Climatic effects of aerosols in China constrained by nationwide measurements

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OUTLINE

- Motivation
- Nationwide measurements of concentrations and optical properties of aerosols by Chinese Academy of Sciences
- Evaluation of the simulated present-day aerosols over China from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP)
- Improved simulation of climatic effect of aerosols
- Future directions

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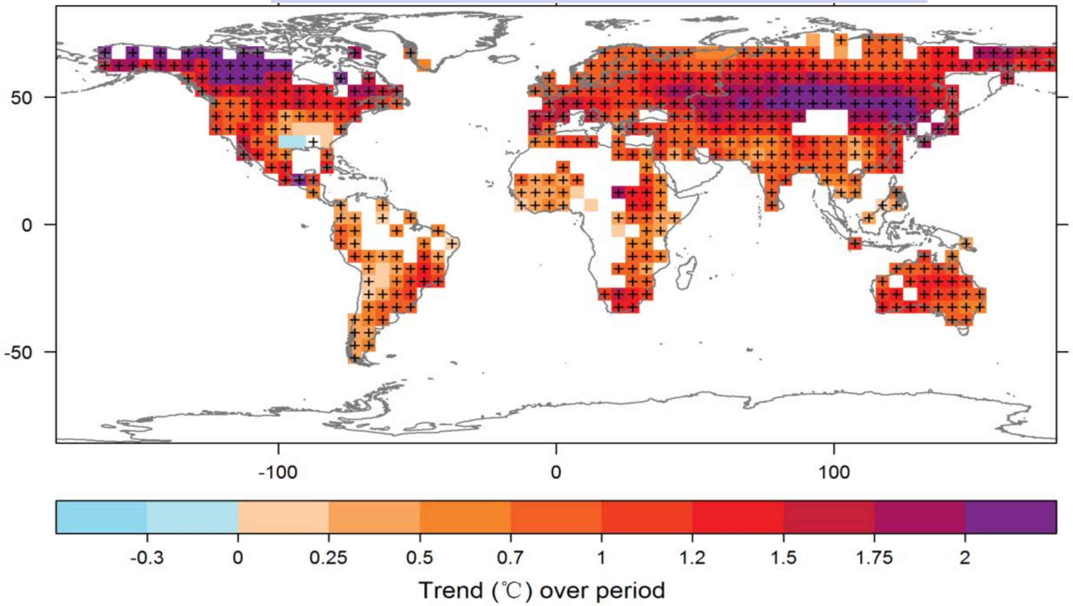
Average Temperature over China Increased by 1.52°C $(100\ yr)^{-1}$

Warming over 1901-2010



- Higher than the global mean warming of 0.89°C over 1901–2012；
- Previously estimated to be 0.5–0.8 °C $(100\ yr)^{-1}$

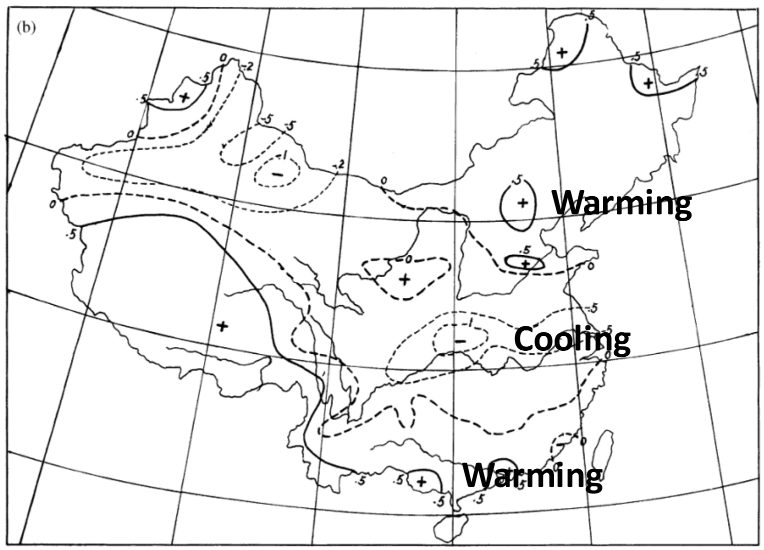
> - **Adopted by CRU datasets；**
> - **China's National Assessment Report on Climate Change (2015)**

第三次气候变化国家报告（2015）

Observed Climate Change in China over 1951-2000

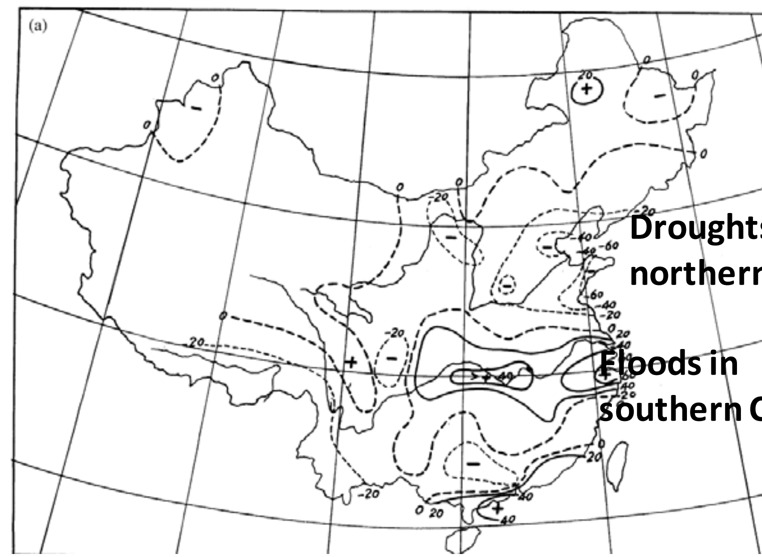
Temperature in summer

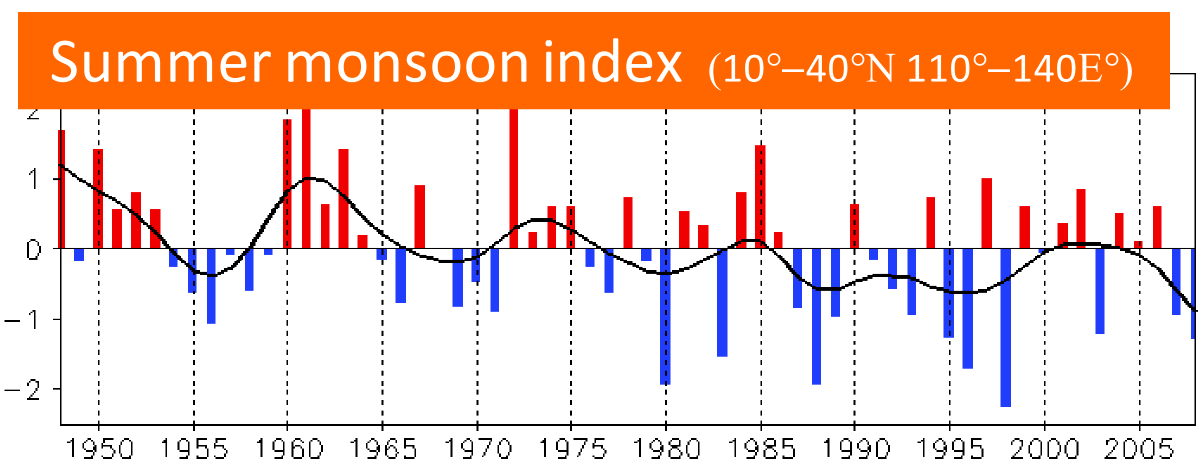
(1979-2000) - (1951-1978)



Precipitation in summer

(1979-2000) - (1951-1978)

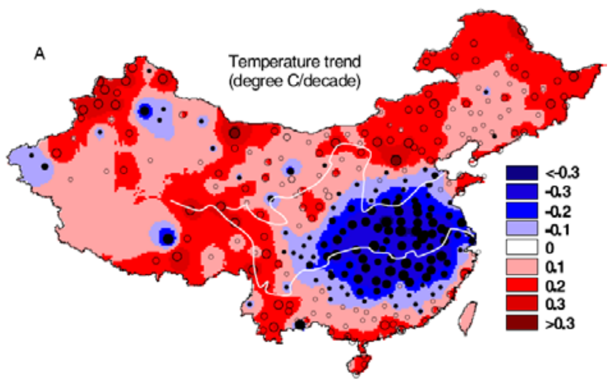




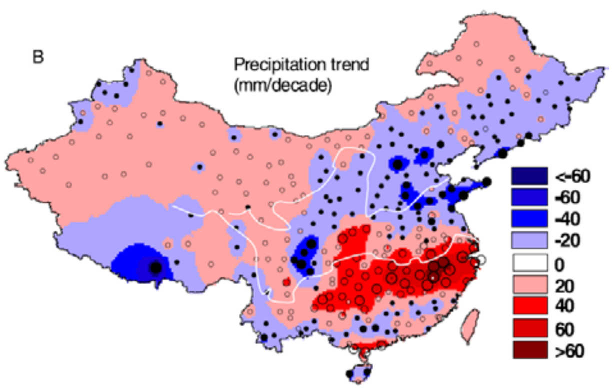
Weakening of East Asian summer monsoon

(Li and Zeng, 2002, 2003, 2005)

Impacts of aerosols on East Asian summer monsoon



(Xu, 2006, *JGR*)



20世纪后半期中国东部气候

Aerosols→ cooling at surface → reduced land-ocean temperature contrast → weakening of EASM → increased (reduced) precipitation in southern (northern) China

Elevated Heat Pump

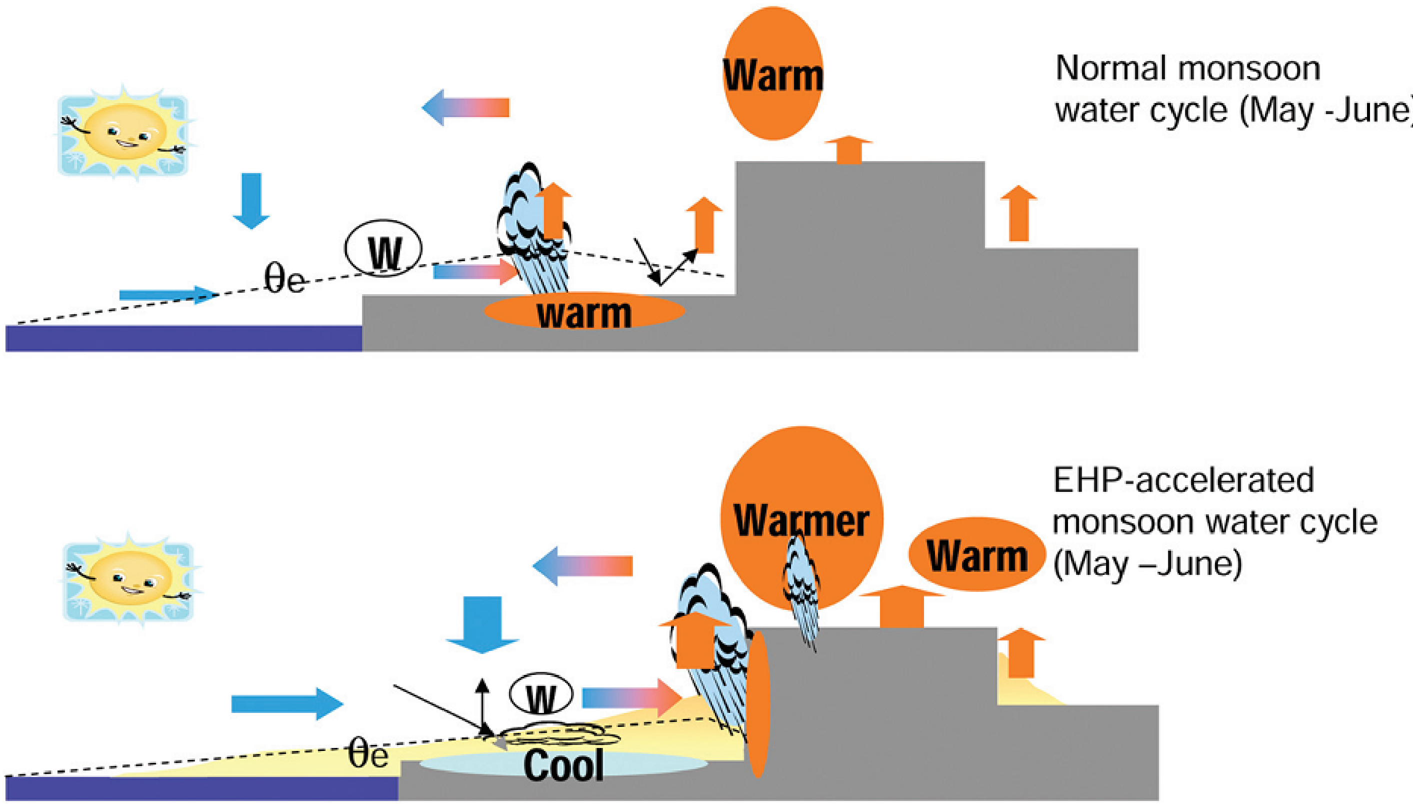


FIG. 3. Schematic showing the monsoon water cycle (top) with no aerosol forcing and (bottom) with aerosol-induced elevated heat pump effect. Low-level monsoon westerlies are denoted by W. The dashed line indicates magnitude of the low-level equivalent potential temperature θ_e. Deep convection is indicated over regions of maximum θ_e. (See text for further discussions.)

Lau et al. (2008)

Simulated Impacts of Aerosols on Temperature in Eastern China

Reference	Model	Ocean	T/E	Period	Aerosol species	Aerosol effects	Echina
Region Model							
Wang et al. (2010)	RegCCMS		E[a]	0-2000[c]	NO_3	D[d]	-0.04
						FI[e]	-0.11
						SI[f]	-0.68
						D+FI+SI	-0.78
Han et al. (2011)	RIEMS	Q-flux	E	0-2000	SO_4+BC+OC+Dust+SS	D	-0.2~-1.6
Wu and Han (2011)	RIEMS		E	0-2000	SO4+OC		-0.9~+0.6
Global Model							
Chang et al. (2009)	CACTUS	Q-flux	T[b]	1951-2000	SO_4	D	-0.40
					BC		+0.62
					SO_4+BC		+0.18
					SO_4+BC+OC		+0.15
					SO_4+BC+OC+SOA+NO_3		-0.78
Zhang et al. (2011)	BCC_AGCM2.0.1	Slab	E	0-2000	SO_4+BC+OC+Dust+SS	D	-0.3~-0.9
Guo et al. (2013)	HiGAM	Slab	E	1950-2000	SO4	D+I[g]	-0.2~-0.6 (Apr-Sep)
					BC	D	-0.4~+0.1 (Apr-Sep)
Kim et al. (2007)	fvGCM+ GOCART	Slab	E	0-2000	SO4	D	-0.2~-0.8 (Spring)
Li et al. (2007)	GAMIL1.1	Slab	T	1951-2000	SO4	D	-0.4~-1 (Summer)
Jiang et al. (2013)	CAM5	Slab	E	1850-2000	SO4	D+I	-0.6~-1.5 (Summer)
					BC	D+I	-0.6~+0.3
					POM	D+I	-0.9~0
					SO4+BC+POM	D+I	-0.2~-1

[a] E: equilibrium climate simulation; [b] T: transient climate simulation;
[c] 0-2000: two simulations are performed, one without aerosols, and the other one with present-day aerosol;
[d] D: direct radiative effect; [e] FI: first indirect radiative effect; [e] SI: second indirect radiative effect; [e] I: FI+SI.

Summary of uncertainties in historical radiative forcing by aerosols in Chapter 8 of IPCC AR5

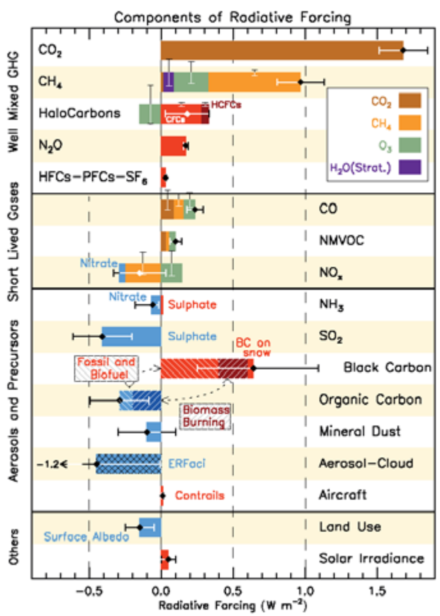


Figure 8.17 | RF bar chart for the period 1750–2011 based on emitted compounds (gases, aerosols or aerosol precursors) or other changes. Numerical values and their uncertainties are shown in Supplementary Material Tables 8.SM.6 and 8.SM.7. Note that a certain part of CH_4 attribution is not straightforward and discussed further in Section 8.3.3. Red (positive RF) and blue (negative forcing) are used for emitted components which affect few forcing agents, whereas for emitted components affecting many compounds several colours are used as indicated in the inset at the upper part the figure. The vertical bars indicate the relative uncertainty of the RF induced by each component. Their length is proportional to the thickness of the bar, that is, the full length is equal to the bar thickness for a ±50% uncertainty. The net impact of the individual contributions is shown by a diamond symbol and its uncertainty (5 to 95% confidence range) is given by the horizontal error bar. ERFaci is ERF due to aerosol–cloud interaction. BC and OC are co-emitted, especially for biomass burning emissions (given as Biomass Burning in the figure) and to a large extent also for fossil and biofuel emissions (given as Fossil and Biofuel in the figure where biofuel refers to solid biomass fuels). SOA havenot been included because the formation depends on a variety of factors not currently sufficiently quantified.

40

ERF of WMGHG is 3.00 (2.22 to 3.78) W m^{-2}. That of CO_2 is 1.68 (1.33 to 2.03) W m^{-2}; that of CH_4 is 0.97 (0.74 to 1.20) W m^{-2}; that of stratospheric ozone-depleting halocarbons is 0.18 (0.01 to 0.35) W m^{-2}.

Emissions of BC have a positive RF through aerosol–radiation interactions and BC on snow (0.64 W m^{-2}, see Section 8.3.4 and Section 7.5). The emissions from the various compounds are co-emitted; this is in particular the case for BC and OC from biomass burning aerosols. The net RF of biomass burning emissions for aerosol–radiation interactions is close to zero, but with rather strong positive RF from BC and negative RF from OC (see Sections 8.3.4 and 7.5). The ERF due to aerosol–cloud interactions is caused by primary anthropogenic emissions of BC, OC and dust as well as secondary aerosol from anthropogenic emissions of SO_2, NO_X and NH_3. However, quantification of the contribution from the various components to the ERF due to aerosol–cloud interactions has not been attempted in this assessment.

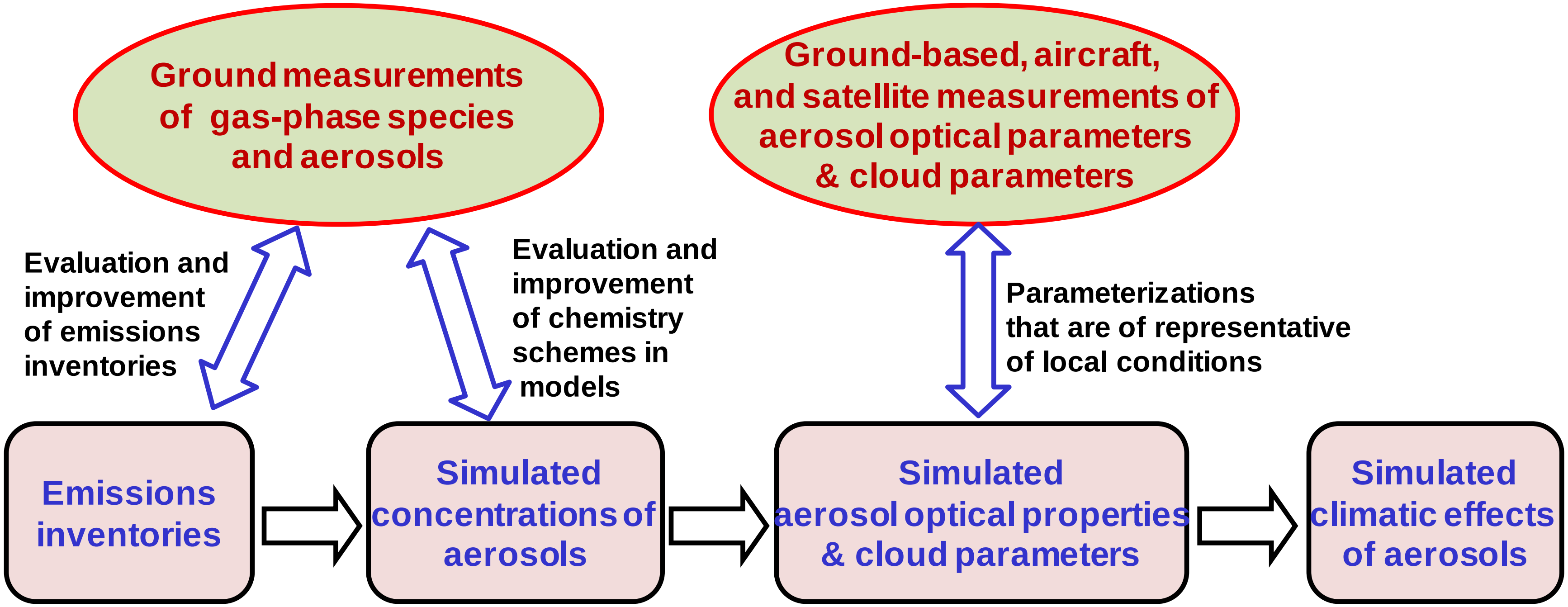
8.5.2 Time Evolution of Historical Forcing

The time evolution of global mean forcing is shown in Figure 8.18 for the Industrial Era. Over all time periods during the Industrial Era CO_2 and other WMGHG have been the dominant term, except for shorter periods with strong volcanic eruptions. The time evolution shows an almost continuous increase in the magnitude of anthropogenic ERF. This is the case both for CO_2 and other WMGHGs as well as several individual aerosol components. The forcing from CO_2 and other WMGHGs has increased somewhat faster since the 1960s. Emissions of CO_2 have made the largest contribution to the increased anthropogenic forcing in every decade since the 1960s. The total aerosol ERF (aerosol–radiation interaction and aerosol–cloud interaction) has the strongest negative forcing (except for brief periods with large volcanic forcing), with a strengthening in the magnitude similar to many of the other anthropogenic forcing mechanisms with time. The global mean forcing of aerosol–radiation interactions was rather weak until 1950 but strengthened in the latter half of the last century and in particular in the period between 1950 and 1980. The RF due to aerosol–radiation interaction by aerosol component is shown in Section 8.3.4 (Figure 8.8).

Although there is *high confidence* for a substantial enhancement in the negative aerosol forcing in the period 1950–1980, there is much more uncertainty in the relative change in global mean aerosol forcing over the last two decades (1990–2010). Over the last two decades th[...] has been a strong geographic shift in aerosol and aerosol precur[...]

- ☐ **There is high confidence for a substantial enhancement in the negative aerosol forcing in the period 1950–1980;**
- ☐ **There is much more uncertainty in the relative change in global mean aerosol forcing over the last two decades (1990–2010);**
- ☐ **Over the last two decades there has been a strong geographic shift in aerosol and aerosol precursor emissions (see Section 2.2.3), and there are some uncertainties in these emissions.**

Assessment on Climatic Effect of Aerosols



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3 Feburary 2011 | VOL 470 | NATURE |

IN FOCUS NEWS

POLICY

China sets 2020 vision for science

Goals include commercialization of research and emphasis on energy, biomedicine and information technology.

BY JANE QIU IN BEIJING

China is betting that an ambitious programme of applied research will help to secure its future as an economic superpower. Innovation 2020, unveiled last week by the Chinese Academy of Sciences (CAS), maintains support for basic research. But the plan will place a new emphasis on translating the research into technologies that can power economic growth and address pressing national needs such as clean energy, said Bai Chunli, vice-president of the CAS, at the academy's annual conference in Beijing, where the plan was announced.

Innovation 2020 is an extension of the Knowledge Innovation Programme (KIP) launched by the CAS in 1998. Under the KIP, the academy streamlined its often overstaffed and outdated institutes, attracted outstanding Chinese researchers who had trained abroad, and tightened up the way it evaluated project proposals and performance. But the CAS now needs to support new priorities, says Duan Yibing, a policy researcher at the CAS Institute of Policy and Management in Beijing. China has become a global economic power, and the world's financial crisis has made scientific innovation more important to economic success than ever before, he says. "Things are a lot different now compared to 13 years ago."

Although the budget of Innovation 2020 is yet to be announced, insiders say it will be part of a continuing surge in the nation's science spending (see 'Spend, spend, spend'). Indeed, the CAS's expenditure on research and development (R&D) in 2009 was about 20 billion renminbi (US$3 billion), seven times the level in 1998, according to a KIP assessment report also released last week. This year's budget for the National Natural Science Foundation of China will increase by 70%, from 10 billion renminbi last year.

Innovation 2020 will kick off with new projects this year in seven key areas, including nuclear fusion and nuclear-waste management; stem cells and regenerative medicine; and calculating the flux of carbon between land, oceans and atmosphere. Other priority areas include materials science, information technology, public health and the environment.

To coordinate resources better and to foster multidisciplinary research, the academy will set up three research centres for space science, clean coal technologies and geoscience monitoring devices. It also plans to build three science parks — in Beijing, Shanghai and Guangdong province, respectively — to accelerate the conversion of basic research into marketable products, especially in renewable energy, information technology and biomedicine.

Pan Jiaofeng, deputy general secretary of the CAS, says the KIP's track record bodes well for the success of the new programme. By the CAS's reckoning, in 2009, researchers that it funded published 3.5 times as many papers in journals listed by the Science Citation Index (SCI) as in 1998. Crucially, the number of papers published in the top 1% of SCI journals, as judged by their impact factor, was 12 times that in 1998. The CAS also calculates that research and development by the KIP generated an income of 140 billion renminbi and tax revenue of 22 billion renminbi in 2009 — respectively 19.5 and 14.5 times the levels in 2000.

But the report acknowledges that there is substantial room for improvement. For example, CAS researchers should aim to become leaders of the international scientific community, and shift their focus away from generating as many papers as possible and towards genuine originality and innovation.

With its emphasis on applied research, the new initiative also "presents a major challenge to the management and organizational capabilities of the academy", says Richard Suttmeier, a science-policy researcher at the University of Oregon in Eugene. He notes that most CAS institutes are focused on academic disciplines and lack the infrastructure needed for commercializing research or directing it towards national needs.

Others think that the emphasis on applied research, national needs and revenue could stifle curiosity-driven research. Without that, says a Shanghai-based researcher who declines to reveal his identity, "it would be very difficult to have genuine innovation". ■

China is investing heavily in renewable-energy research as it builds its capacity in, for example, solar power.

CHINA DAILY/REUTERS

SPEND, SPEND, SPEND

China's investment in science has risen rapidly over the past decade.

Gross domestic expenditure on R&D as a percentage of gross domestic product

Japan / United States / United Kingdom / China / India

3.5, 3.0, 2.5, 2.0, 1.5, 1.0, 0.5

2000, 2002, 2004, 2006, 2008

SOURCE: UNESCO

NATURE.COM
For all the latest research from China, see: www.nature.com/nchina

CAS Innovation 2020

CAS Strategic Priority Program:
Climate Change – Carbon Flux and Related Issues

CAS project on climatic effect of aerosols

(Chief Scientists: H. Liao, J. Cao)
(~11.5 M US Dollars)

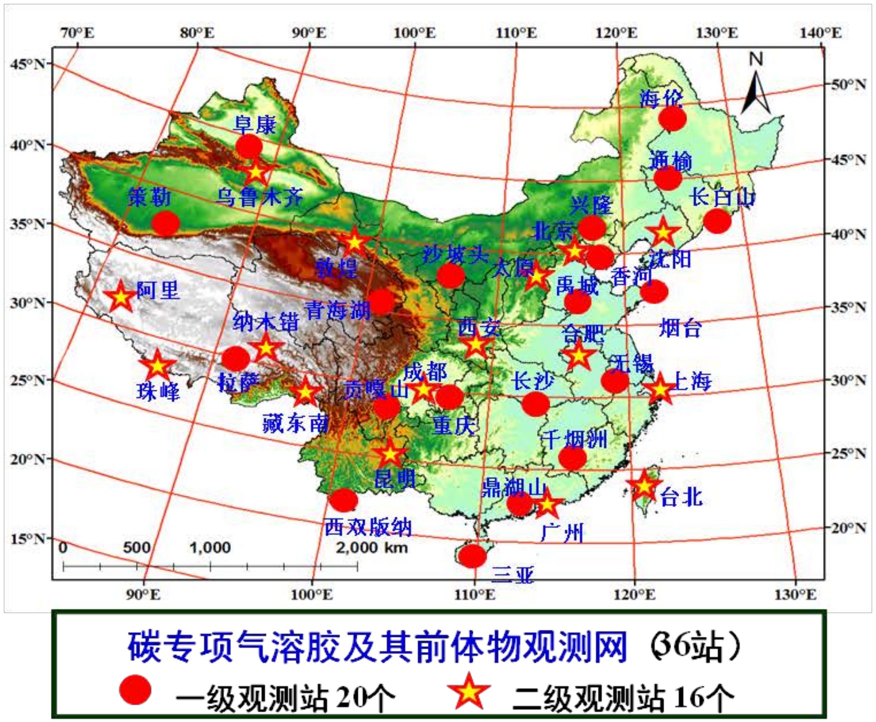
CAS Project on Climatic Effect of Aerosols

Expected Outcomes:

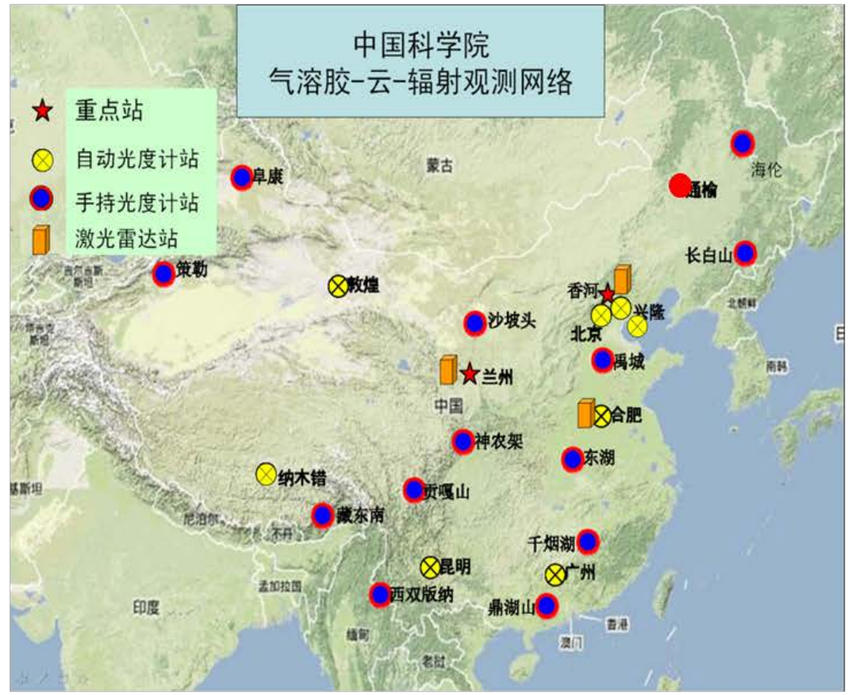
- First dataset with nationwide continuous measurements of size-resolved and speciated aerosols;
- Improved parameterizations of aerosol optical properties that are representative of regional aerosol concentrations and meteorological conditions in China;
- Improved aerosol-cloud parameterizations for China domain with spatial and temporal variations;
- Increased confidence with the simulated climatic effects of aerosols in China.

Aerosol Observation Networks of Chinese Academy of Sciences Launched in 2011

Measurements of conc.

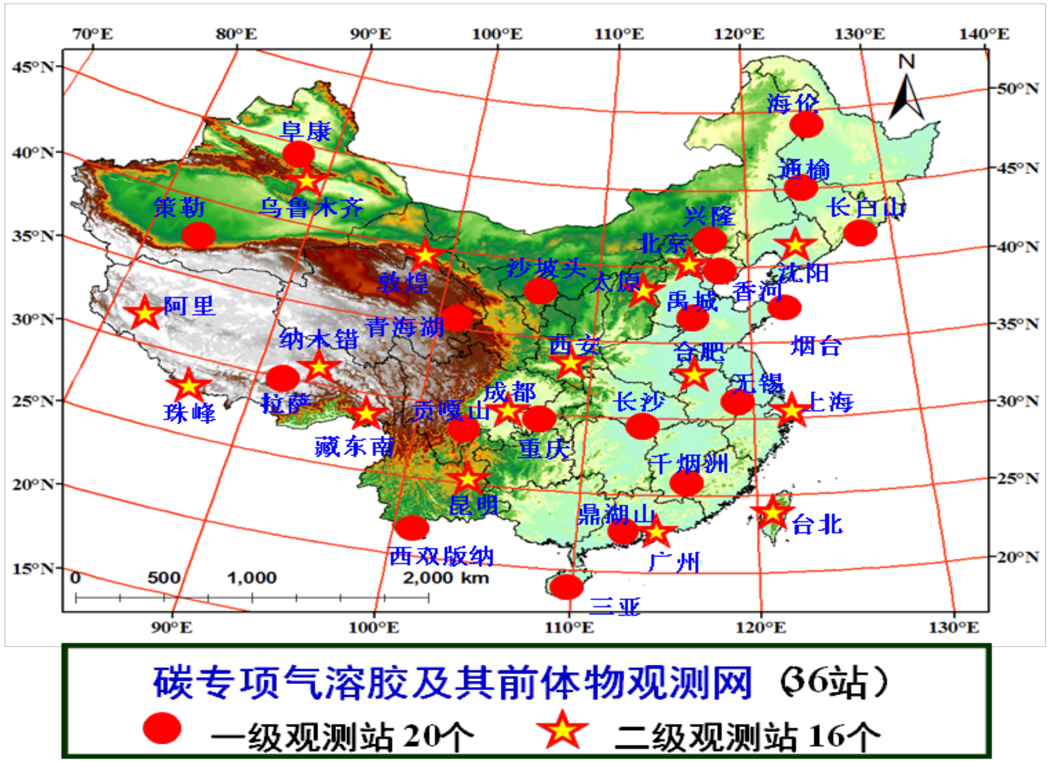


Measurements of optical properties



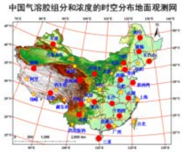
Measurements of Aerosol Concentrations

(PI: Prof. YS Wang)



Continuous measurements (2011-2014) of size-resolved speciated aerosol concentrations for 9 size bins of <0.43, 0.43-0.65, 0.65-1.1, 1.1-2.1, 2.1-3.3, 3.3-4.7, 4.7-5.8, 5.8-9.0, >9.0 μm

Jinyuan Xin et al., 2015: The Campaign on Atmospheric Aerosol Research Network of China: CARE-China. Bull. Amer. Meteor. Soc., 96(7), 1137–1155.

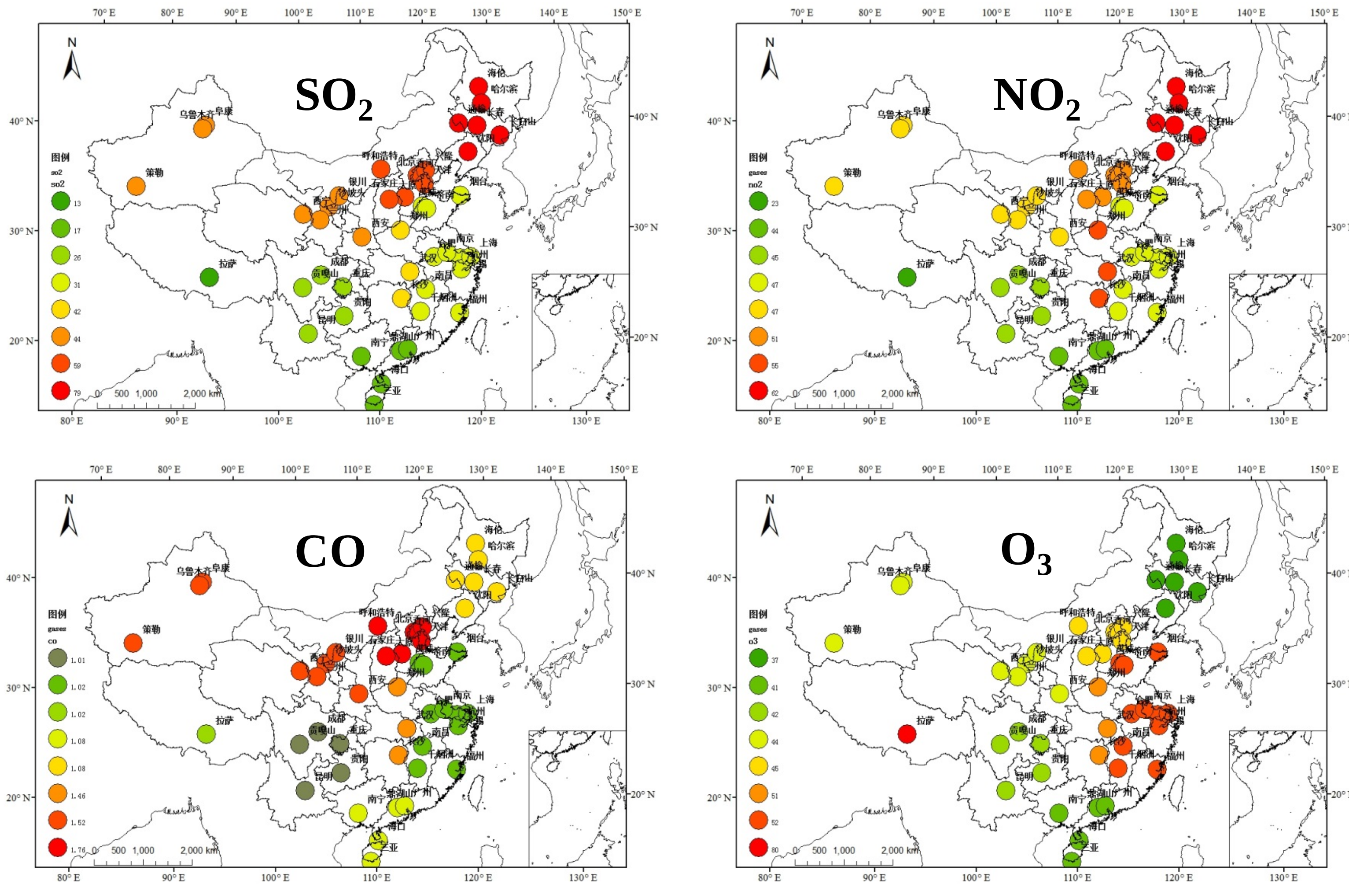


Parameters Measured at Ground Stations

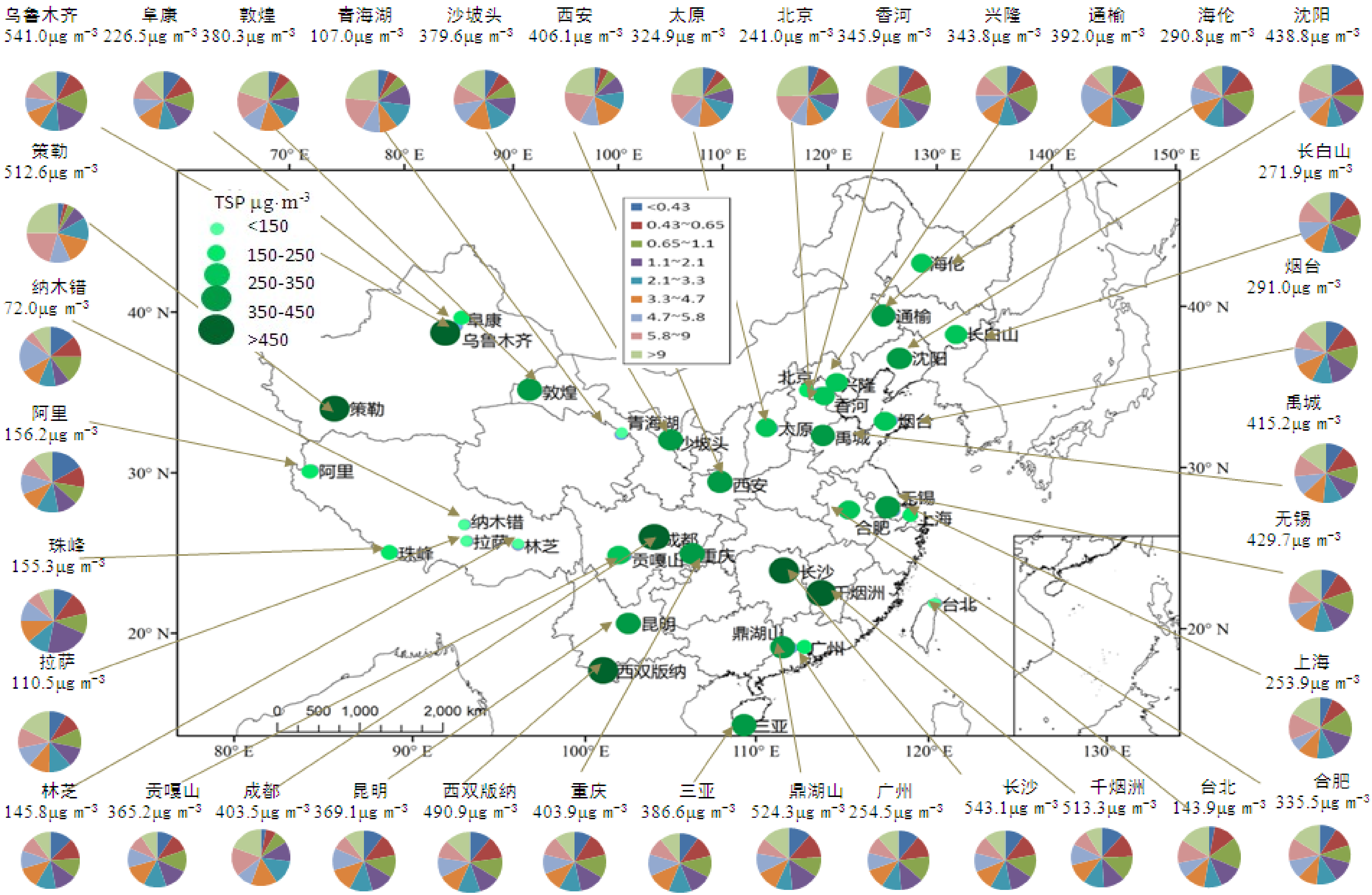
观测任务	实验内容	分析方式	频次
1. 气溶胶在线、分级浓度及VOC钢瓶采样	(1) PM2.5 (2) 气溶胶9级粒径段浓度谱 (3) VOCs采样	(1) TEOM PM2.5 (2) Andersen/石英膜/天平 (3) 钢瓶	小时 每周 每周
2. 气溶胶气态前体物在线	SO_2, NO, NO_2, CO及大气光化学强度标志物O_3浓度	Thermo 42I, 43I, 48I, 49I自动分析仪	小时
3. 气溶胶分级采样EC/OC分析	分级EC/OC，石英膜分级	热光碳分析仪	每2周
4. 气溶胶分级无机盐	10种水溶性盐，石英膜分级	离子色谱（IC）	每2周
5. 气溶胶分级OC分类	(1)OC中SOA含量（石英膜） (2)OC中烷、芳烃、有机酸、醇酮酯等成分	(1)热解析-GC/MS (2)多维萃取-GC/MS、IC	每2周
6. SOA前体物VOCs	60种以上SOA的前体物VOCs	CCS-GC/MS分析/采样罐	每周
7. CERN常规气象辐射观测	(1) 常规气象数据 (2) 常规太阳辐射数据	(1) Visala自动气象站 (2) Visala太阳辐射计	小时

注：观测网在长白山、兴隆、香河、烟台、阜康、青海湖、拉萨、重庆、长沙、鼎湖山10个站点采用CO在线观测，其余站点采用罐采样分析（数据频次每周）。

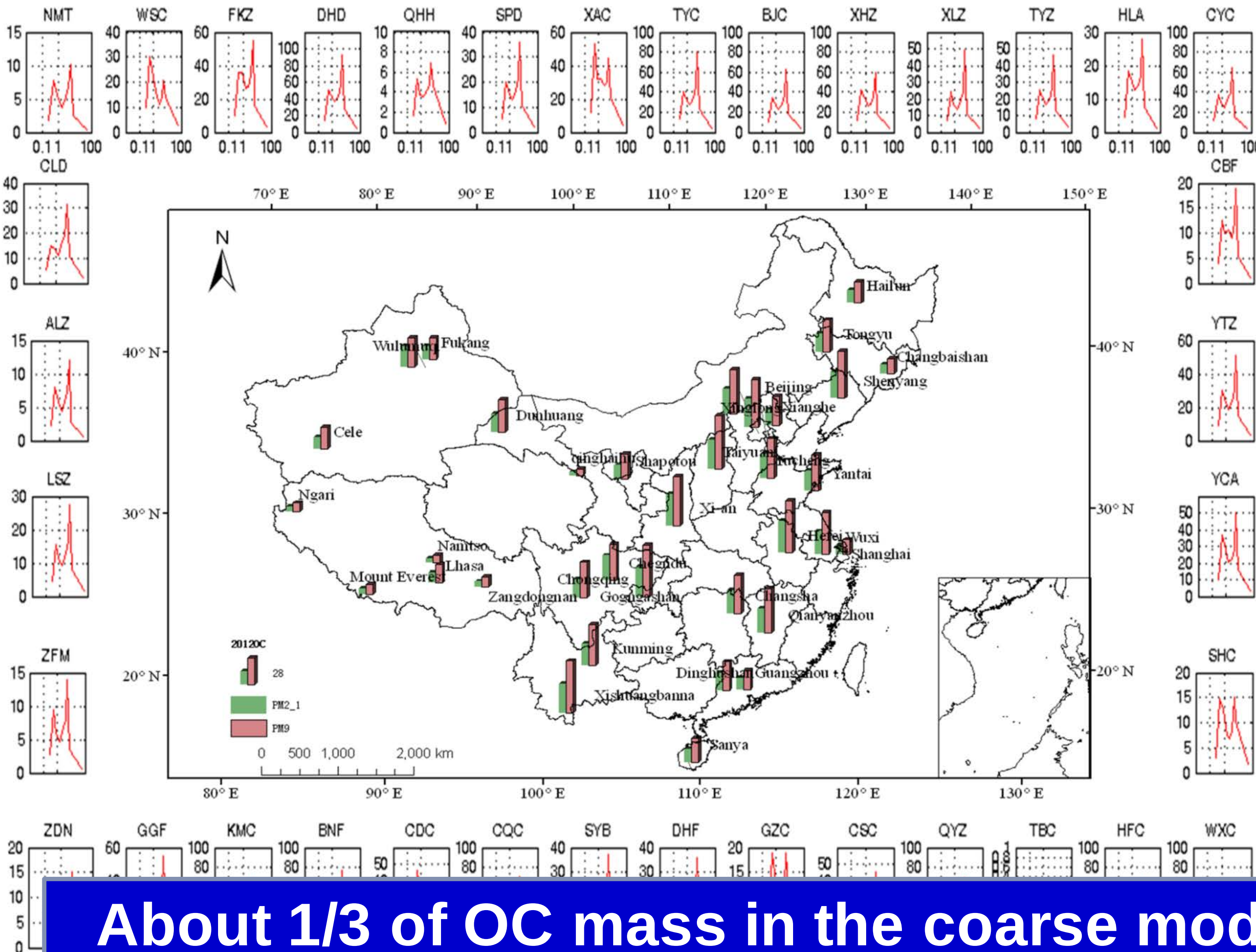
Observed Annual Mean Concentrations of Aerosol Precursors



Size-resolved Aerosol Mass Concentrations in Spring of 2013

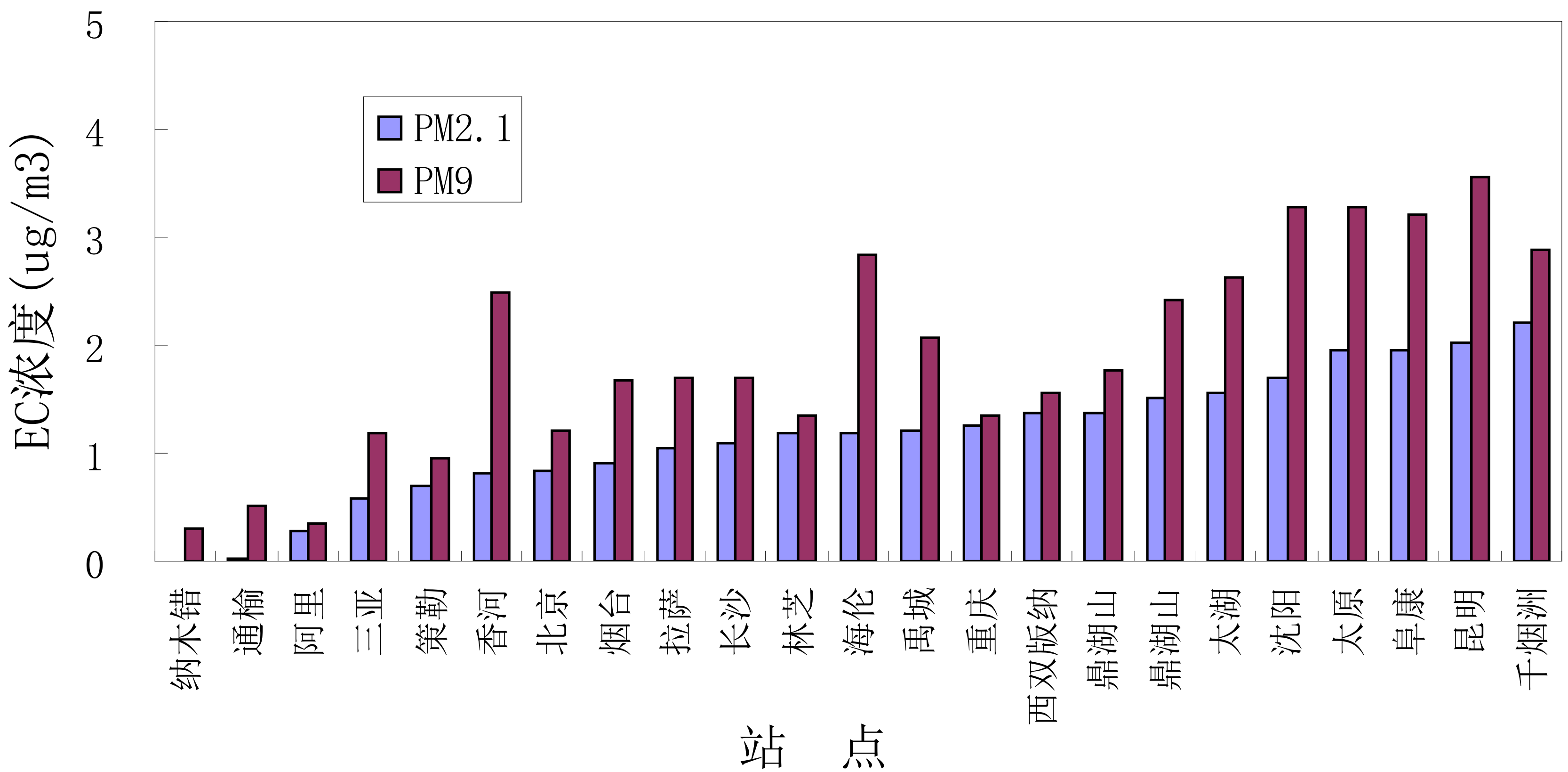


Size-resolved Concentrations of OC

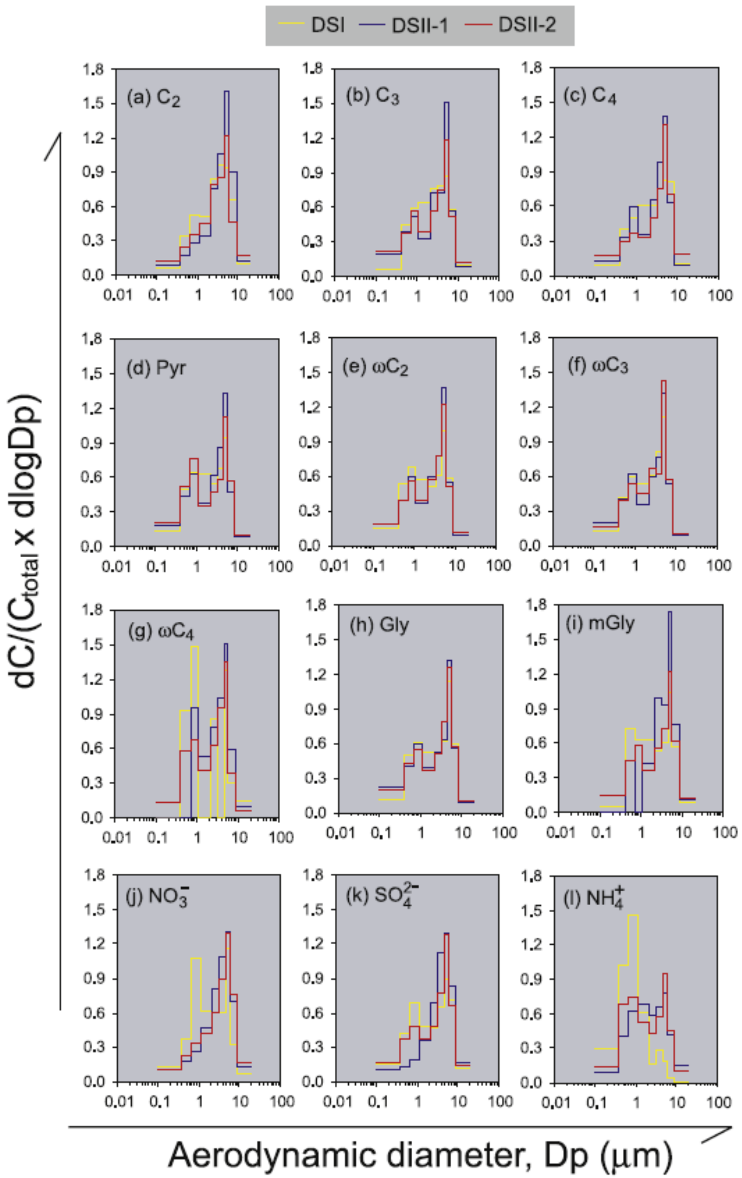


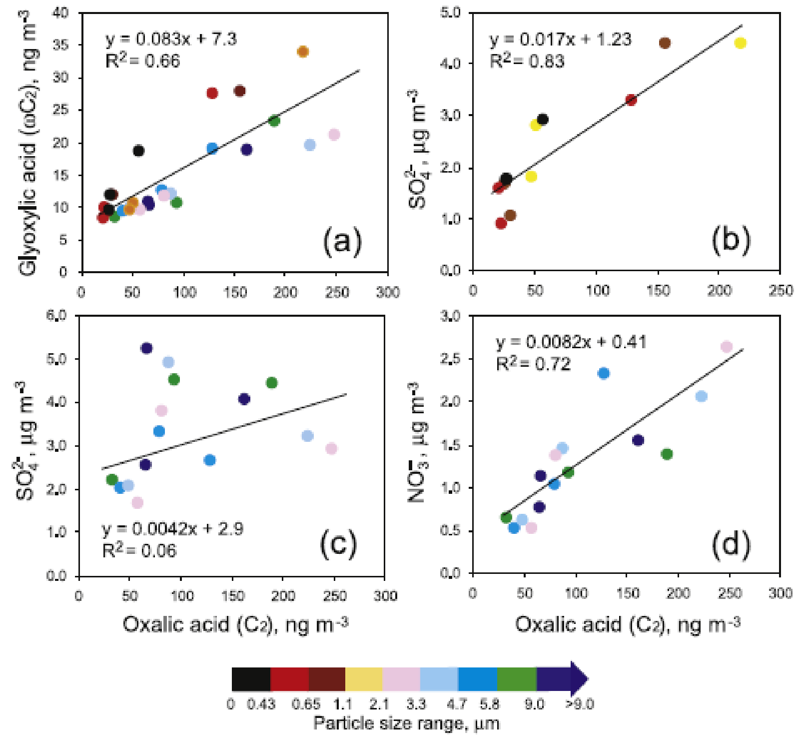
About 1/3 of OC mass in the coarse mode

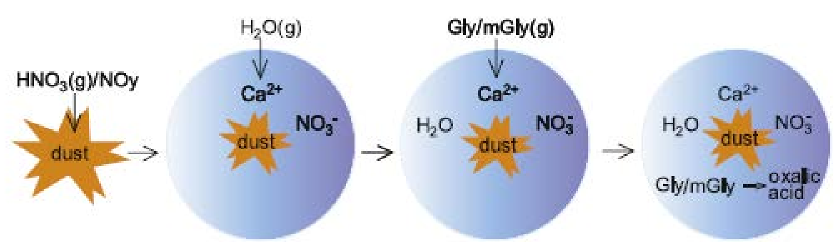
Nationwide measurements show that a large fraction of BC mass in the coarse mode



Formation of SOA over Dust Particles

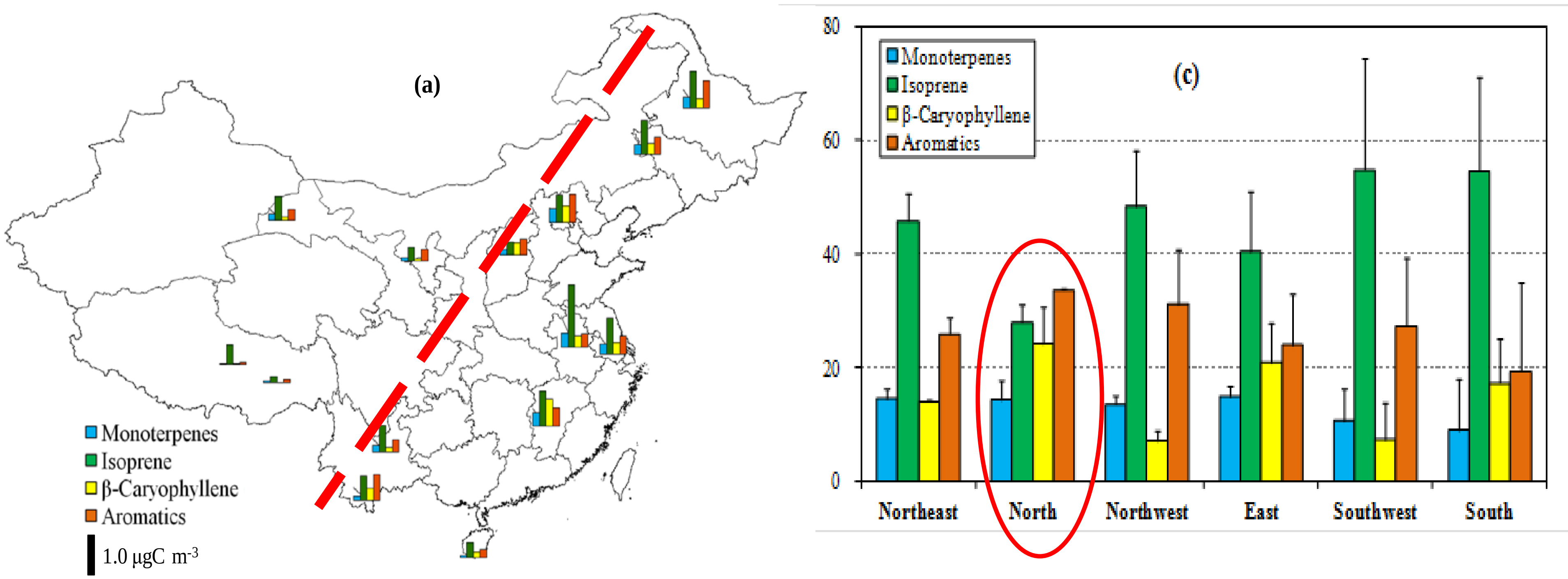






(Wang et al., AE 2015)

Spatial distribution and sources of SOA in China



Isoprene and aromatics are the major precursors of SOA

(Ding et al. JGR 2014; Shen et al., ACP 2015)

Biogenic vs. anthropogenic SOA

Biogenic（isoprene, monoterpene, and sesquiterpenes）
Anthropogenic（aromatics）

(Ding et al. JGR 2014; Shen et al., ACP 2015)

SCIENTIFIC REPORTS

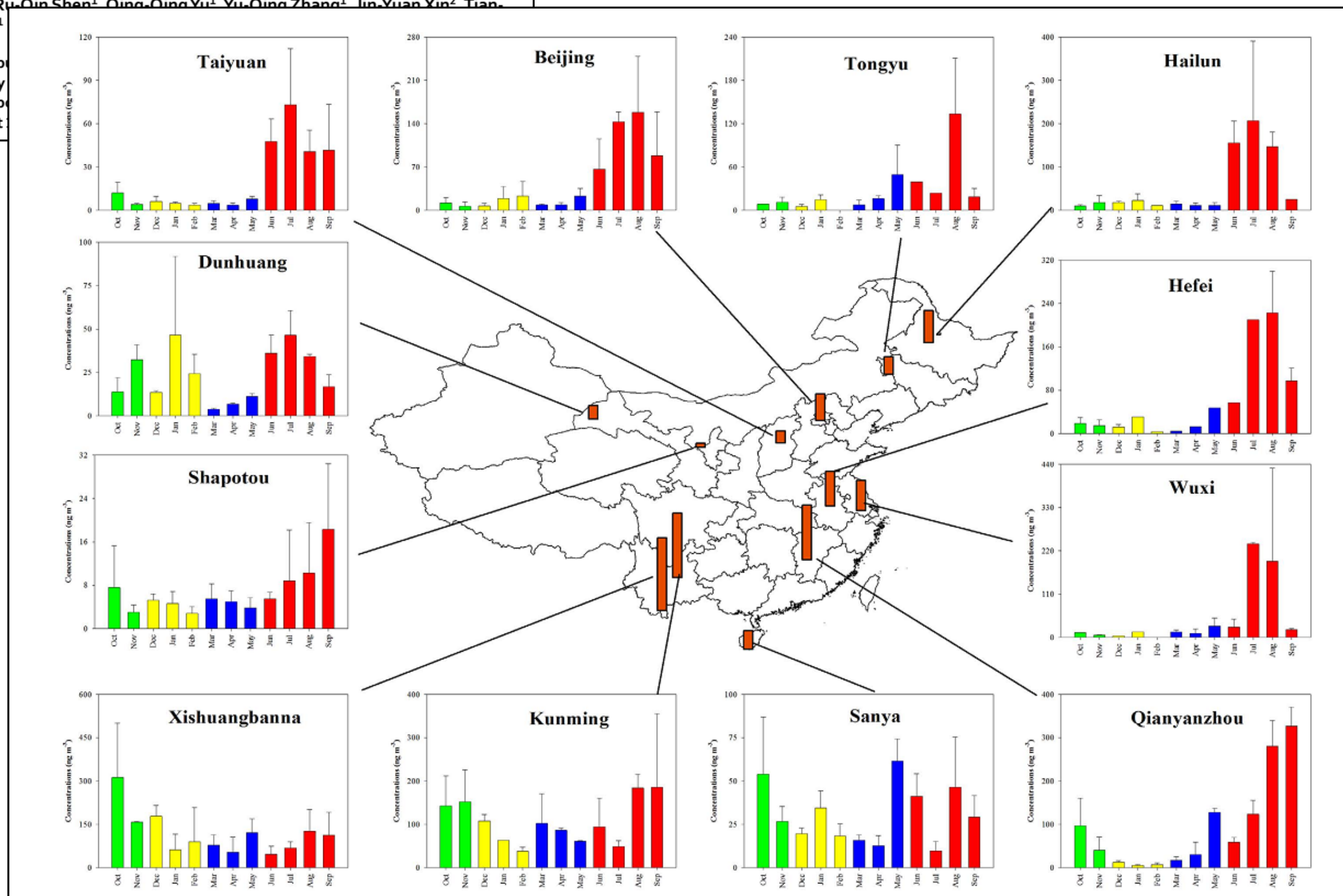
OPEN

Spatial and seasonal variations of isoprene secondary organic aerosol in China: Significant impact of biomass burning during winter

Received: 05 November 2015
Accepted: 31 December 2015
Published: 04 February 2016

Xiang Ding[1], Quan-Fu He[1], Ru-Qin Shen[1], Qing-Qing Yu[1], Yu-Qing Zhang[1], Jin-Yuan Xin[2], Tian-Xue Wen[2] & Xin-Ming Wang[1]

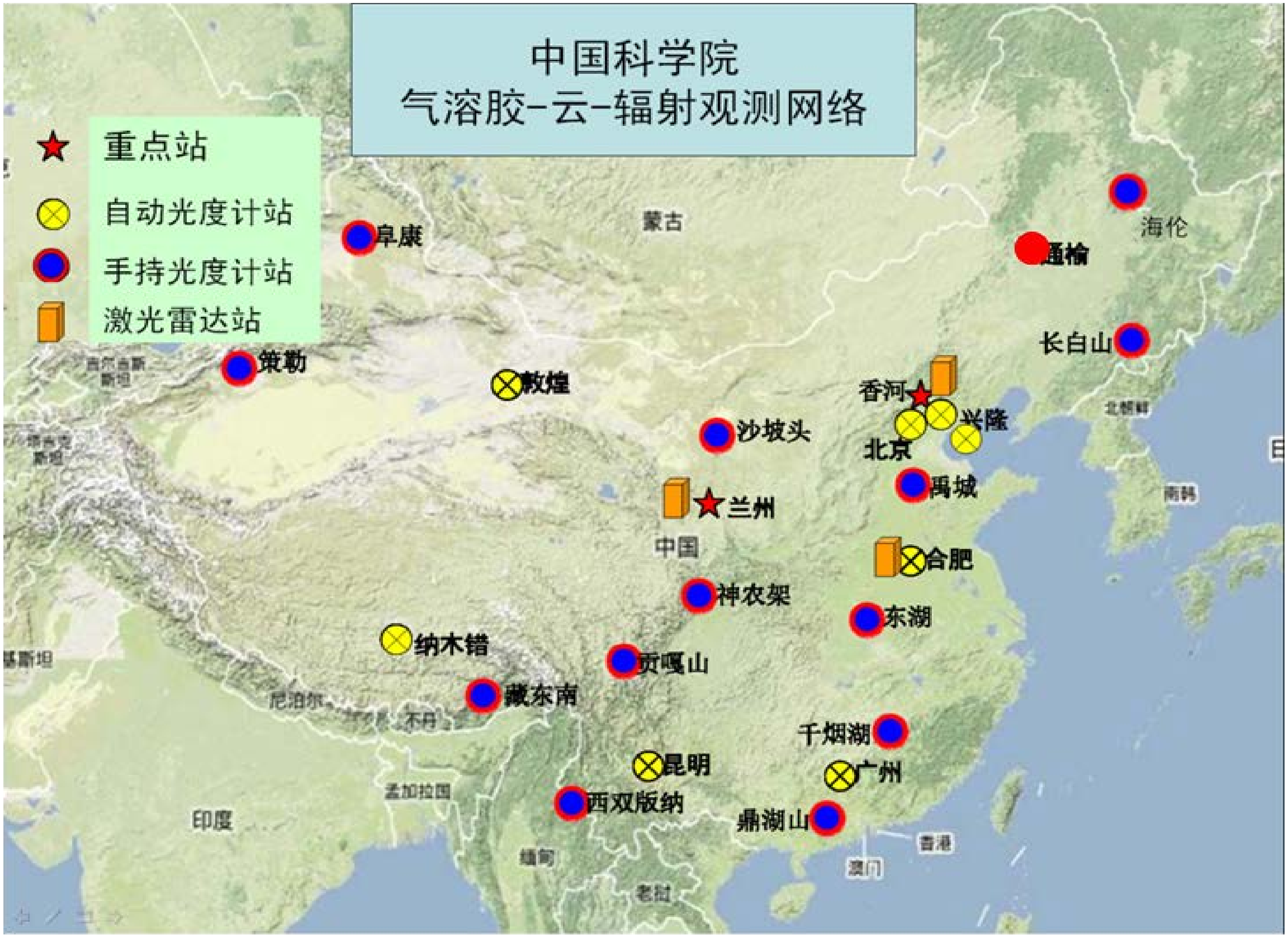
Isoprene is a substantial contrib… of isoprene SOA (SOA_I) is highly… information regarding SOA_I in p… SOA_I tracers was undertaken at …



Ding et al., Scientific Reports, 2016

Aerosol-Cloud-Radiation Measurements

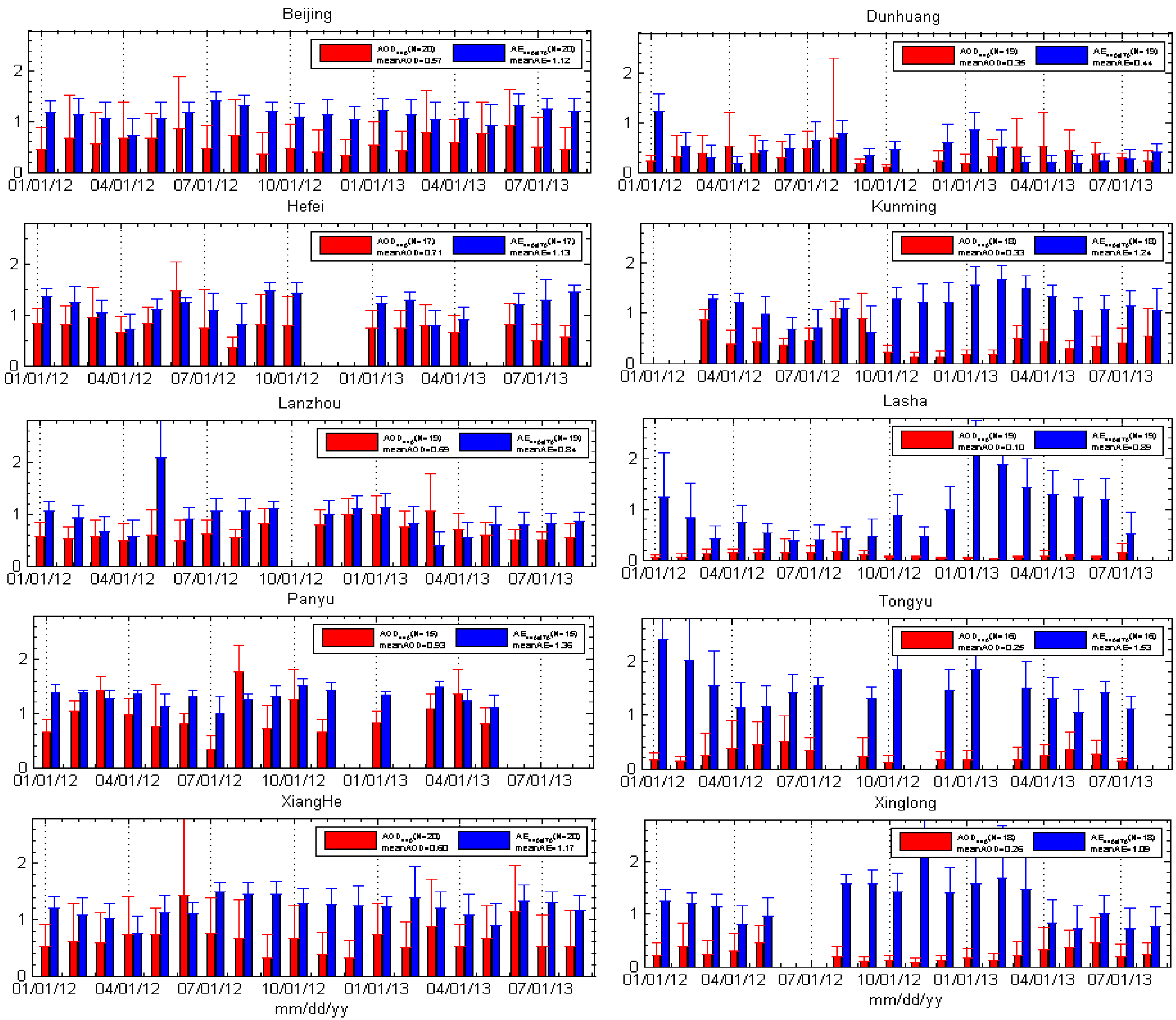
PI: Prof. P.C. Wang



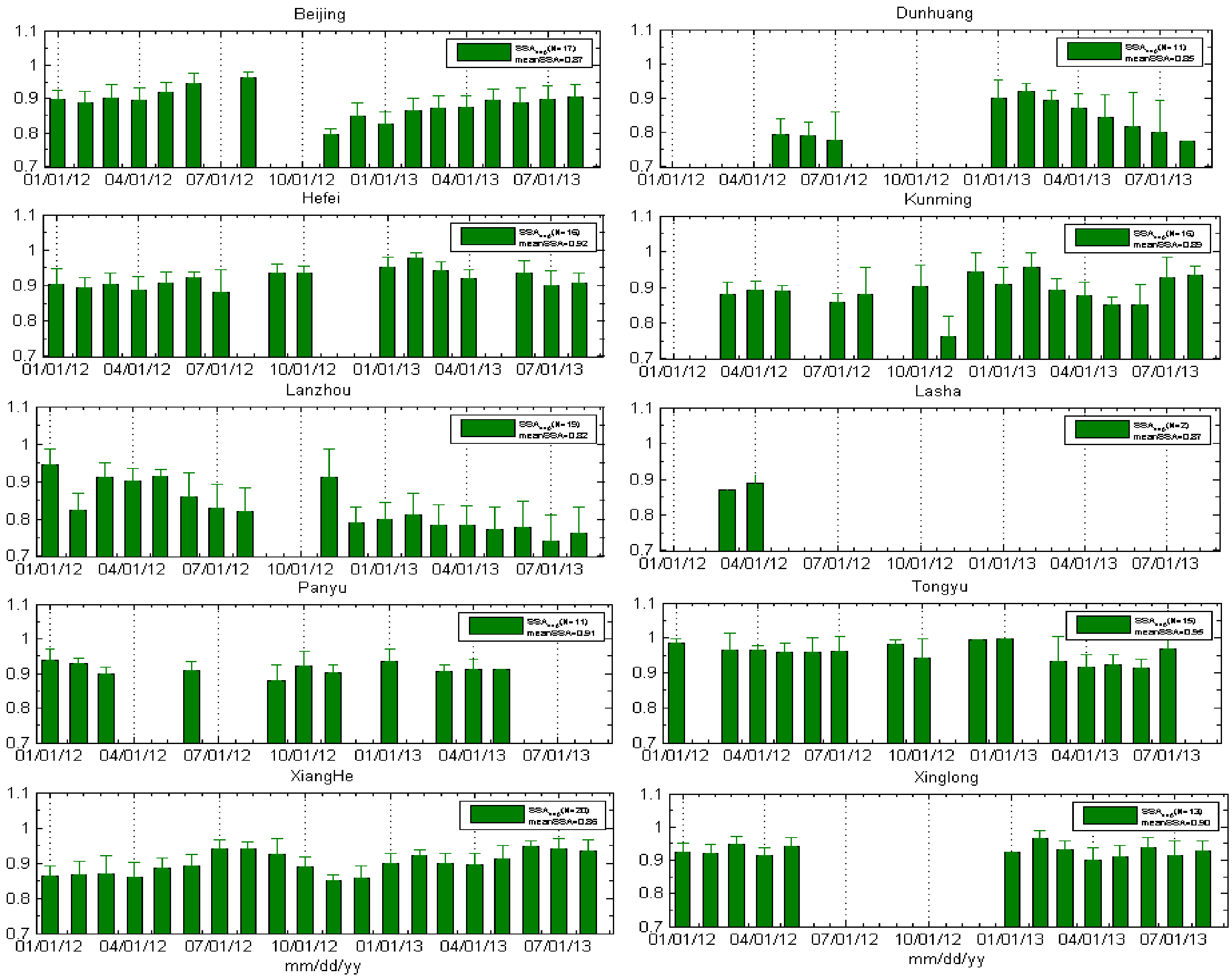
Aerosol-Cloud-Radiation Measurements

观测站点	观测时间	数据清单	频次
自动光度计站(CIMEL sunphotometer) (10个)：通榆、香河、兰州、纳木错、敦煌、合肥、广州、昆明、北京、兴隆	2012.01 -2015.12	（1） 气溶胶光学厚度(AOD) （2） 气溶胶单次散射反照率(SSA) （3） 气溶胶尺度谱(Size Distribution)	小时 小时 小时
手持光度计站 (handheld hazemeter) (13个)：长白山、禹城、鼎湖山、贡嘎山、阜康、沙坡头、东湖、千烟湖、神农架、西双版纳、策勒、藏东南、漠河	2012.01 -2015.12	（1） 气溶胶光学厚度 (AOD) （2） 气溶胶尺度指数	每日 每日
香河、兰州重点站	2012.10 -2014.12	（1） 云特性观测数据，包括云滴有效半径、云液态水含量、云型、云量、云底高度； （2） 气溶胶特性观测数据，包括光学厚度、单次散射反照率、粒子尺度谱； （3） 辐射观测数据，包括直接辐射、散射辐射、短波总辐射、长波总辐射； （4） 常规气象资料，包括温度、湿度、气压。	小时 小时 小时 小时
香河、合肥、兰州激光雷达观测站	2012.10 -2014.12	（1） 气溶胶消光系数垂直分布廓线	小时

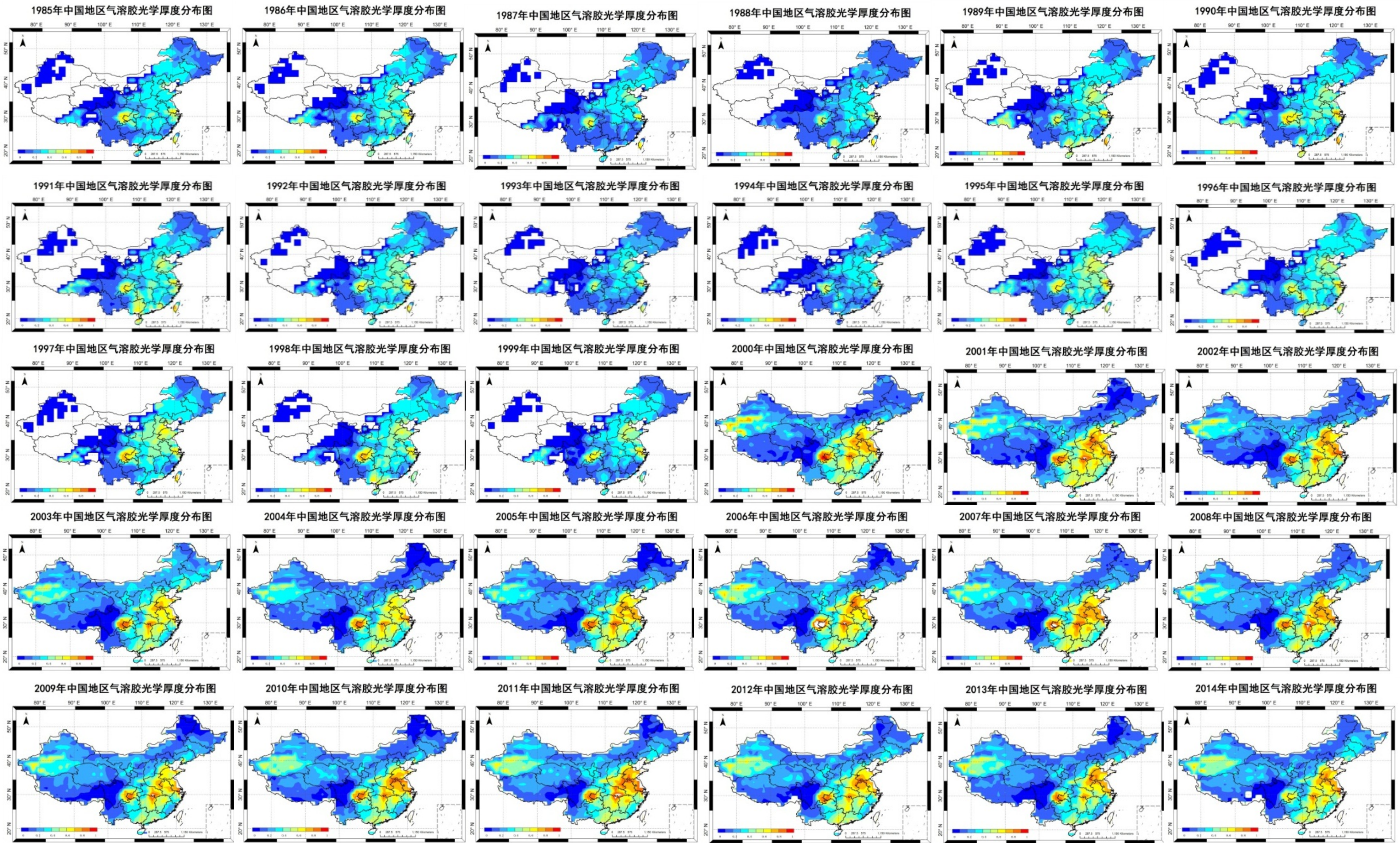
Measured Monthly Mean AOD



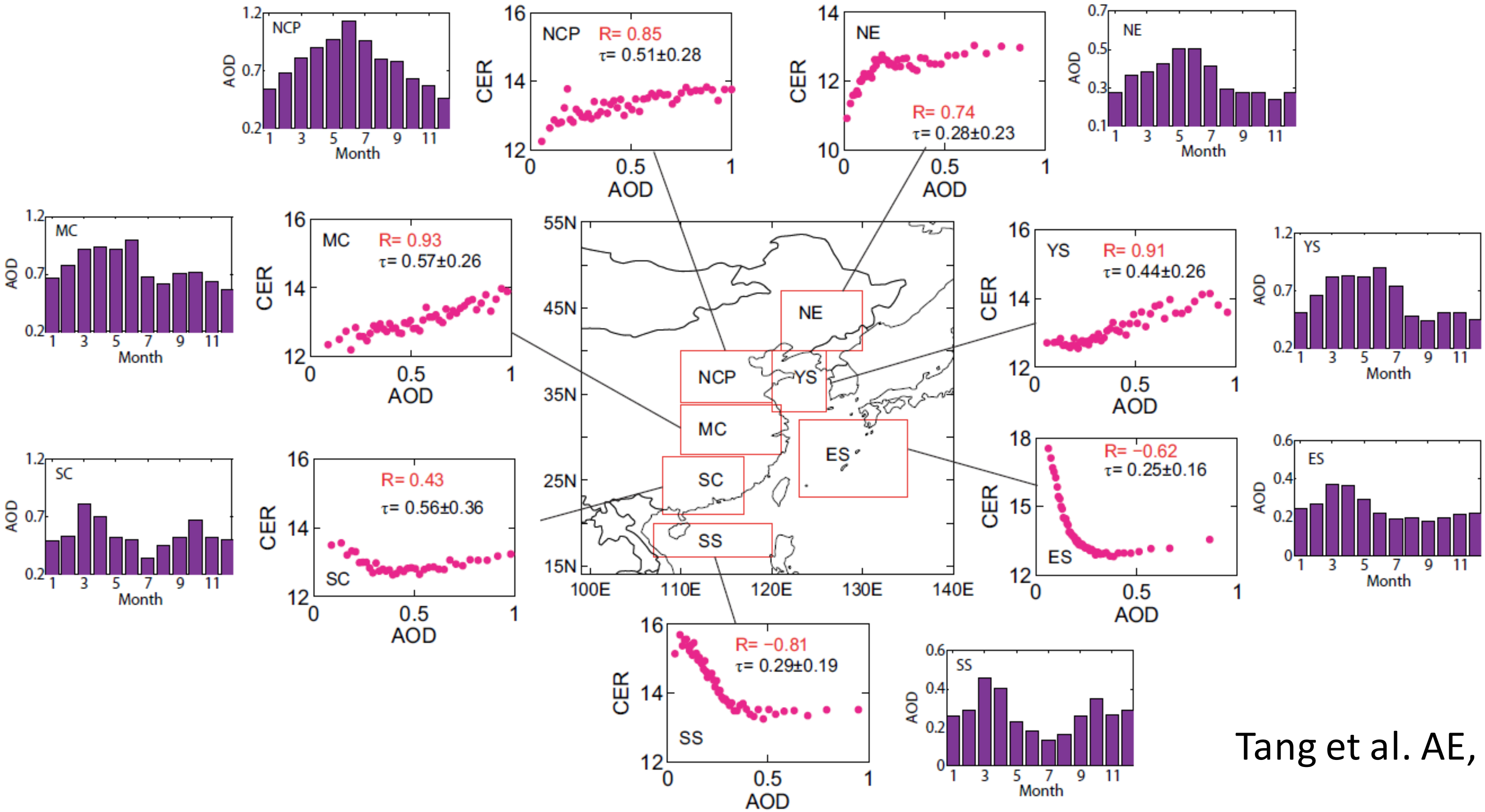
Measured Monthly Mean SSA



1985-2014 AOD from AVHRR and MODIS



Correlations between Cloud Effective Radius and AOD



Tang et al. AE, 2014

- Twomey effect was observed over ocean;
- Positive correlations between aerosol optical depth and cloud effective radius were found over land;
- Positive correlations are attributed to the associated changes in relative humidity and wind fields.

OUTLINE

- Motivation
- Nationwide measurements of concentrations and optical properties of aerosols by Chinese Academy of Sciences
- Evaluation of the simulated present-day aerosols over China from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP)
- Improved simulation of climatic effect of aerosols
- Future directions

Simulated aerosol concentrations and AOD from the ACCMIP models were downloaded from the British Atmospheric Data Center

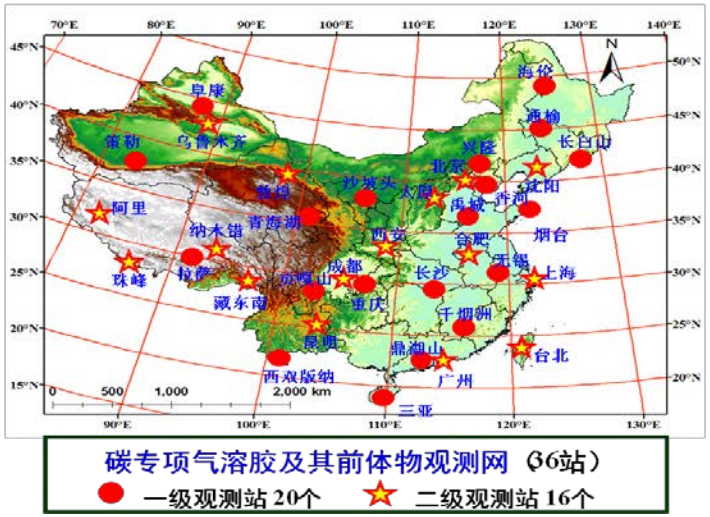
Model	Resolution (Lat/Lon/Lev)	Aerosols	Reference
CESM-CAM-superfast	1.875/2.5/L26	S	Lamarque et al. (2012)
CICERO-OsloCTM2	2.8/2.6/L60	BC,OC (SOA), S, N, NH4, D, SS	Skeie et al. (2011)
GEOSCCM	2/2.5/L72	BC, OC, S, D, SS	Oman et al. (2011)
GFDL-AM3	2/2.5/L48	BC,OC (SOA), S, N, NH4, D, SS	Donner et al. (2011)
GISS-E2-R	2/2.5/L40	BC,OC (SOA), S, N, NH4, D, SS	Shindell et al. (2013)
GISS- TOMAS	2/2.5/L40	BC, OC, S, NH4, D, SS	Lee and Adams (2010)
HadGEM2	1.25/1.875/L38	BC, OC(SOA), S, D, SS	Collins et al. (2011)
LMDzORINCA	1.895/3.75/L19	BC	Szopa et al. (2012)
MIROC-CHEM	2.8/2.8/L80	BC, OC (SOA), S, D, SS	Watanabe et al. (2011)
NCAR-CAM3.5	1.875/2.5/L26	BC, OC (SOA), S, D, SS	Lamarque et al. (2012)
NCAR-CAM5.1	1.875/2.5/L30	BC, OC (SOA), S, D, SS	Liu et al. (2012)
STOC-HadAM3	5.0/5.0/L19	S, N, NH4	Stevenson et al. (2004)

http://badc.nerc.ac.uk

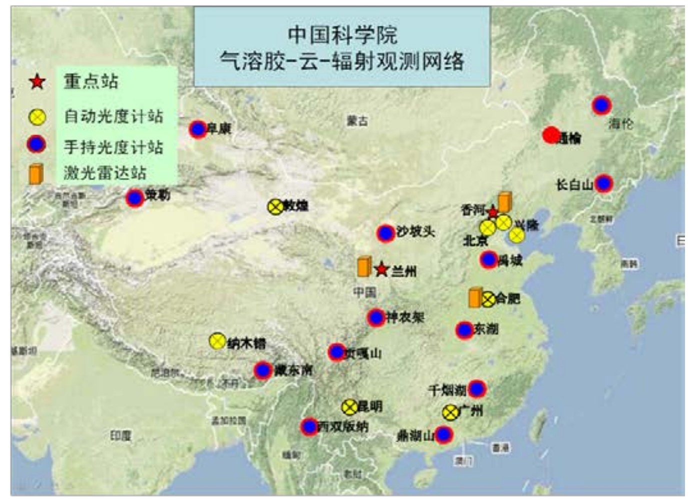
Aerosol datasets used for evaluation of ACCMIP models

(1) Aerosol Observation Networks of Chinese Academy of Sciences Launched in 2011

Measurements of conc.



Measurements of optical properties



- Continuous measurements over years 2011-2014;
- Size-resolved speciated aerosol concentrations for 9 size bins of <0.43, 0.43-0.65, 0.65-1.1, 1.1-2.1, 2.1-3.3, 3.3-4.7, 4.7-5.8, 5.8-9.0, >9.0 μm;
- For measurements of AOD using CIMEL sunphotometer, data processing procedures are the same as those of AERONET .

Aerosol datasets used for evaluation of ACCMIP models

(2) Measured concentrations collected from the literature

BC+OC

Qingdao (121°E ,36
Qingdao (120.5°E ,36
Fenghuanshan (124°E ,40.5°N
Waliguan, Qinghai-T Plateau (100.9°E ,36
Lin'an (120.4°E ,31
Cape D'Aguilar, Hong (114.3°E ,22.0°
Chnshu (119.4°E ,30
Waliguan Mount (100.9°E ,36.3°
Lin'an (119.7°E ,30
Shang Dian Zh (117.1°E ,40.7°
Cape D'Aequie (114.3°E ,22.2°
Long Feng Mount (127.6°E ,44.7°

$PM_{2.5}$

Beijing (116.5°E, 39.9°N)
Changchun (125.2°E, 45.5°N)
Qingdao (120.2°E,36.0°N)
Tianjin (117.1°E, 39.0°N)
Xi'an (108.6°E, 34.2°N)
Yulin (109.5°E, 38.2°N)
Chongqing (106.3°E, 29.4°N)
Guangzhou (113.1°E, 23.1°N)
Hong Kong (115.1°E, 25.2°N)
Hangzhou (120.1°E, 30.2°N)
Shanghai (121.3°E, 31.1°N)
Nanjing (118.5 E, 32.0°N)
Wuhan (114.2°E, 30.4°N)
Xiamen (118.0°E, 24.3°N)
Shenzhen (114.1 E, 24.3°N)

Sulfate

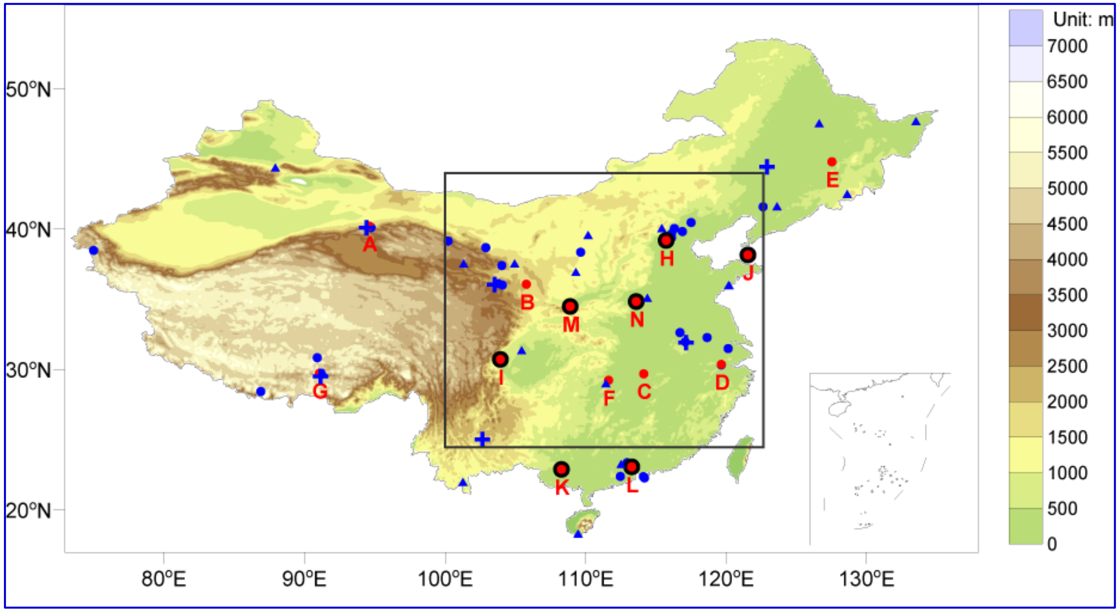
Beijing(116.4°E ,3
Nanjing(118.8°E ,3
Shanghai(121.5°E ,
Hong Kong(114.2°E
Qingdao(121°E ,3
Dalian (121.5°E ,
Fenghuanshan (124°E
Lin' an(120.4°E ,3

Nitrate

Beijing(116.4°E ,39.9°N)	September 2000	Autumn	11.16μg m-3	He et al. (2001)
		Winter	15.35μg m-3	
		Spring	7.26 μg m-3	
	2001-2003	Spring	11.92 μg m-3	Wang et al. (2005)
		Summer	11.18 μg m-3	
		Autumn	9.14 μg m-3	
		Winter	12.29 μg m-3	
Nanjing(118.8°E ,32.0°N)	2001	FEB	8.06 μg m-3	Yang et al. (2005)
		SEP	3.24 μg m-3	
Shanghai(121.5°E ,31.2°N)	20 March 1999 -27 March 2000	Spring	5.4 μg m-3	Ye et al. (2003)
		Summer	2.92 μg m-3	
		Autumn	5.12 μg m-3	
		Winter	9.64 μg m-3	
Hong Kong(114.2°E ,22.3°N)	November 2000 to February 2001 and June to		1.20 μg m-3	Ho et al. (2006)
Yulin (109.43°E ,38.20°N)	30 March to 1 May 2001		1.3 μg m-3	Xu et al. (2004)
Xi' an(108.9°E ,34.3°N)	1996 -1997	Autumn	22 μg m-3	Zhang et al. (2002)
		Winter	65 μg m-3	
		Spring	33 μg m-3	
		Summer	16 μg m-3	
Qingdao(121°E ,36.5°N)	25 Feb–15 Mar, 2002		10.3 μg m-3	Takami et al. (2006)
	17 Feb–02 Mar, 2001		12.5 μg m-3	
Dalian (121.5°E ,39°N)	25 Feb–16 Mar, 2002		12.8 μg m-3	
Fenghuanshan (124°E ,40.5°N)	17 Feb–01 Mar, 2001		7.3 μg m-3	
Lin' an(120.4°E ,31.3°N)	18 Feb- 30 Apr 2001		6.5 μg m-3	Wang et al. (2004)

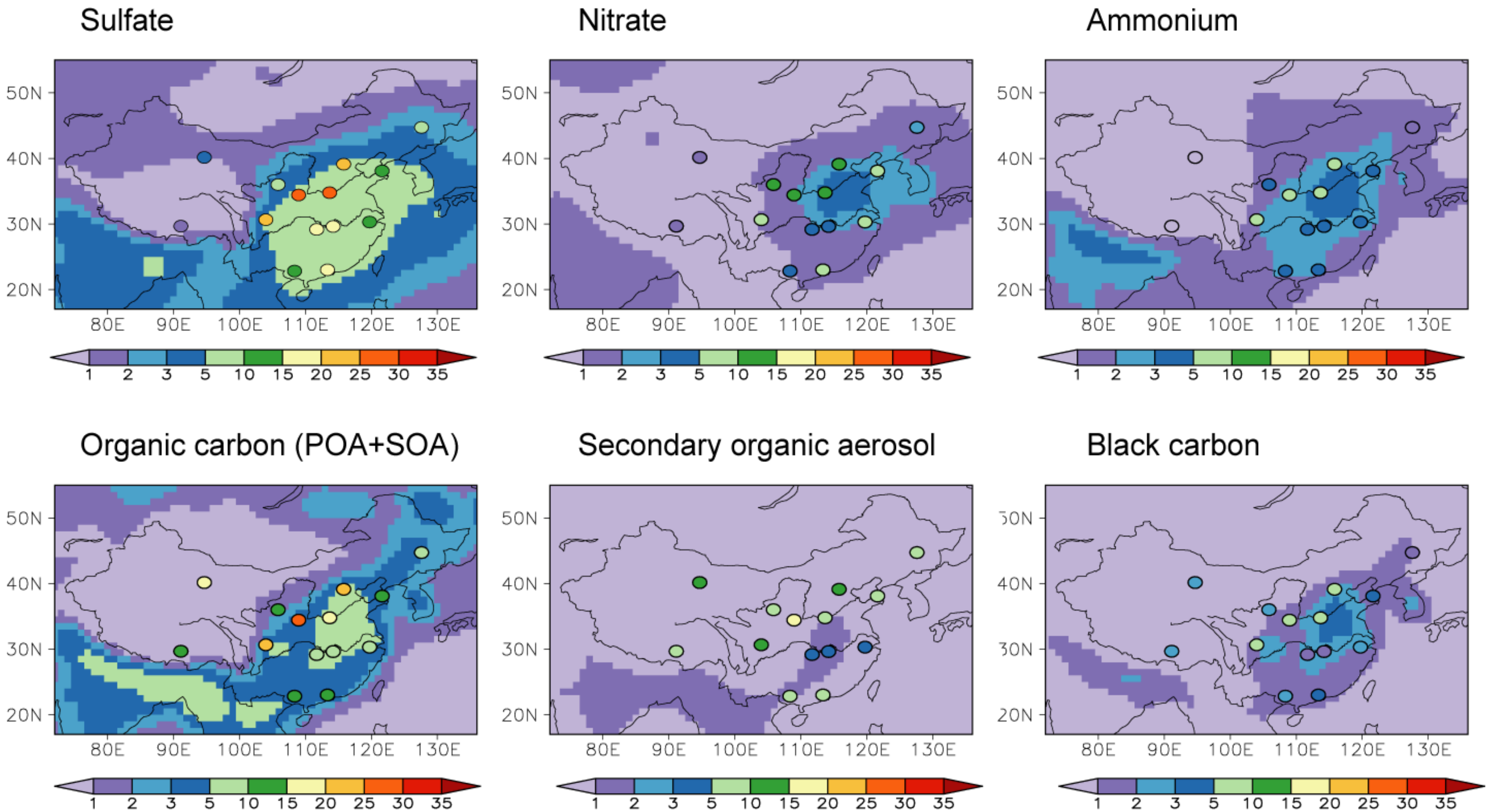
Aerosol datasets used for evaluation of ACCMIP models

(3) Measured concentrations at CAWNET and AOD from other sources



- Measured concentrations at 14 CAWNET sites (red circles) of the China Meteorological Administration (CMA) Atmosphere Watch Network (CAWNET)
- Measured AOD from
  -- 25 AERONET sites (blue circles) (Holben et al., 1998)
  -- 20 sites (blue triangles) of China Sun Hazemeter Network (CSHNET) (Xin et al, 2006)
  -- Satellite measurements

Multi-model mean surface-layer concentrations from ACCMIP vs. Measurements at CAWNET sites

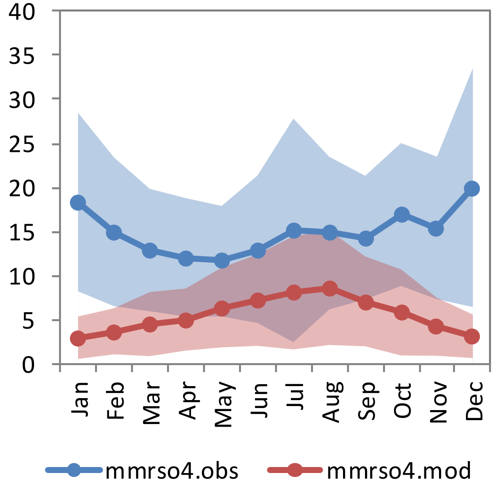


- Shades: ACCMIP concentrations for year 2000
- Circles: Measurements at CAWNET sites for 2006-2007

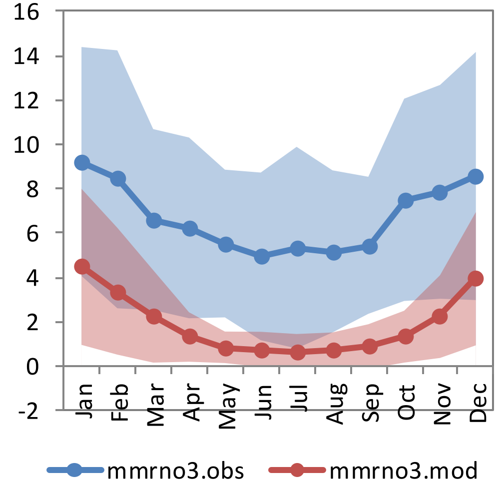
Unit: $\mu g\ m^{-3}$

Simulated surface-layer concentrations from ACCMIP models vs. Measurements at CAWNET sites

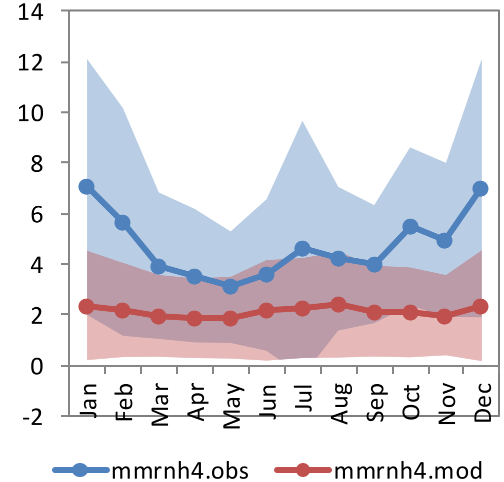
Sulfate



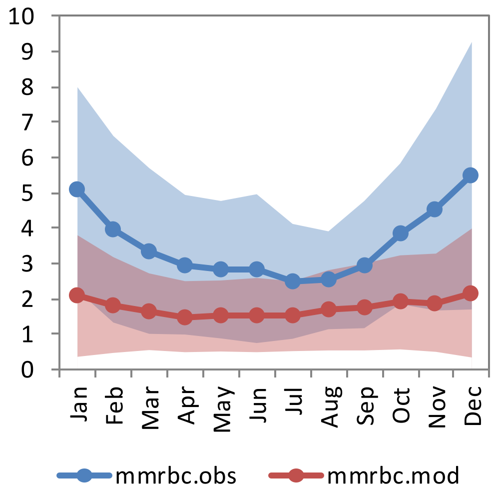
Nitrate



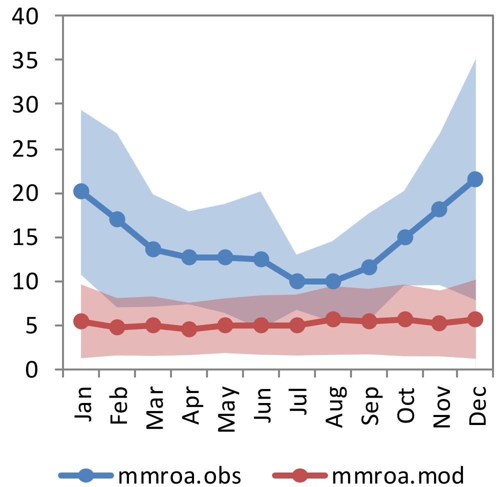
Ammonium



BC



OC



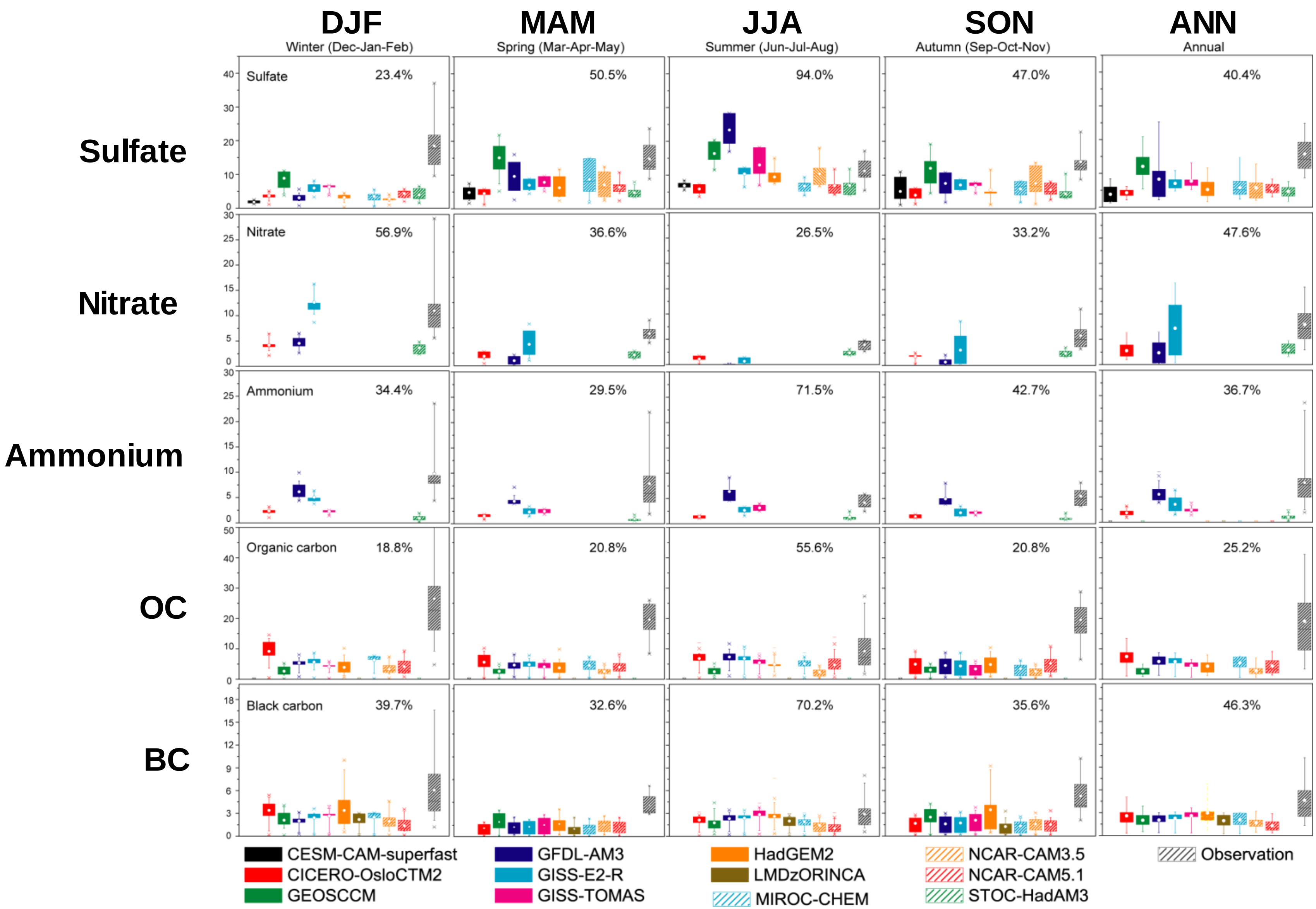
- **Red: Multi-model mean conc.;**
- **Blue: Observed conc.**
- **Both simulated and measured concentrations are averaged over CAWNET sites;**

The ACCMIP models underestimate aerosol concentrations in China

Annual mean bias (MB, unit: $\mu g\ m^{-3}$) and normalized mean bias (NMB, unit:%)

	Sulfate		Nitrate		Ammonium		OA		SOA		BC	
	MB	NMB	MB	NMB	MB	NMB	MB	NMB	MB	NMB	MB	NMB
CESM-CAM-superfast	-11.6	-77.3%										
CICERO-OsloCTM2	-11.9	-79.7%	-5.5	-81.8%	-3.6	-74.9%	-6.9	-47.7%	-7.3	-88.4%	-1.8	-50.9%
GEOSCCM	-5.8	-38.8%					-10.6	-73.0%			-1.7	-47.5%
GFDL-AM3	-6.8	-45.2%	-5.6	-83.8%	+0	+0.5%	-8.0	-55.5%	-8.0	-96.7%	-2.1	-58.3%
GISS-E2-R	-10.0	-66.7%	-3.7	-55.8%	-3.0	-61.8%	-8.0	-55.4%	-7.1	-85.6%	-1.9	-53.8%
GISS-TOMAS	-8.2	-54.9%			-2.9	-61.2%	-9.6	-66.0%			-1.6	-44.7%
HadGEM2	-9.4	-62.7%					-8.8	-60.5%	-7.3	-88.2%	-0.8	-22.2%
LMDzORINCA											-2.3	-64.3%
MIROC-CHEM	-11.0	-73.5%					-9.5	-65.8%	-8.2	-98.3%	-2.3	-63.1%
NCAR-CAM3.5	-8.8	-58.4%					-10.8	-74.3%	-8.1	-98.2%	-2.0	-55.6%
NCAR-CAM5.1	-9.3	-62.1%					-7.4	-51.3%	-5.6	-67.2%	-2.3	-63.2%
STOC-HadAM3	-10.6	-70.8%	-4.6	-68.9%	-3.8	-79.8%						
Multi-model mean												
All sites	-9.4	-62.7%	-4.9	-72.7%	-2.6	-55.2%	-8.8	-61.0%	-7.4	-89.0%	-1.9	-52.1%
Urban sites	-13.7	-67.9%	-6.9	-76.8%	-4.3	-62.6%	-11.1	-62.8%	-9.1	-89.9%	-3.1	-59.7%
Rural sites	-5.0	-51.7%	-2.9	-64.4%	-1.0	-36.3%	-6.6	-58.2%	-5.7	-87.5%	-0.7	-32.8%

Simulated surface-layer concentrations from ACCMIP models (color bars) vs. Measurements from the literature (grey bars)



Simulated AOD from ACCMIP models vs. Satellite measurements

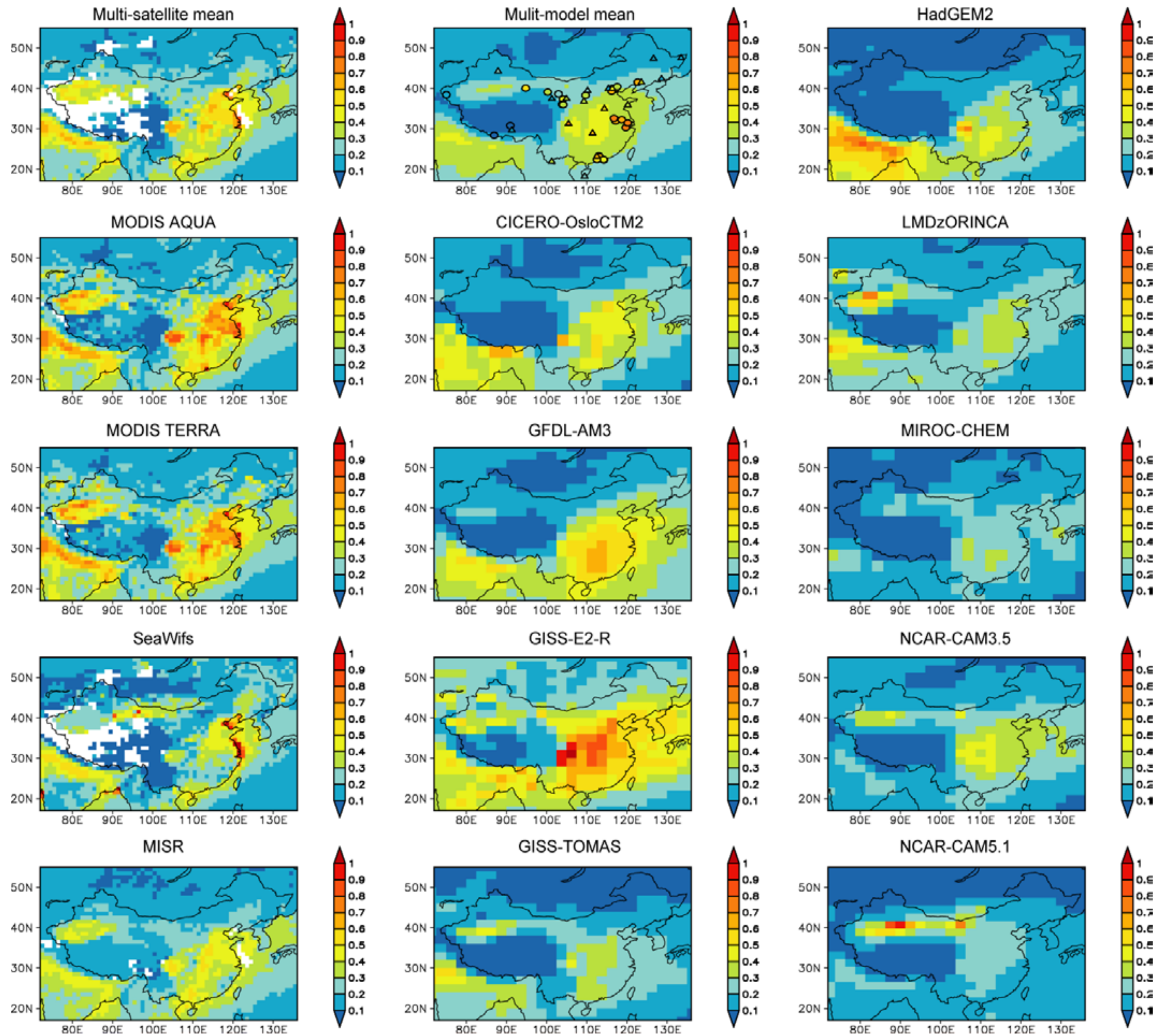
Multi-satellite mean

MODIS AQUA (2002-2005)

MODIS TERRA (2001-2005)

SeaWifs (2000-2005)

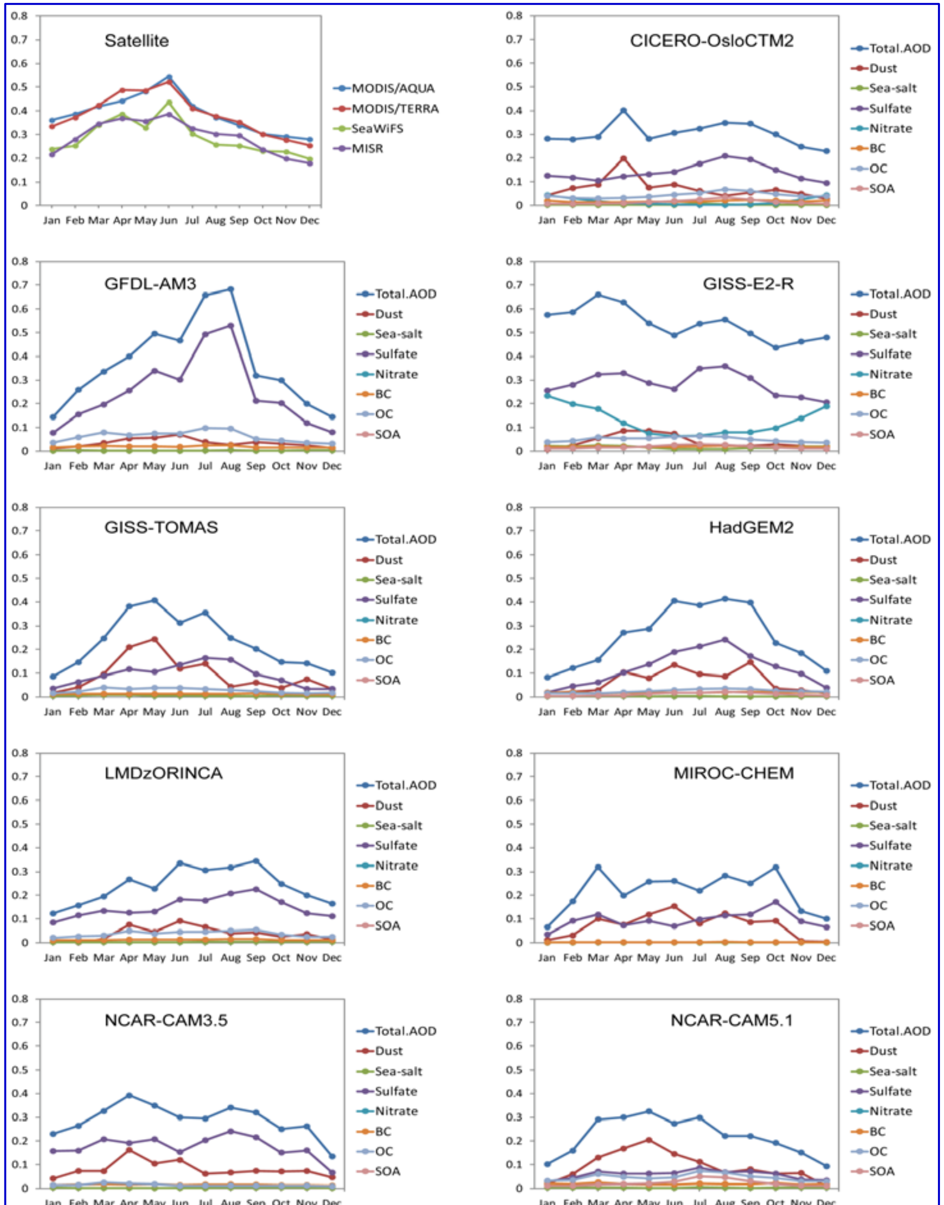
MISR (2000-2005)



the

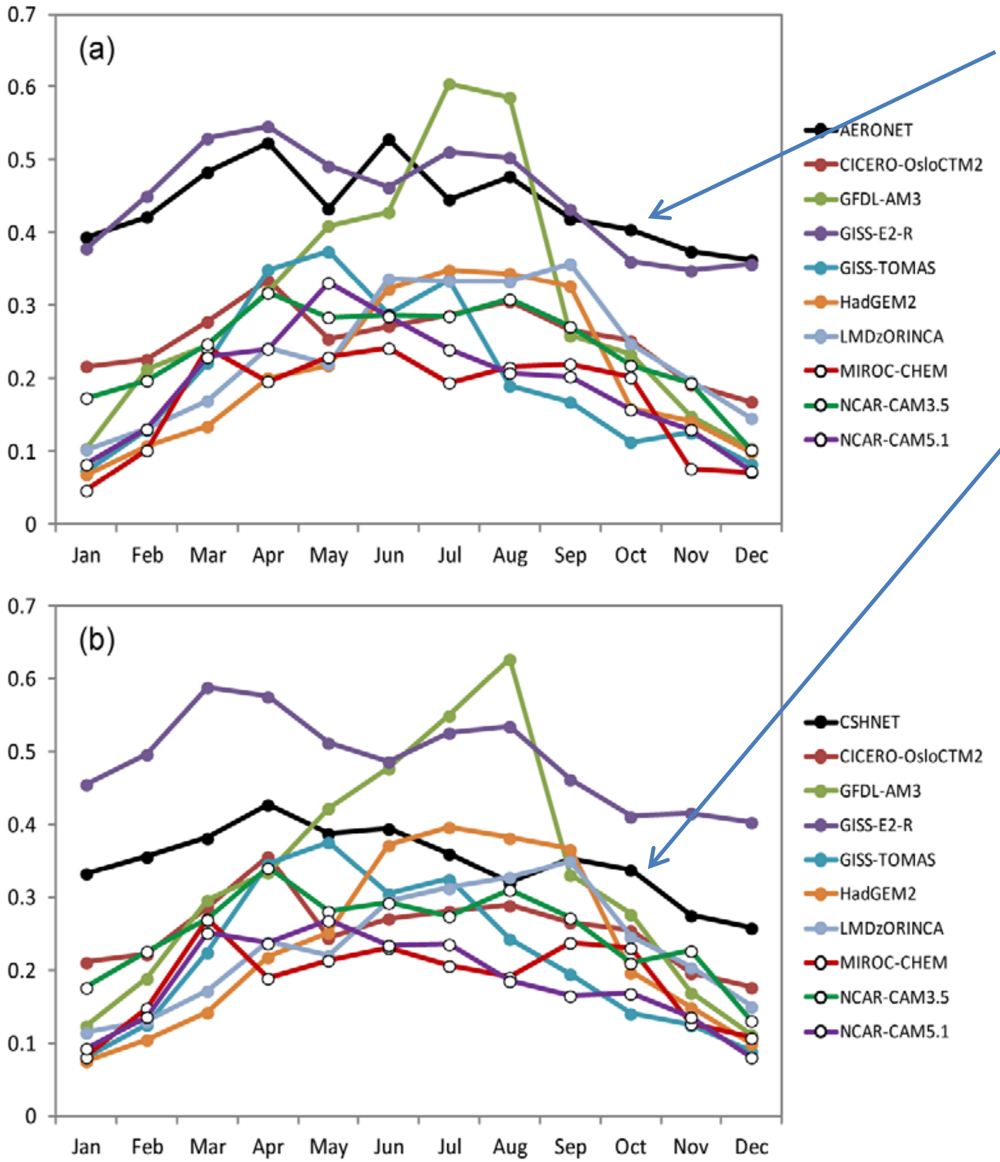
Simulated AOD from the ACCMIP models

Satellite retrievals



- Both model results and satellite measurements are averaged over eastern China (100°–122°E, 25°–45°N);
- Satellite measurements show one peak in March or April and the other peak in June;
- Simulated AOD values peak in March-May and/or July-October;
- The most dominant aerosol species that contribute to the simulated AOD are sulfate and mineral dust in most models.

Simulated AOD from ACCMIP models vs. Ground-based measurements

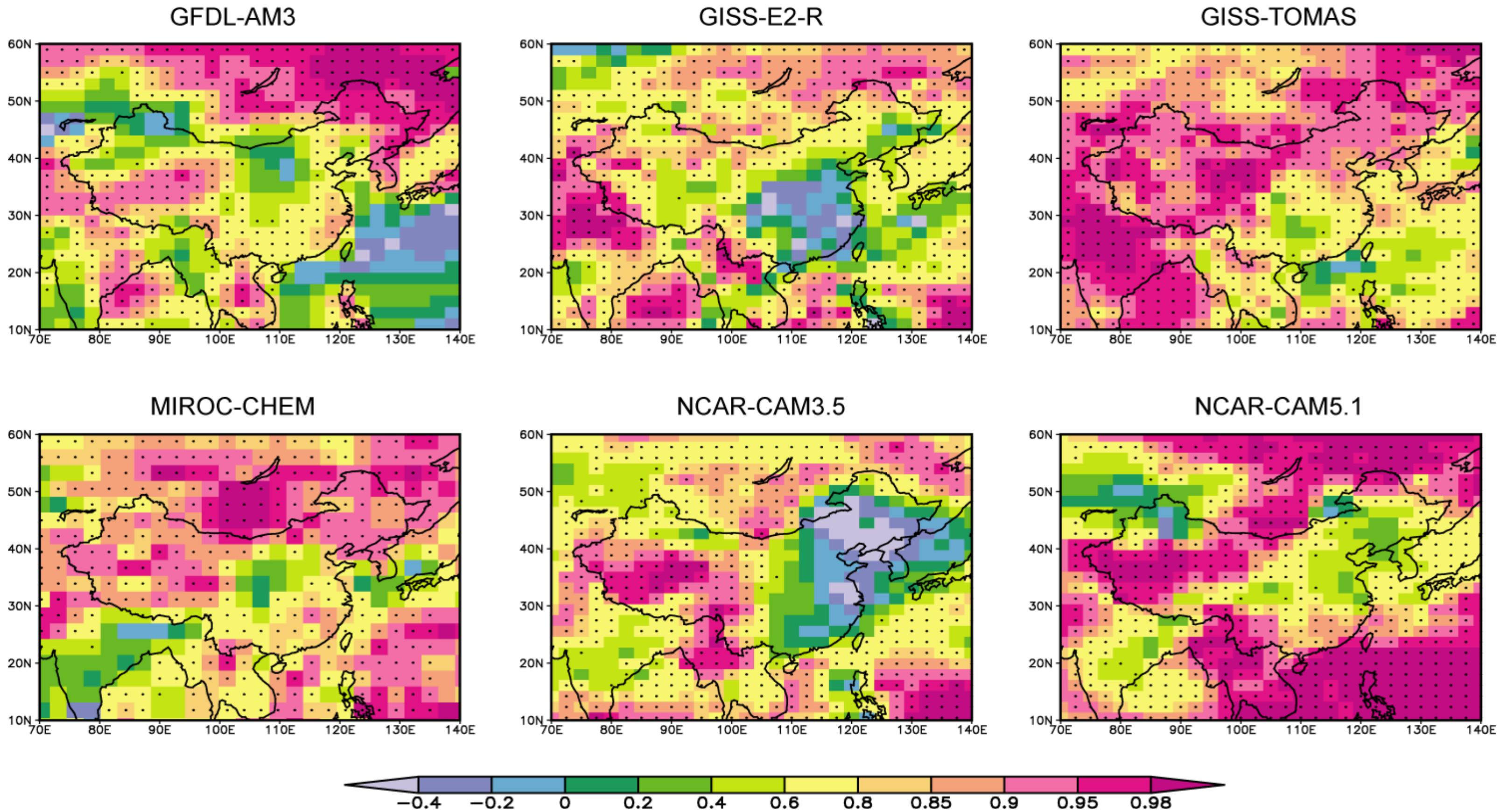


Black solid line: AOD from AERONET+CAS

Black solid line: AOD from CSHNET+CAS

The multi-model mean AOD values show normalized mean bias of –37% at AERONET+CAS sites and of –23% at CSHNET+CAS sites

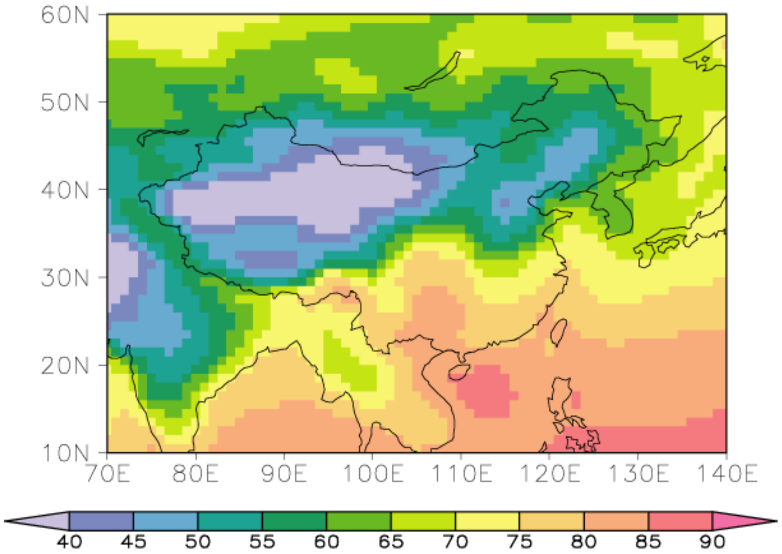
Correlation coefficients between monthly surface-layer aerosol concentrations and monthly AOD from the ACCMIP models



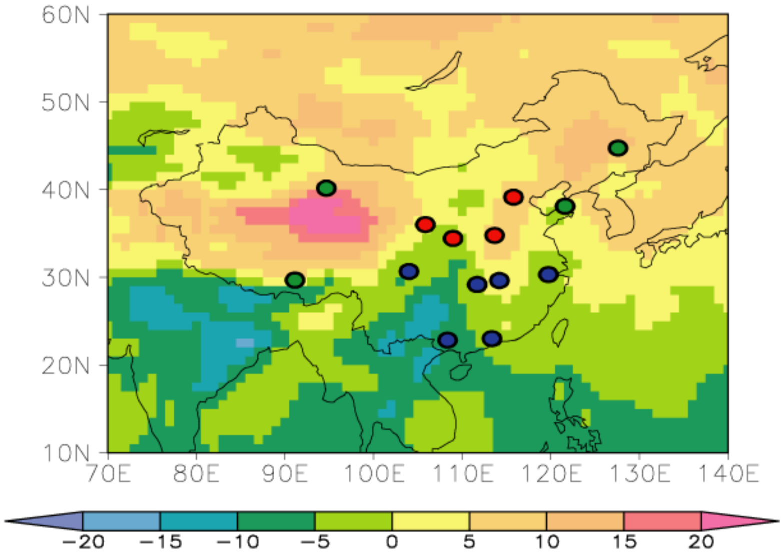
- The models need to simulate accurately the hygroscopic growth of sulfate;
- The models need to capture not only the surface-layer concentrations but also column burdens , especially for BC and OC in the middle troposphere as a result of the springtime inflow from South Asia.

Biases in simulated relative humidity in the ACCMIP models (Year 2000 surface-layer RH)

NASA/GEOS4 assimilated RH averaged over years 1996-2005



ACCMIP – GEOS4



The ACCMIP models overestimate relative humidity by up to 10% in northern China whereas underestimate relative humidity by up to 15% in southern China.

Conclusions and Suggestions

- The ACCMIP models underestimate concentrations of all major aerosol species in China. On an annual mean basis, the multi-model mean concentrations of sulfate, nitrate, ammonium, organic carbon, and black carbon show normalized mean biases of –63%, –73%, –54%, –72%, and –53%, respectively.
- The multi-model mean AOD values show normalized mean bias of –37% at AERONET sites and of –23% at CSHNET sites in China.
- Analyses suggest that more accurate representation of (1) the magnitudes and seasonal variations of concentrations of all anthropogenic aerosols, (2) biomass burning aerosols in the middle troposphere, (3) relative humidity and hygroscopic growth of aerosols are essential for simulating climatic effect of aerosols in China in current climate models.
- There is a mismatch between model year and the years of measurements, which does not influence our conclusions. Justifications have been done by using the GEOS-Chem simulations of concentrations and AOD with changes in emissions and assimilated met fields for years 2000-2013.

OUTLINE

- Motivation
- Nationwide measurements of concentrations and optical properties of aerosols by Chinese Academy of Sciences
- Evaluation of the simulated present-day aerosols over China from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP)
- Improved simulation of climatic effect of aerosols
- Future directions

IPCC AR5 underestimated the role of aerosols in China in historical and future changes in climate?

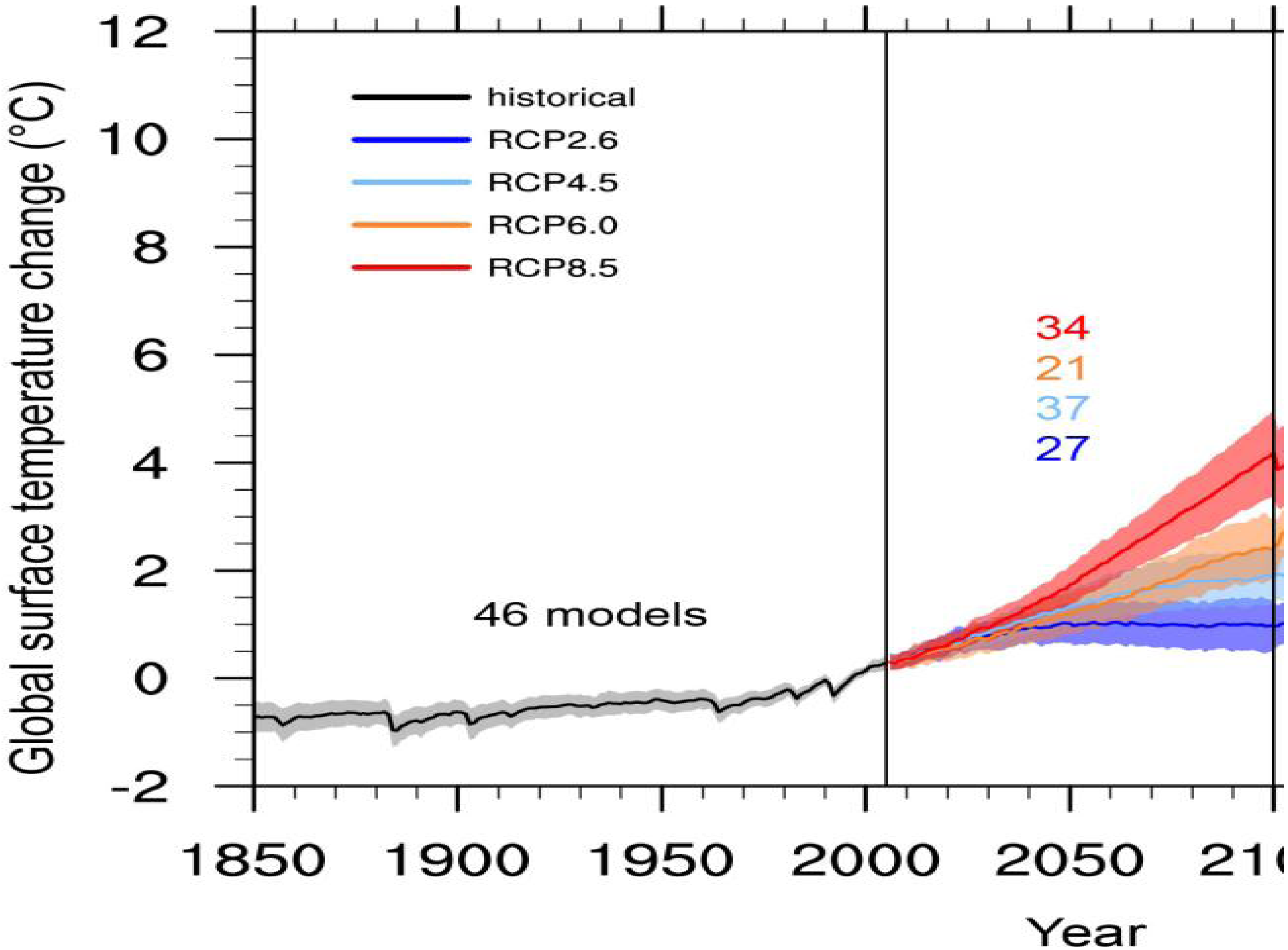
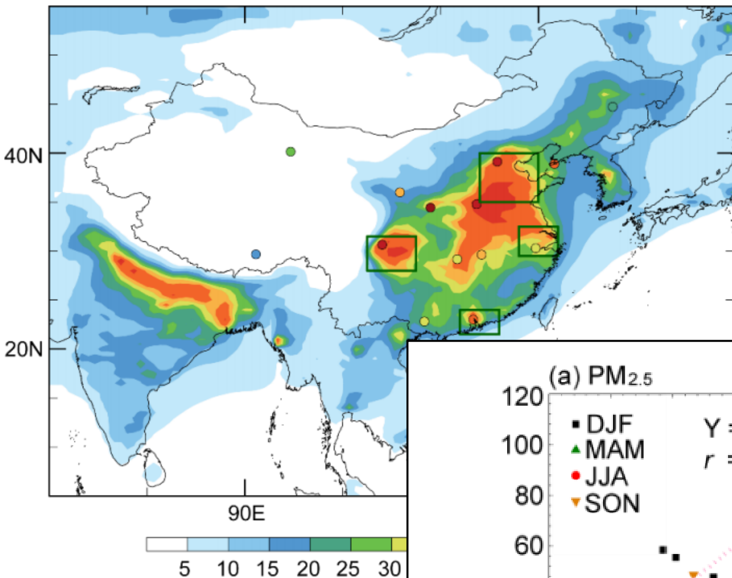
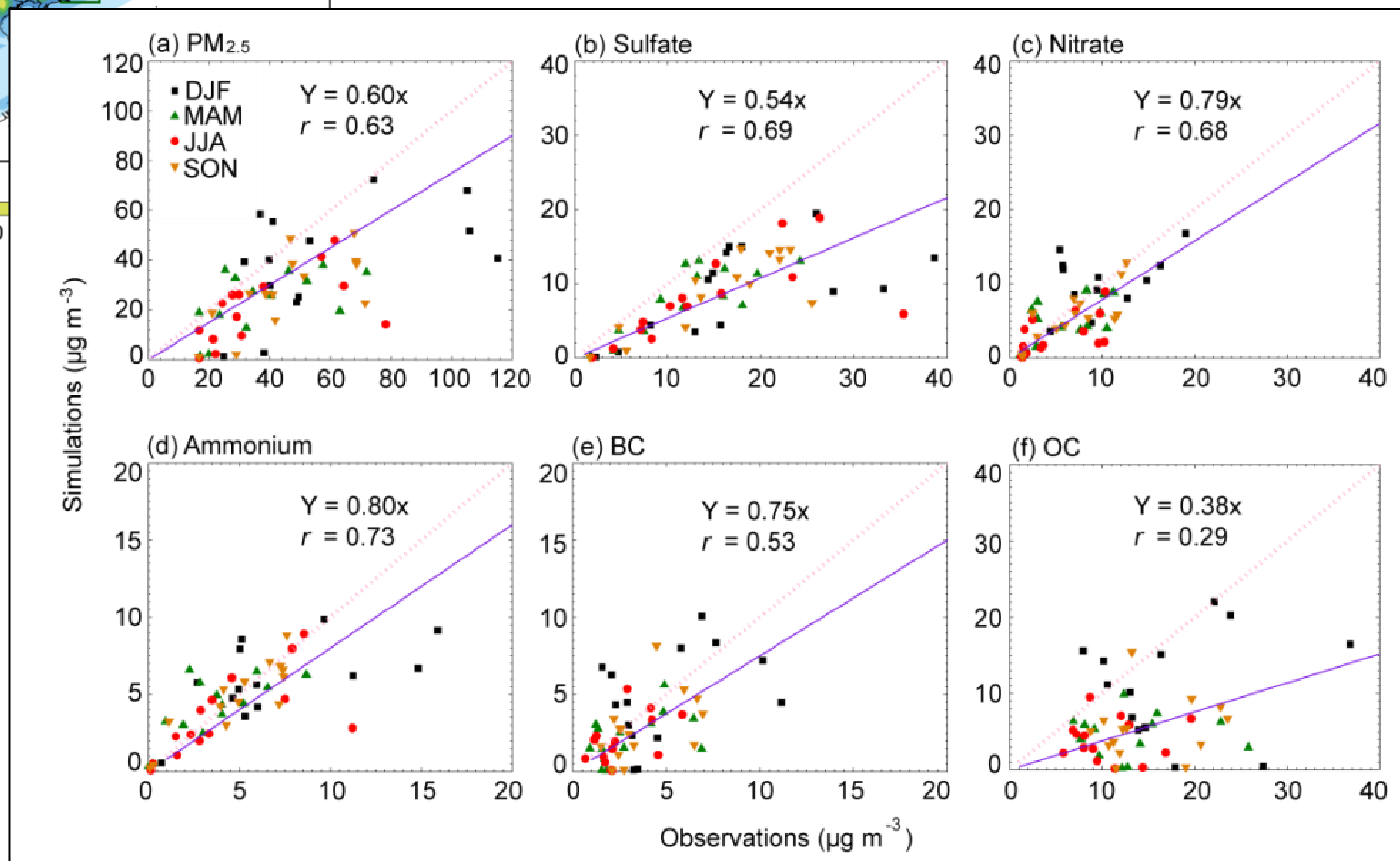


Figure 12.5

Comparisons of simulated year 2010 aerosol concentrations from the GEOS-Chem model with 2006-2007 measurements from CAWNET (Zhang et al., 2012)





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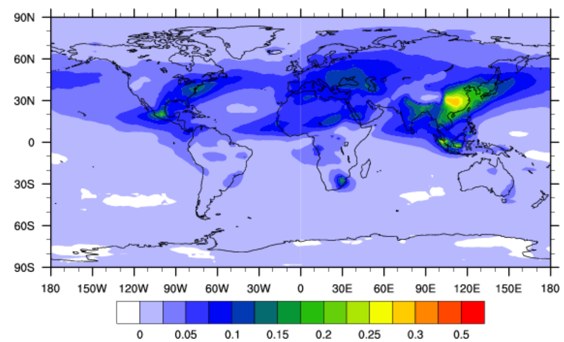
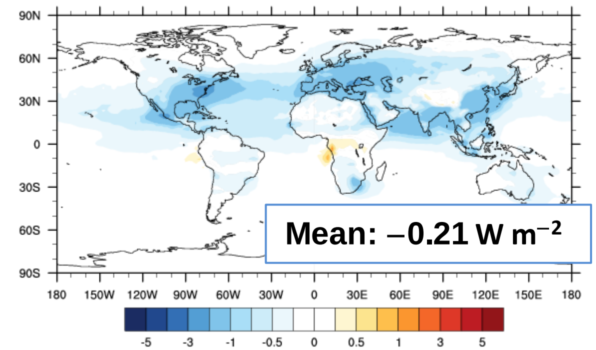
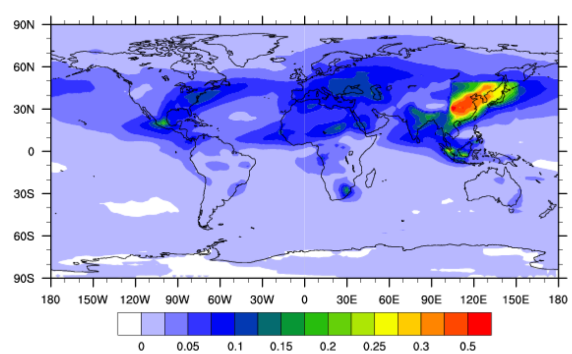
	Anthrop. AOD	TOA DRF

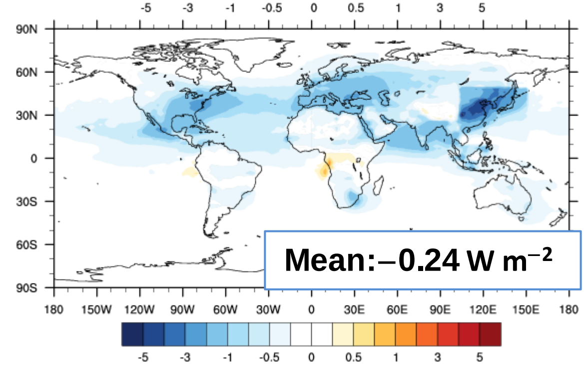
NCAR CAM



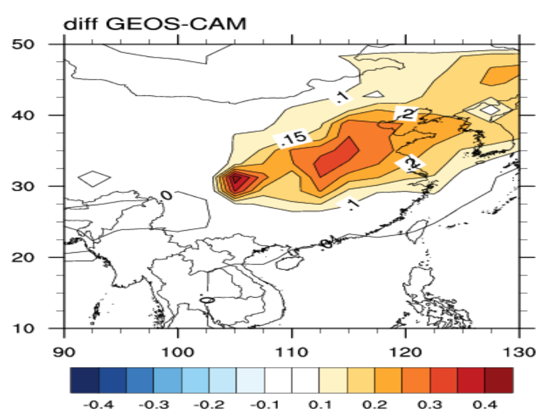


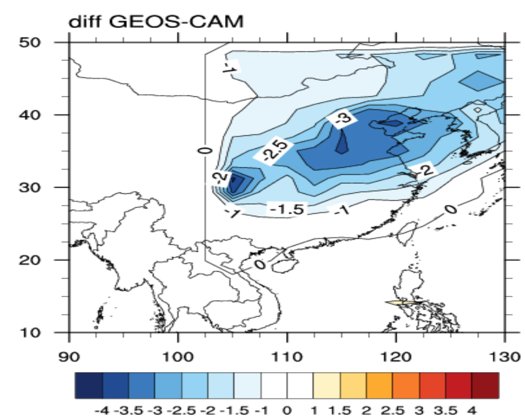
GEOS-Chem





GEOS-Chem – CAM



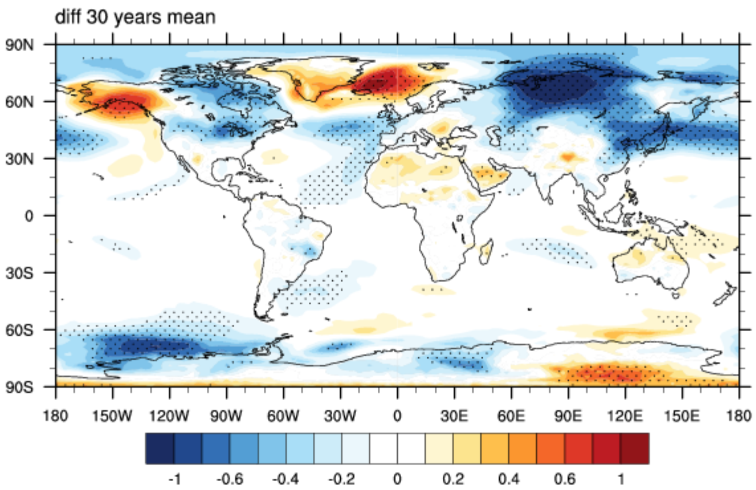


ΔAOD is about 0.3

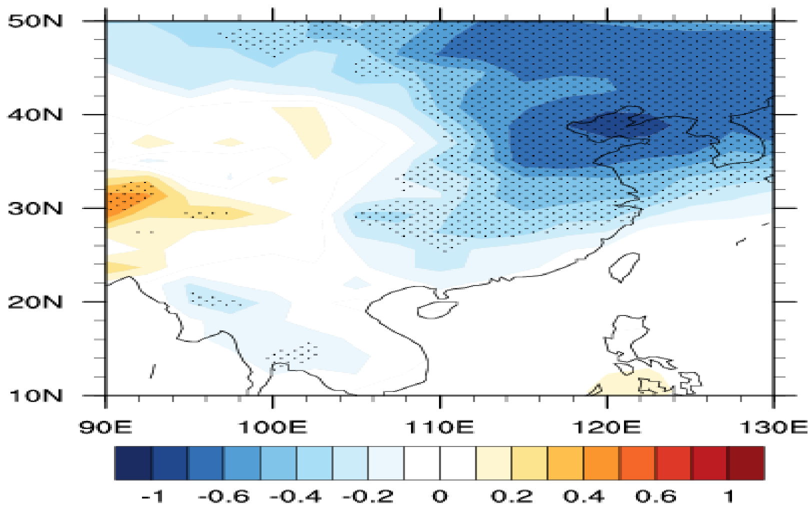
ΔDRF : –0.16 W m^{-2}

averaged over eastern China

Differences in simulated year 2000 surface-air temperature (GEOS-Chem –CAM)



ΔGlobalMean: –0.06 ° C

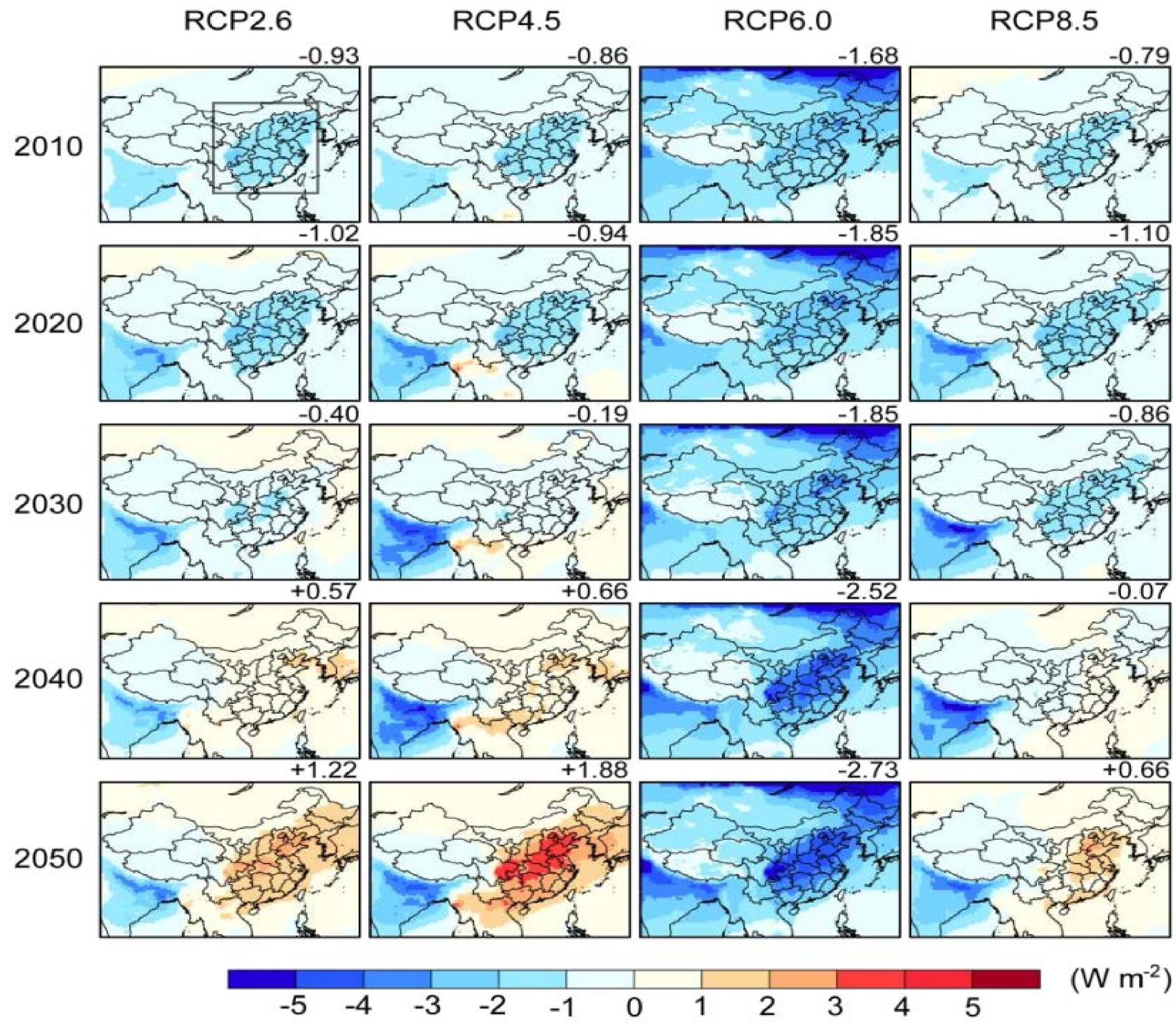


ΔEastChina: : –0.29 ° C

(105-122.5°E, 20-40 ° N)

Equilibrium climate， Q-Flux Ocean， aerosol DRF only

Projected changes in annual mean all-sky TOA aerosol DRF (W m^{-2}) in China for the period 2010–2050 (relative to 2000)



Li et al., JGR, in press

Future Directions

- **Model development to simulate aerosol microphysics and mixing states;**
- **Accurate representation of chemical composition and concentrations of aerosols in China in climate models;**
- **Nation-wide continuous measurements of concentrations and optical properties; Data sharing;**
- **Measurements of cloud properties;**
- **Understanding aerosol-climate feedbacks in China.**