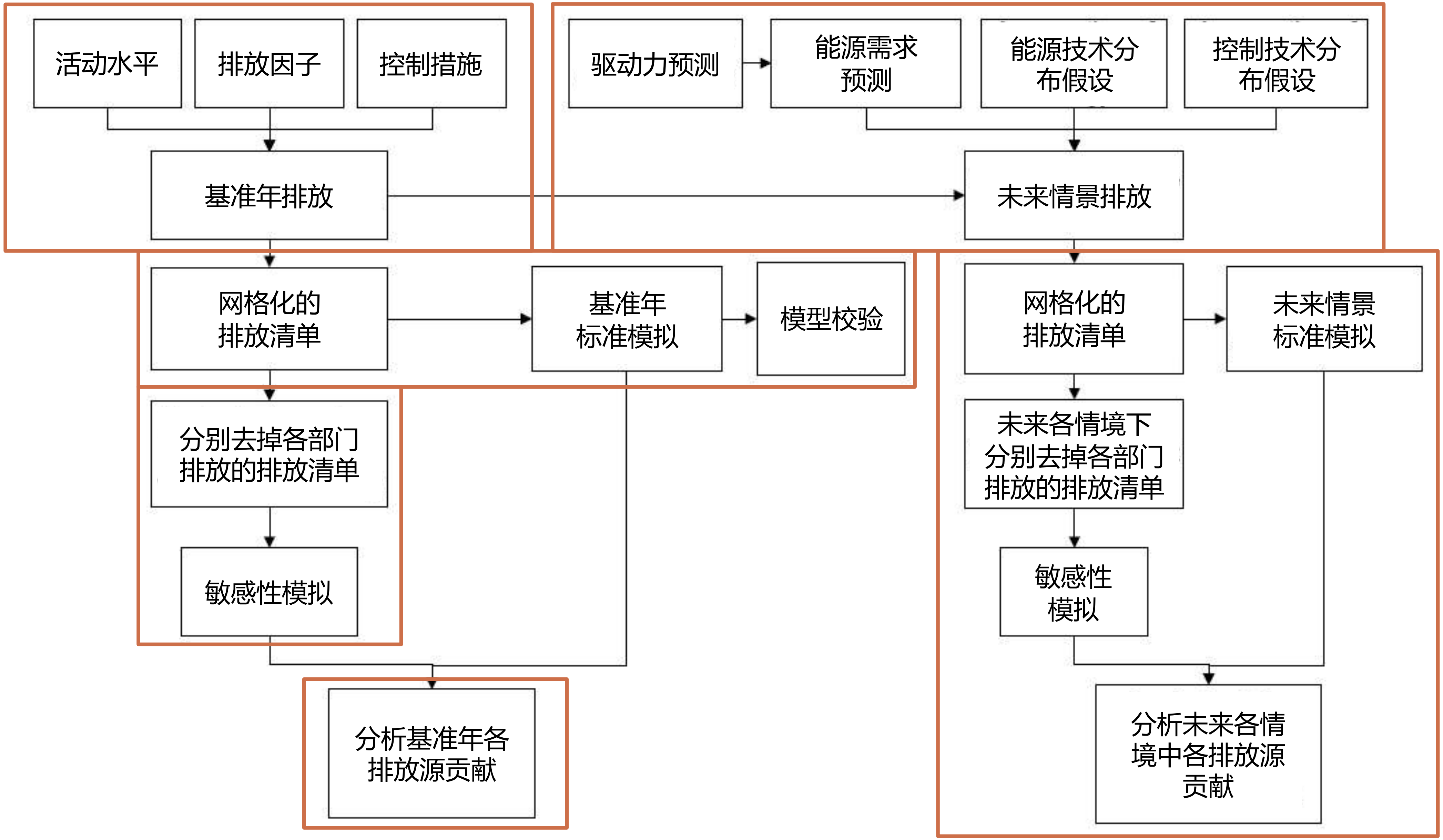
$PM_{2.5\ coal}$

- f_{coal} x 大气$PM_{2.5}$浓度→ 来自各排放源的大气$PM_{2.5}$浓度
- f_{coal} x ambient $PM_{2.5}$ → ambient $PM_{2.5}$ attributable to each source

Disease Burden

- 利用集成暴露响应曲线（IER）和来自各排放源的大气$PM_{2.5}$浓度→ 各排放源所致的疾病负担
- Use integrated exposure response functions and cause-specific mortality estimates in combination with **$PM_{2.5\ coal}$** → source contribution to disease burden

1. 计算各污染源贡献比例 f_{coal} Estimating f_{coal}



基准年排放 Emissions in base year

污染物
Specious:

SO_2

NO_X

PM

VOCs

部门**Sectors:**

电厂
Powerplant combustion
工业燃烧
Industry combustion
工业过程
Industry process
民用化石燃烧
Domestic fossil fuel
民用生物质
Domestic biofuel
交通
Traffic
开放燃烧
Open burning
溶剂使用
Solvent use

排放量
Emissions
:

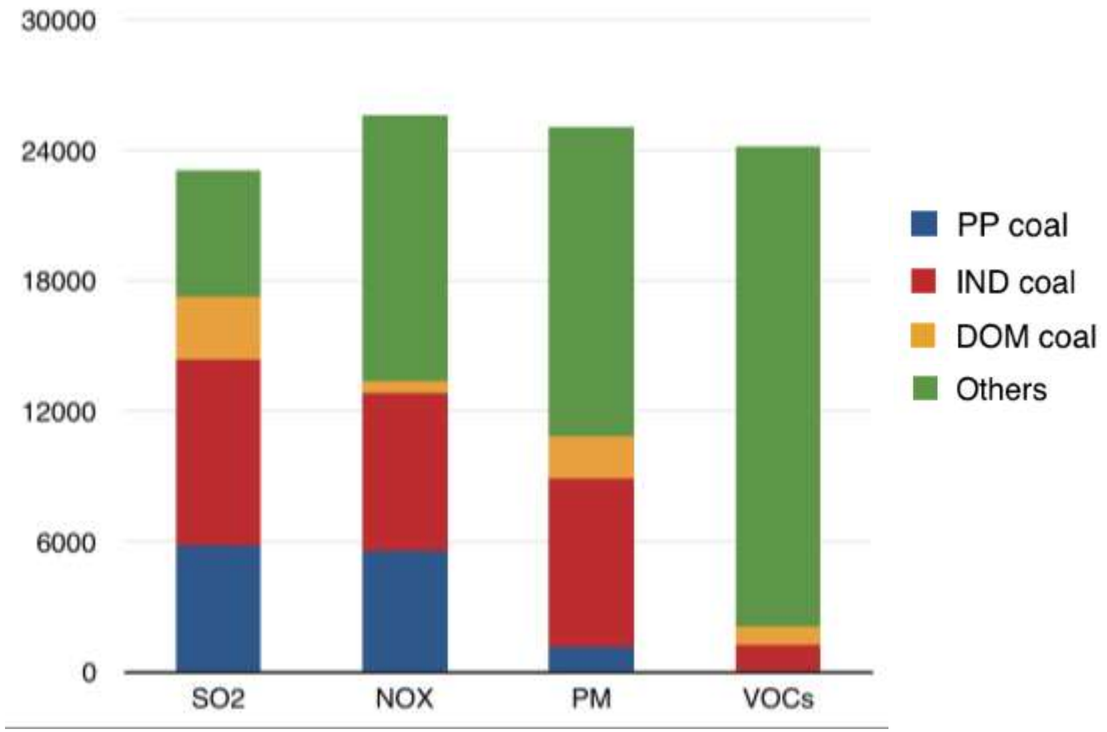
23 Tg

25.6 Tg

26 Tg

24 Tg

主要燃煤部门的污染物排放
Emissions from major sources



2013年，燃煤造成的排放占SO_2排放的75%，NO_X 排放的54%，一次PM_{10}排放的40%，一次$PM_{2.5}$排放的35%.

In the year of 2013, coal is responsible for 75% of the SO_2 emissions, 54% of the NO_X emissions, 40% of the primary PM_{10} emissions, and 35% of the primary $PM_{2.5}$ emissions.

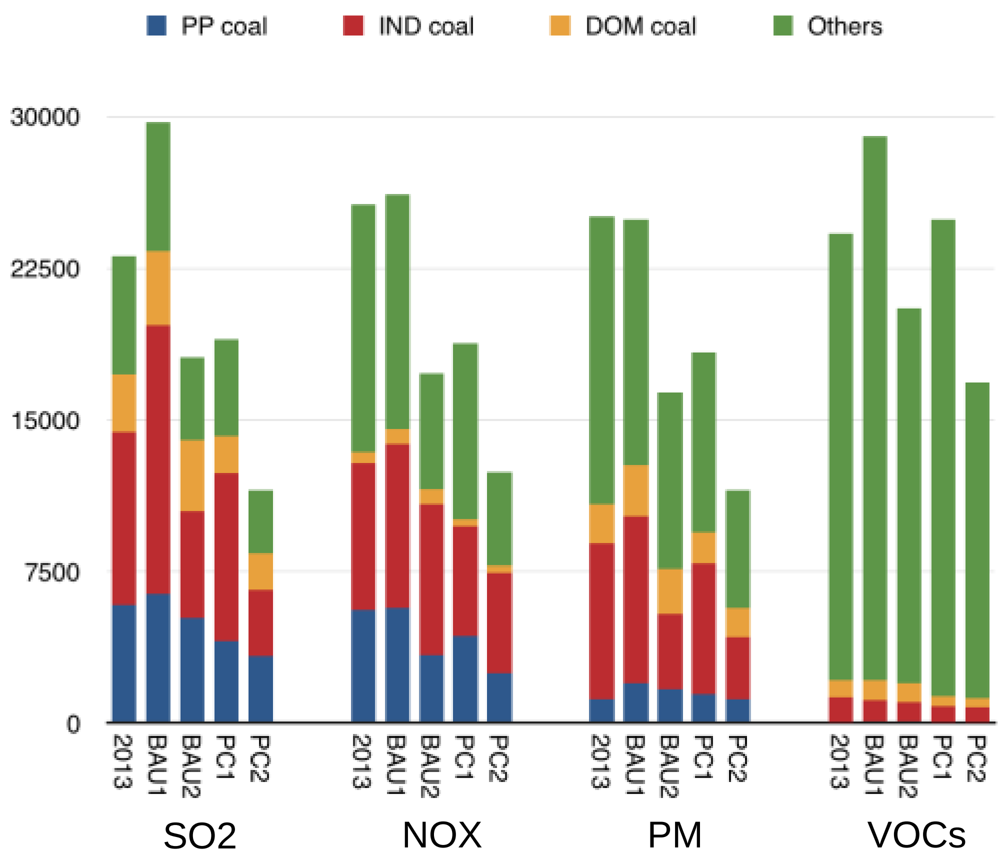
2030年未来情景 2030 Future scenarios

能源情景 Energy scenario	情景描述 Description	排放情景 Emission scenario	情景描述 Description
Business as usual (BAU)	根据现行的政策法规和执行情况（至2013年底） Current legislation & implementation status (to end of 2013)	BAU[1]	2011–2015年间假定我国的"十二五"规划得到实施，在2016年后假设控制政策逐渐缓慢加严。 Based on "12th Five-Year Plan for Environmental Protection"; New emission standards released during 2011-2013; progressively strengthened control policies afterwards.
		BAU[2]	技术上可行的减排措施得到了最大限度的应用，是可实现的最大限度减排策略。 Full implementation of technically feasible control technologies by 2030, regardless of cost.
Alternative policy (PC)	根据新推广的节能政策和更严格的执行情况。由于更节能的生活方式导致的能源需求增长减慢（高能耗工业产品，建筑面积和住宅服务需求，机动车，发电量，供暖）；推广清洁和可再生能源，提高能效的技术。 New stringently enforced energy-policies including life style changes, structural adjustment & efficiency improvements.	PC[1]	同BAU1 Same end-of-pipe control strategy as BAU[1]
		PC[2]	同BAU2 Same end-of-pipe control strategy as BAU[2] Maximum feasible reductions of emissions

未来排放 Future emissions

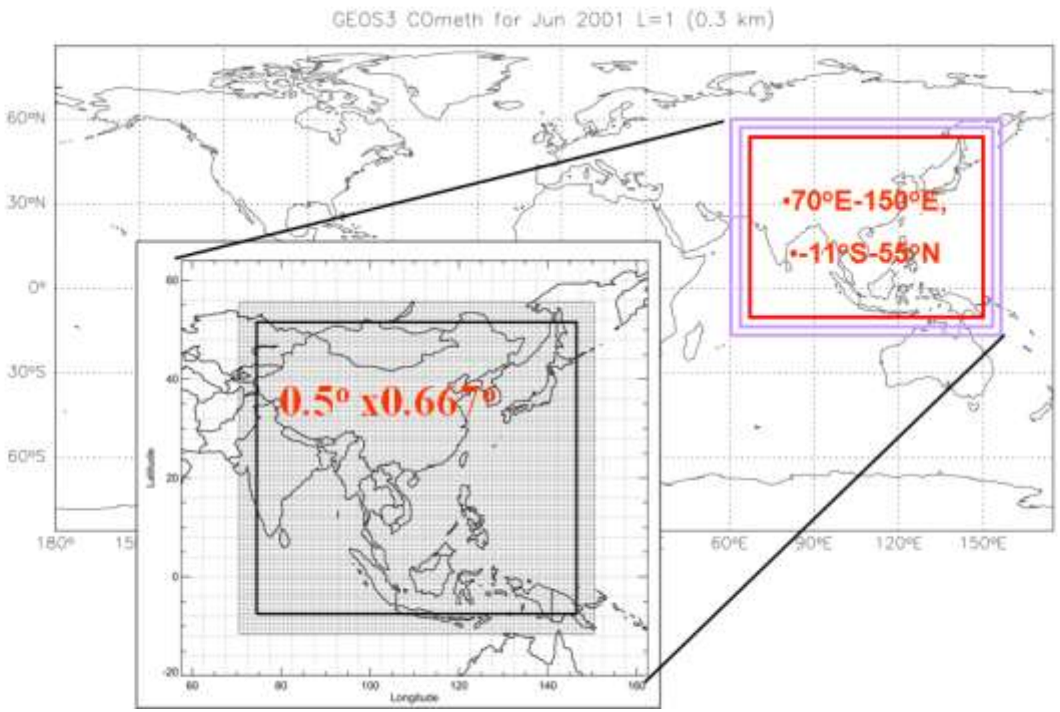
未来主要大气污染物排放
Future emissions in each scenario (Tg)

	2013	BAU1	BAU2	PC1	PC2
SO_2	23.0	29.7	18.1	19.0	11.5
NO_X	25.6	26.1	17.3	18.7	12.4
PM	26.0	24.9	16.4	18.3	11.5
VOCs	24.0	29.0	19.6	24.1	16.1



- PC2中主要污染物较BAU1降低了50%左右；
  Emissions in PC2 decreased by around 50% compared with BAU1;
- 燃煤仍然是主要排放源；
  Coal burning remains as the major source.

大气化学模式 GEOS-Chem model



模拟区域 Region:

东亚 Nested domain for Asia (70°-150°E, -10°-55°N)

分辨率 Resolution:

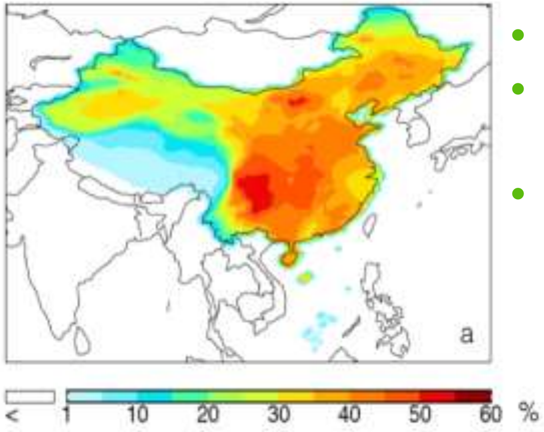
水平分辨率：0.5°×0.667°
Horizontal resolution: 0.5 latitude by 0.667 longitude
垂直分辨率：47层
Vertical: 47 vertical layers up to 0.01 hPa

气象场 Met fields:

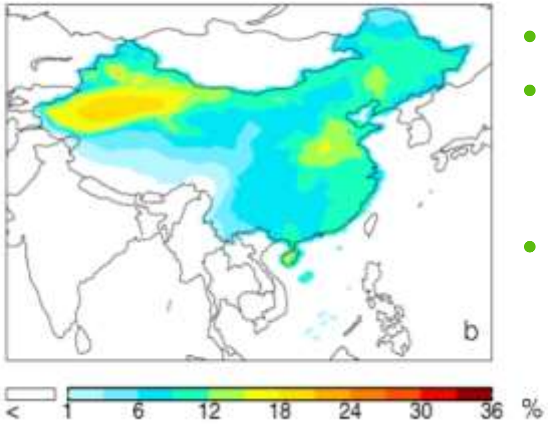
GEOS-5同化气象场（2012年）
GEOS-5 assimilated meteorological fields (2012)

边界场 Boundary fields:
由4°×5°全球模拟提供，每三小时更新一次
Tracer concentrations at the lateral boundaries are provided by a global GEOS-Chem simulation at 4 latitude by 5 longitude horizontal resolution and updated in the nested-grid model every 3 h.

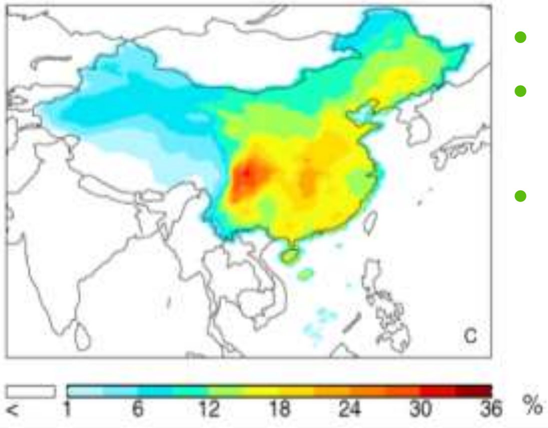
2013年燃煤部门对大气PM2.5贡献比例
Simulated percentage contributions in 2013 from coal burning



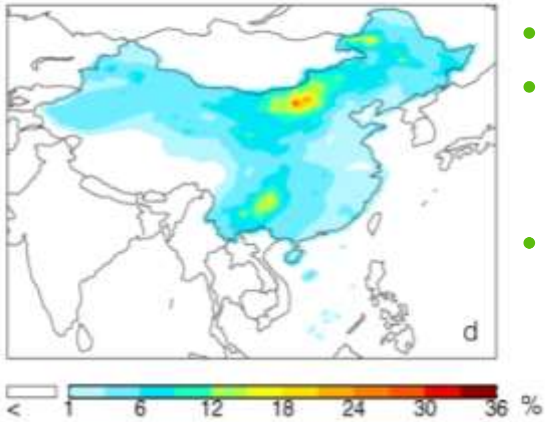
- 全部燃煤 Total Coal:
- 四川盆地 50.19%；
  Sichuan Basin: 50.19%;
- 内蒙古 50%以上
  Inner mongolia: more than 50%



- 电厂燃煤 Power Plant Coal:
- 华北平原 12%；
  North China Plain: 12.04%, larger number of power plants
- 新疆
  Xinjiang: few other sources



- 工业燃煤 Industrial Coal:
- 四川盆地 26%
  Sichuan Basin: 26%;
- 华北平原 16.7%
  长江中下游地区 20.5%
  North China Plain and Middle Yangtze River: 16.77% and 20.47%

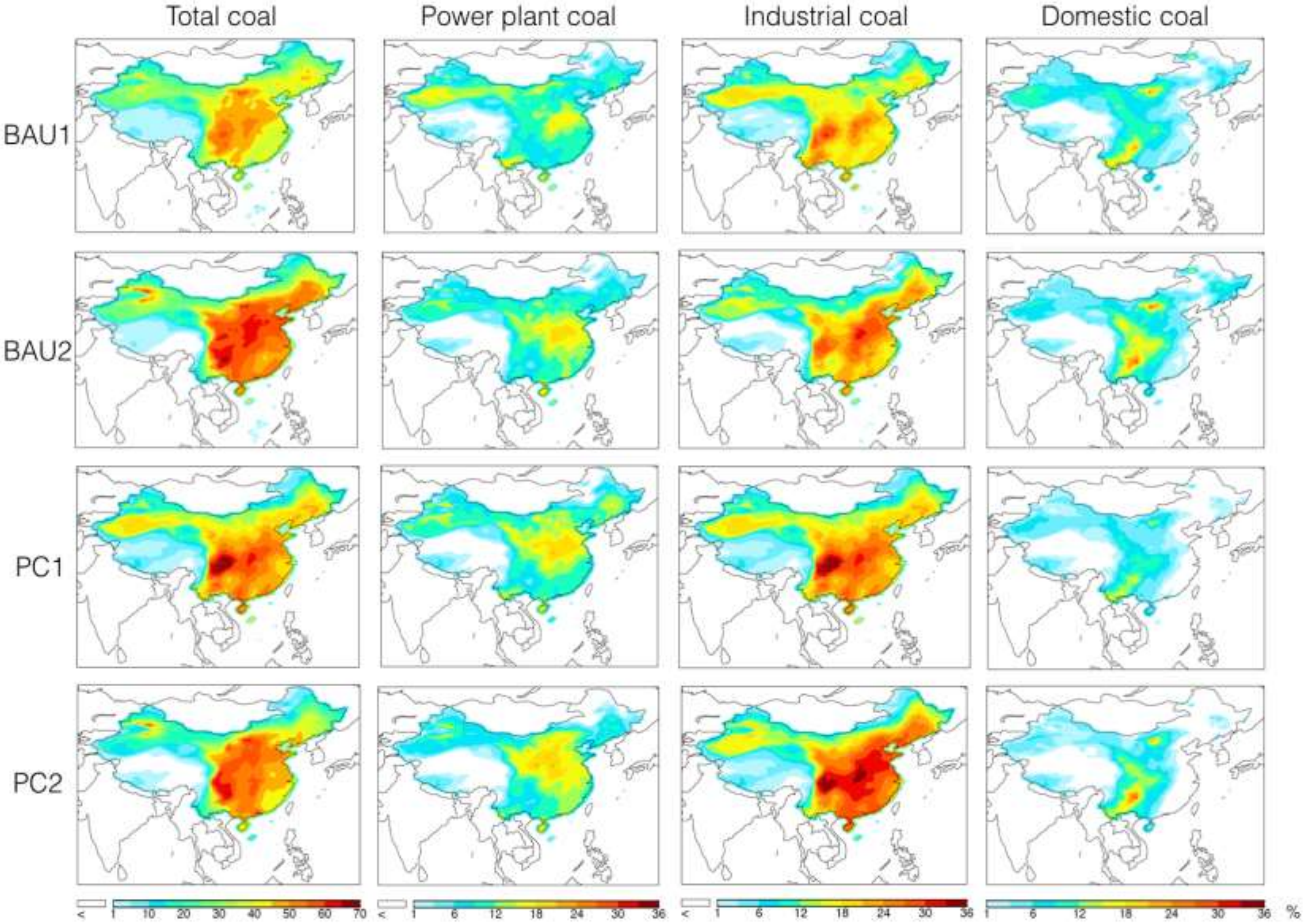


- 民用燃煤 Domestic Coal:
- 内蒙古个别地区 25%
  Inner mongolia: 25%, large amount of raw coal burning
- 贵州 15%
  Guizhou: 15%, high sulfur content

			Contributions from coal burning in		
	Mean $PM_{2.5}$	Total coal burning	Power plant	Industry	Domestic
National Average*	56.7	22.5 (39.6%)	5.6 (9.8%)	9.6 (17.0%)	2.2 (4.0%)

未来情景中的燃煤贡献

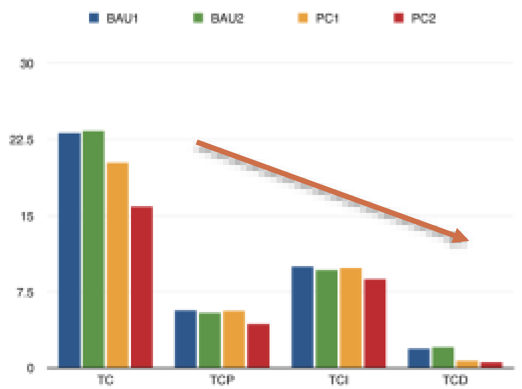
Coal burning contribution in future scenarios



未来各情境下，各部门对$PM_{2.5}$的贡献空间分布与基准年相似，但数值上有所不同

Contributions from coal combustion and sub sectors basically followed the pattern in base year, but the values are different.

Absolute contributions in 2030



Percentage contributions in 2030

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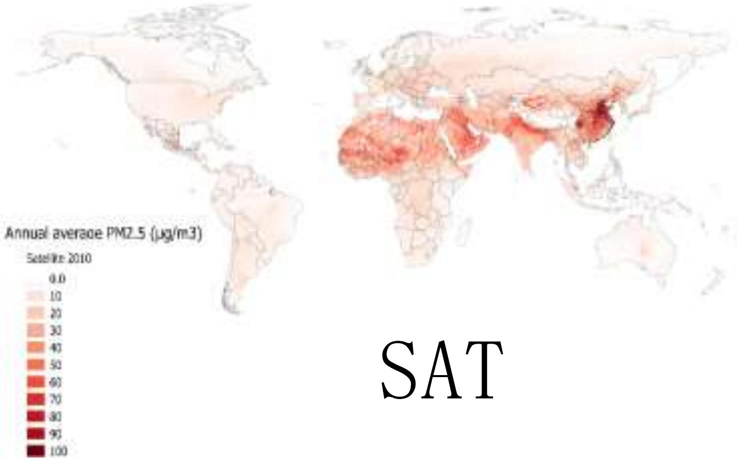
- 利用集成暴露响应曲线（IER）和来自各排放源的大气$PM_{2.5}$ 浓度→ 各排放源所致的疾病负担
- Use integrated exposure response functions and cause-specific mortality estimates in combination with **$PM_{2.5\ coal}$** → source contribution to disease burden

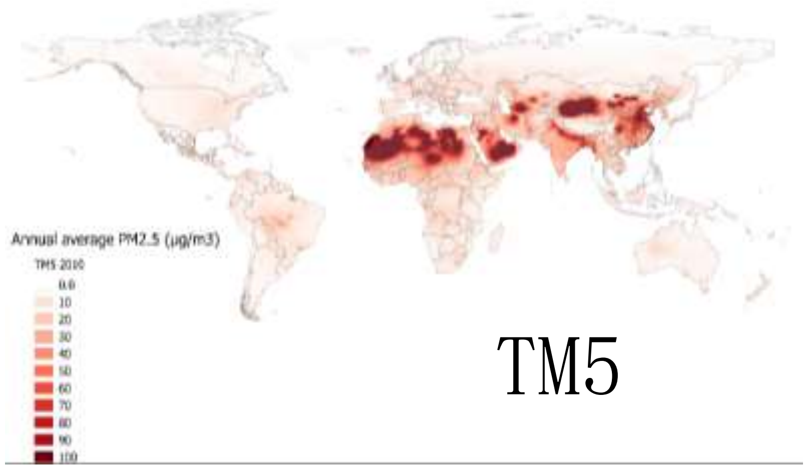
2.估算各部门对大气$PM_{2.5}$浓度的贡献

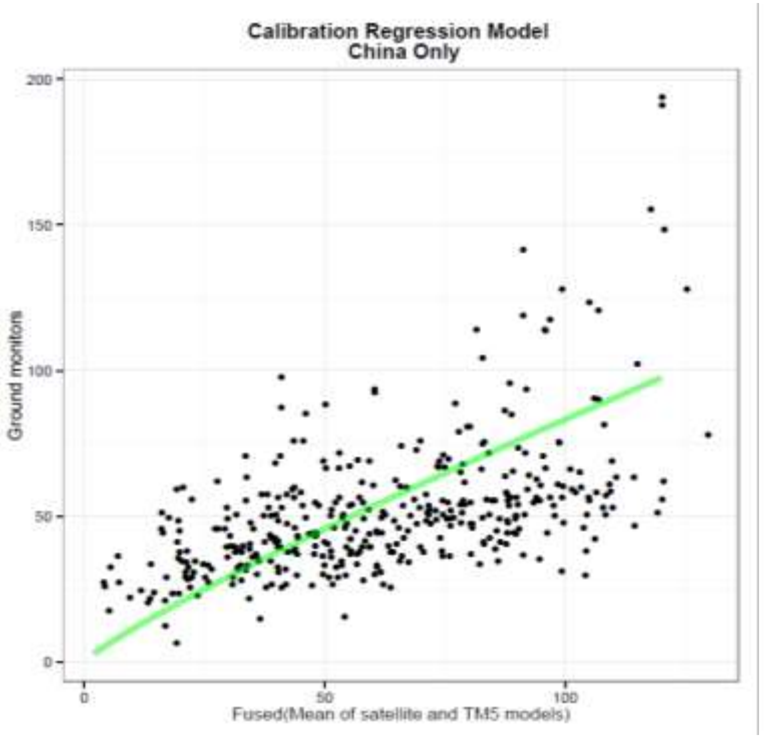
Estimating ambient $PM_{2.5}$ attributable to coal combustion

- 估算基于模型模拟与卫星数据(SAT, TM5)，并与地面观测数据校验
  - 0.1° x 0.1° 分辨率
  - 使用SAT 2010-2011年趋势外推至2013年

- Final estimates based on average of (1.4 million) grid cell values (SAT, TM5) and calibrated (regression model) with measurements
  - 0.1° x 0.1° resolution
  - extrapolated to 2013 using 2010-2011 trend in SAT

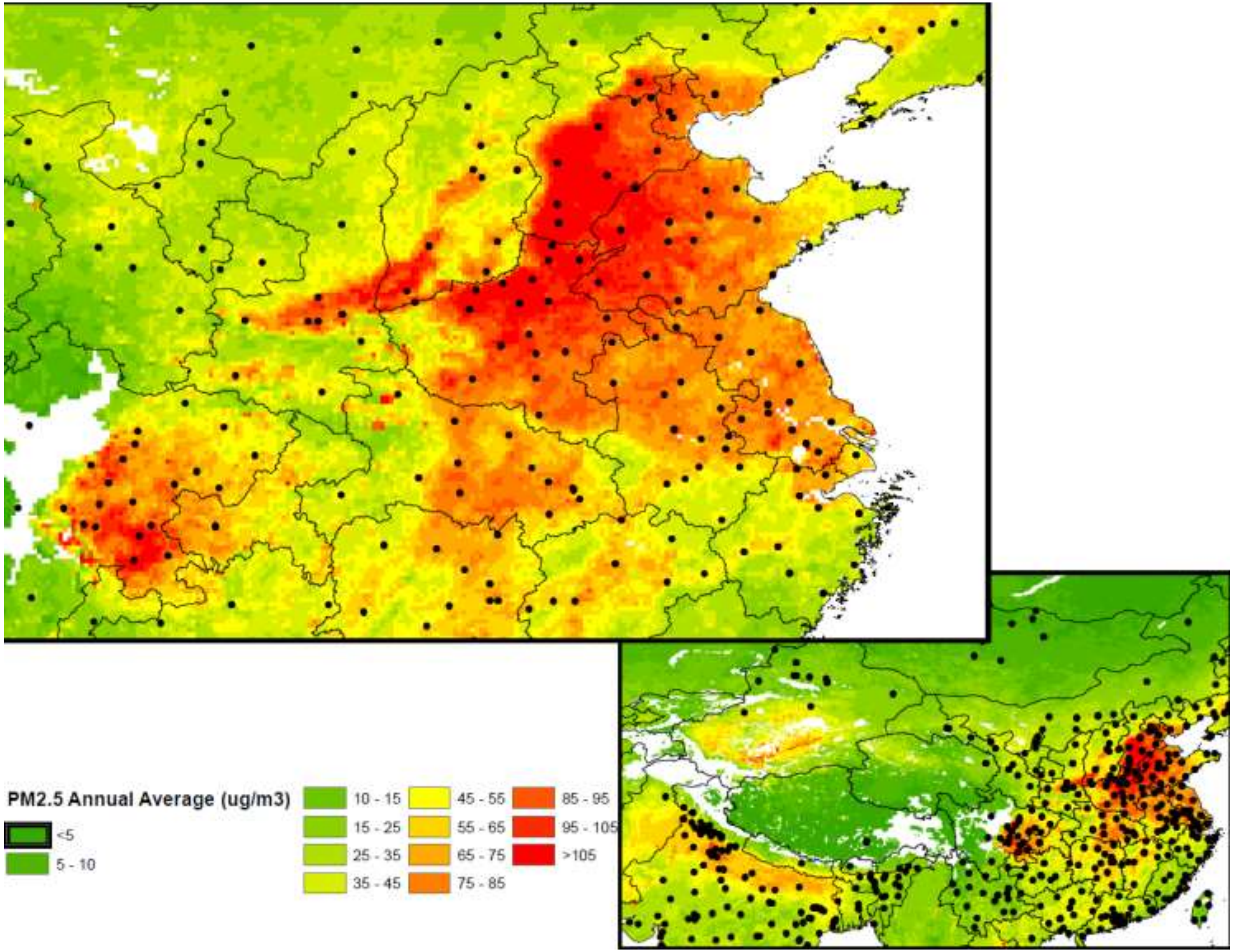






Brauer et al., 2015

地面观测数据（2013年均）
Ground measurements – China (2013 annual average)



- 90 个 $PM_{2.5}$ 观测站点
  90 Locations $PM_{2.5}$ measurements
- 304 个由 PM_{10} 观测数据估算得到的$PM_{2.5}$观测数值
  304 Locations $PM_{2.5}$ estimated from PM_{10} measurements

Brauer et al., 2015

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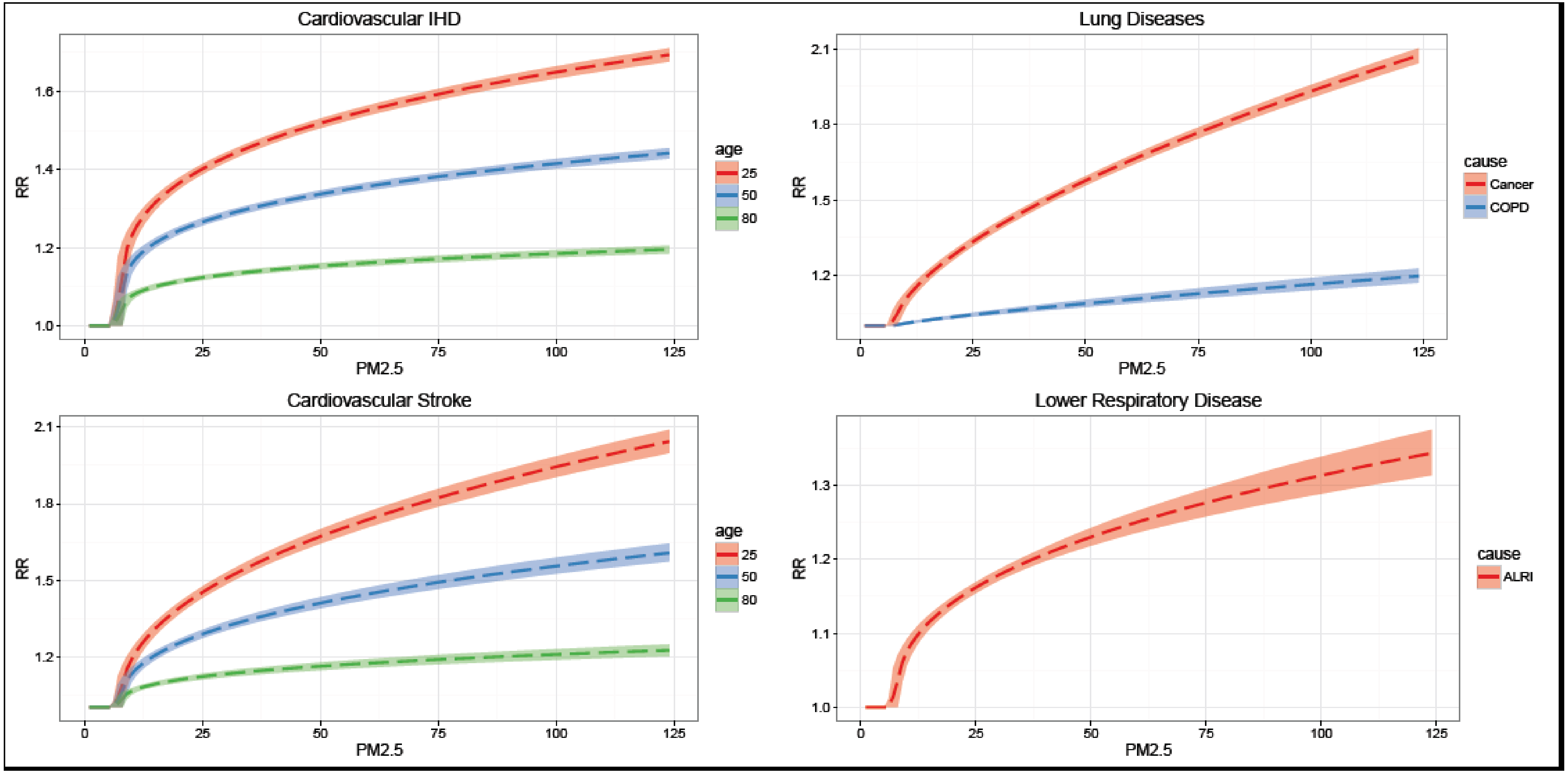
3. 集成的暴露响应曲线
Integrated Exposure-Response Functions



Forouzanfar et al. 2015; Burnett et al. 2014

基准年疾病负担估算结果

Estimated disease burden in base year (2013)

部门 Sector	平均$PM_{2.5}$贡献	死亡数 Deaths
全部PM2.5 All Ambient PM2.5	54.3	916,000
全部燃煤 Total Coal	21.9	366,000
电厂燃煤 Powerplant Coal	5.2	86,500
工业燃煤 Industrial Coal	9.4	155,500
非煤工业源 Non Coal Industial	5.6	95,000
民用燃煤 Domestic Coal	2.4	41,000
民用生物质 Domestic Biomass	8.0	136,500
交通源 Traffic	8.2	137,500
开放燃烧 Open Burning	4.1	70,000
溶剂使用 Solvent Use	(0.1)	-850

177,500

Source sector contributions to mean population-weighted ambient $PM_{2.5}$ and $PM_{2.5}$ - attributable deaths (95% UI) in China, 2013.

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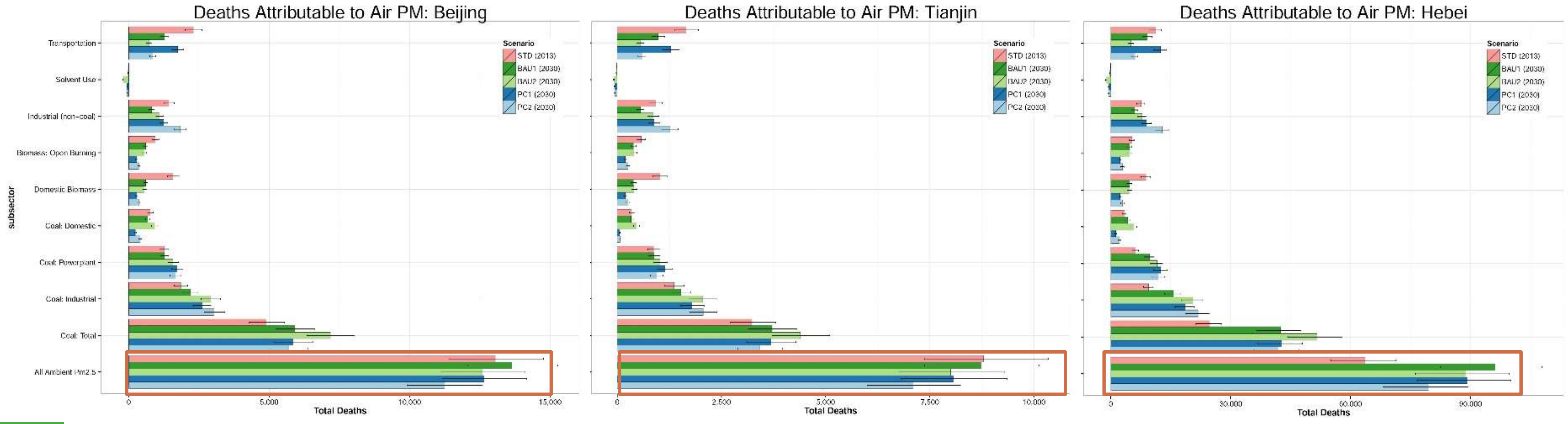
省级疾病负担估算：以京津冀地区为例
Provincial level results: Jing-Jin-Ji region

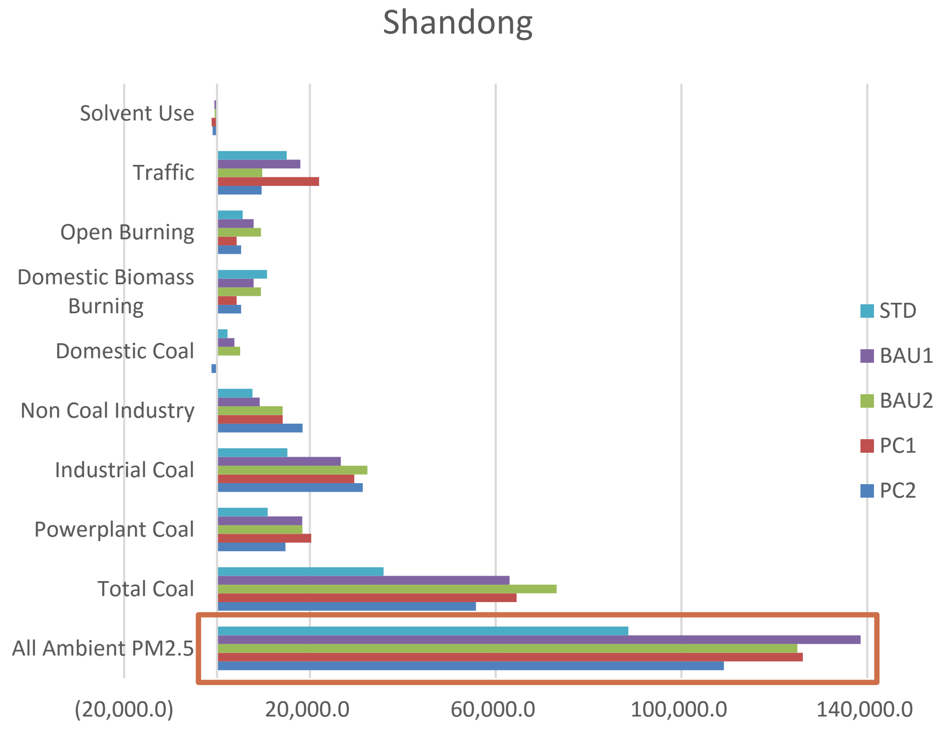
- 2013年燃煤所致 $PM_{2.5}$的疾病负担: 北京 4900 例 (全部$PM_{2.5}$: 13,000), 天津 3200 (8800), 河北 24,600 (63,700)；Deaths attributable to PM2.5 in 2013: Beijing 4900 due to coal (of the total 13,000), Tianjin 3200 (8800), Hebei 24,600 (63,700);
- 北京和天津的疾病负担在多数未来情景中有所下降, 而河北省的未来趋势与全国相似，疾病负担有所升高；Deaths in Beijing&Tianjin for most future scenarios decrease, while patterns in Hebei generally followed the national projections
- 北京和天津的下降主要由于民用部门、交通源和开放燃烧等部门的贡献降低；Decreases projected in Beijing and Tianjin are due to decreases in the impact of other source sectors such as transportation, domestic (coal and biomass) and open biomass burning in most of the future scenarios.

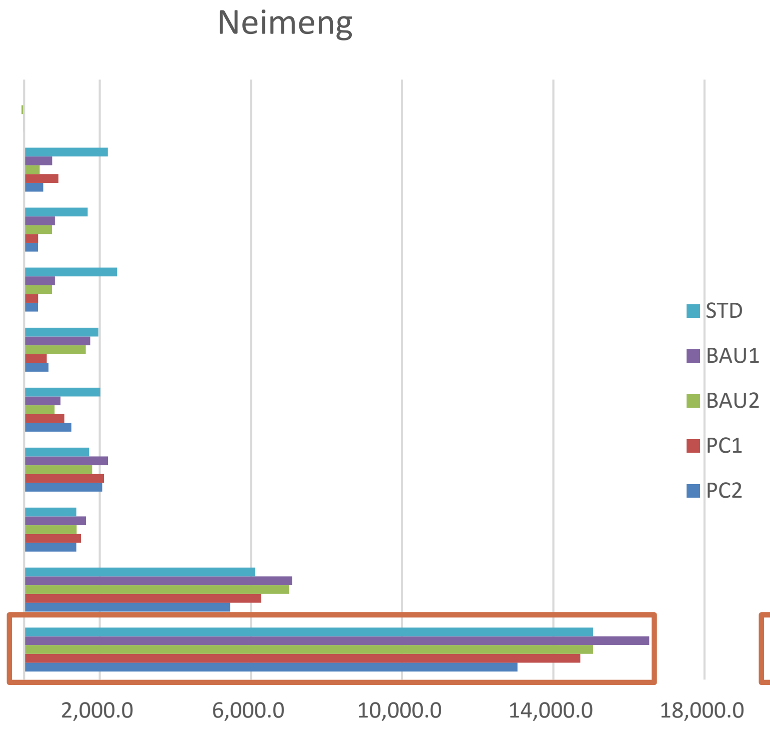


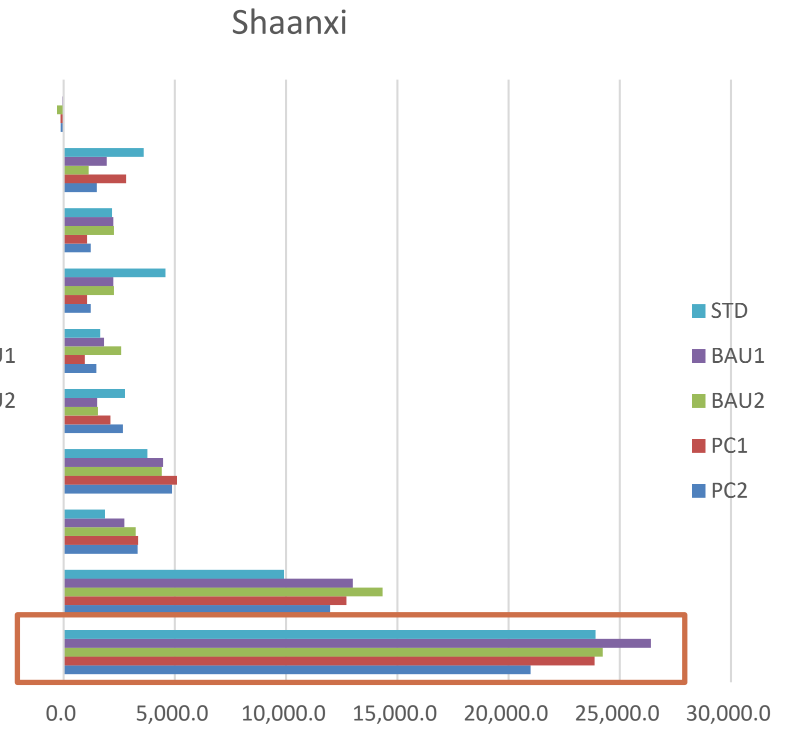
省级疾病负担估算：山东、内蒙古和陕西

Provincial level results: Shandong, Inner Mongolia and Shaanxi

- 2013年燃煤所致 $PM_{2.5}$的疾病负担: 山东 3600 例 (全部$PM_{2.5}$: 88500), 内蒙古 6000 (15000), 陕西 9900 (24000)；Deaths attributable to PM2.5 in 2013: Shandong 3600 due to coal (of the total 88500), 内蒙古 6000 (15000), 陕西 9900 (24000);
- 内蒙和陕西的疾病负担在多数未来情景中有所下降, 而山东省的未来趋势与全国相似，疾病负担有所升高；Deaths in Inner Mongolia & Shaanxi for most future scenarios decrease, while patterns in Shandong generally followed the national projections.







总结 Conclusions

- 2013年，中国燃煤所致的大气$PM_{2.5}$导致 Coal combustion $PM_{2.5}$ in China (2013) caused:
  - 大气$PM_{2.5}$暴露的40%；40% of exposure to ambient $PM_{2.5}$
  - 366,000例死亡；366,000 deaths
- 工业燃煤, 民用燃烧（包括生物质及煤炭）是大气$PM_{2.5}$所致疾病负担的最大贡献源, 应在政策制定中给予优先考虑；Industrial coal, domestic (biomass and coal) combustion: largest contributors to ambient $PM_{2.5}$ attributable mortality in 2013, which should be prioritized in policies;
  - 民用燃烧(177,000) > 工业燃煤 (155,000) > 交通 (137,000) > 电厂燃煤 (86,500) Domestic combustion (177,000 deaths) > industrial coal (155,000) > transportation (137,000) > power plant coal combustion (86,500)
- 由于未来能源与末端排放政策的实施，2030年共减少280,000例死亡；但由于人口老龄化和疾病率的上升，2030年各情境下大气$PM_{2.5}$所致的死亡人数均有所上升(99 - 130 万), 需要更严格的控制$PM_{2.5}$水平以实际降低疾病负担。The deaths due to $PM_{2.5}$ reduced by 280,000 in 2030 due to energy and end-of-pipe emission control policies. Increases in future deaths attributable to ambient PM2.5 for all scenarios (0.99 - 1.3 million deaths in 2030), due to the aging population & increased prevalence of diseases impacted by $PM_{2.5}$. Strict control of PM levels needed to reduce burden, given demographic trends.
- 尽管未来情景中诸多努力以降低大气污染物排放，但燃煤对大气$PM_{2.5}$及疾病负担的贡献在各情景中均有所上升. 因此需要更严格的措施来降低燃煤和其他主要大气污染源的排放。Coal contribution to ambient $PM_{2.5}$ and disease burden increases in all scenarios despite the effort toward emission reduction. Urgent need for even more aggressive strategies to reduce emissions from coal combustion (and other sectors).

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