Tracking the Carbon Footprint: Chinese Scientists at the Forefront

追踪碳足迹：中国科学家在行动

Climate Change: Carbon Budget and Relevant Issues

Purpose, Current Advances and Perspective

气候变化主题：碳收支和中国相关问题

--碳专项的目标、进展及未来研究方向

Speaker: Prof. LU Daren

报告人：碳专项首席科学家吕达仁院士，

Institute of Atmospheric Physics,

Chinese Academy of Sciences

中国科学院大气物理研究所

Climate Change: Carbon Budget and Relevant Issues

One of seven strategic priority research programs launched by CAS in 2011

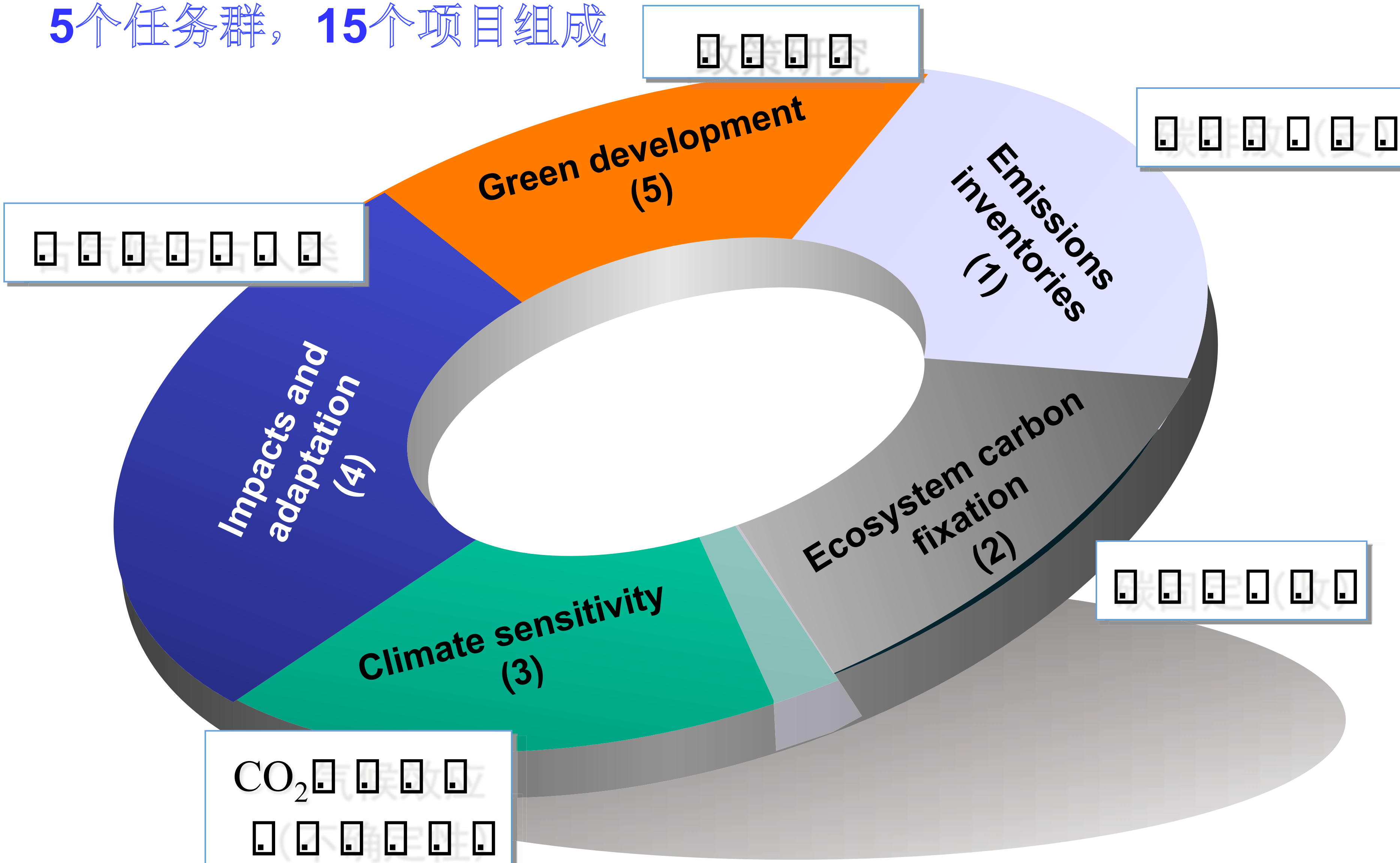
Chief Scientist: LU Daren 吕达仁

Funding from CAS: 800 million Chinese Yuans (~100 Million Euro) 总经费：8亿人民币

Scientists involved: ~ 4000 scientists within and outside CAS 参研人员~4000人

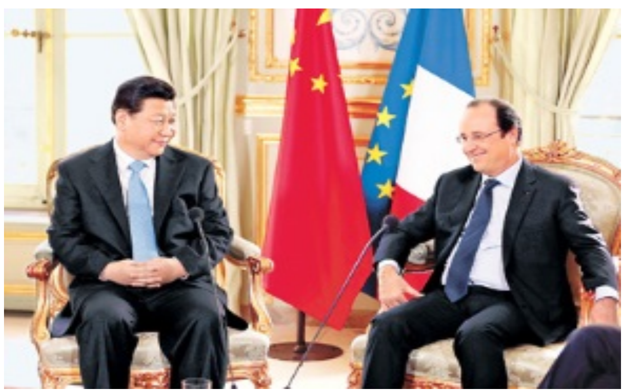
Five major themes of the program (15 projects)

5个任务群，15个项目组成



China Government has being paid more attention to carbon emission related works:

The U.S.-China Joint Announcement on Climate Change was issued during APEC Meeting 2014 in Beijing. President Xi Jinping and President Barack Obama reaffirmed the importance of strengthening bilateral cooperation on climate change. 习近平、奥巴马作为中美两个排放大国元首一直致力于应对气候变化的双边合作。



Chinese Government is seeking to strengthen multilateral cooperation on climate change with France and many countries. 中国政府全力支持巴黎气候大会，在国际上寻求多边合作，共同应对气候问题。

China intends to achieve the peaking of CO2 emissions around 2030 and to make best efforts to peak early. 2030

Major missions (1)
Emissions inventories □ □ □ □ □

To establish independent carbon emission measurement system in energy, cement and other industries, and quantitatively assess greenhouse gas emission caused by land use;

基于我国能源、自然过程和土地利用及畜牧业等的特点，测算我国特有的排放因子参数，构建我国碳排放核算方法和卫星监测系统，形成天地一体化的碳排放核算和监测体系。

- Emissions from energy use and cement production
- Methane and nitrous oxide emissions from land use and livestock
- Satellite Observation of CO_2 fluxes

- 能源消费与水泥生产排放
- 土地利用与畜牧业的甲烷和氧化亚氮排放
- 卫星反演的"净排放"

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China Government has paid more attention to carbon emission data as follows：

《国家中长期科学和技术发展规划纲要2006-2020》
《National Media-long Science and Technology Plan 2006- 2020》

《“十二五”控制温室气体排放工作方案》
《National 12th five-year plan for Controlling Greenhouse gas》

《中国“十二五”应对气候变化科技发展专项规划》
《National 12th five-year Science plan for Climate Change》

《 国家应对气候变化规划（2014-2020年）》
《National Plan for Climate Change （2014-2020）》

F“尽快构建W一套科学、完整、统W一的应对气候变化的统计指标体系R 建立和完善温室气体排放基础统计制度R 建立健全温室气体排放数据信息系统G P(**Forming national carbon emission data statistics and system as soon as possible)**

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Emission Inventory Group

项目4U 卫星反演的F“净排放G
Project 4U Satellite-Derived “Net Emissions"

天地W一体化
Space-ground Integration

实测监测系统
Measurement monitoring system

项目1U 能源消费与水泥生产排放
Project 1U Energy consumption and emission of cement production

项目2U 土地利用与畜牧业的甲烷和氧化亚氮排放
Project 2U Land use and CH_4 and NO emissions for livestock

项目3U 自然过程碳排放
Project 3U CO_2 Emission during natural processes

Target: **Based on the characteristics of energy, natural processes, land use and livestock in China, the targets include: estimate the emission factors parameters, construct accounting method of carbon emissions and satellite monitoring system, form the integrated space-ground systems on carbon accounting and monitoring, obtain the international reorganization.**

Carbon Dioxide Emissions from fossil fuel in China

—The emission of energy consumption and cement production

The calculation equation of CO_2 emissions from fossil fuels:

$$CO_2 = \sum P \times FO \times C \times 44/12$$

P: annual fuel consumption data; **FO:** the fraction of each year's fuel production that is oxidized; **C:** the average carbon content of each fuel group Fossil fuels include coal, crude oil, natural gas

Research Content:

(1) The different energy consumption amount;

(2) Carbon content of the different fuel;

(3) Carbon oxidized fraction of the main industry for energy utilization;

(4) The dynamic database of China carbon emission and forecast model

Power	Petroleum refining	Natural gas
Iron&steel	Oil terminal using	Coal seam gas
Non-Ferrous Metal industry	Bulk chemicals	Coke oven gas
Building material	Fine chemicals	LNG
Traditionlal coal chemical industry	Cement	
New coal chemical industry		
Civil coal		

Main Progress of the project □

Energy consumption and emission of cement production□

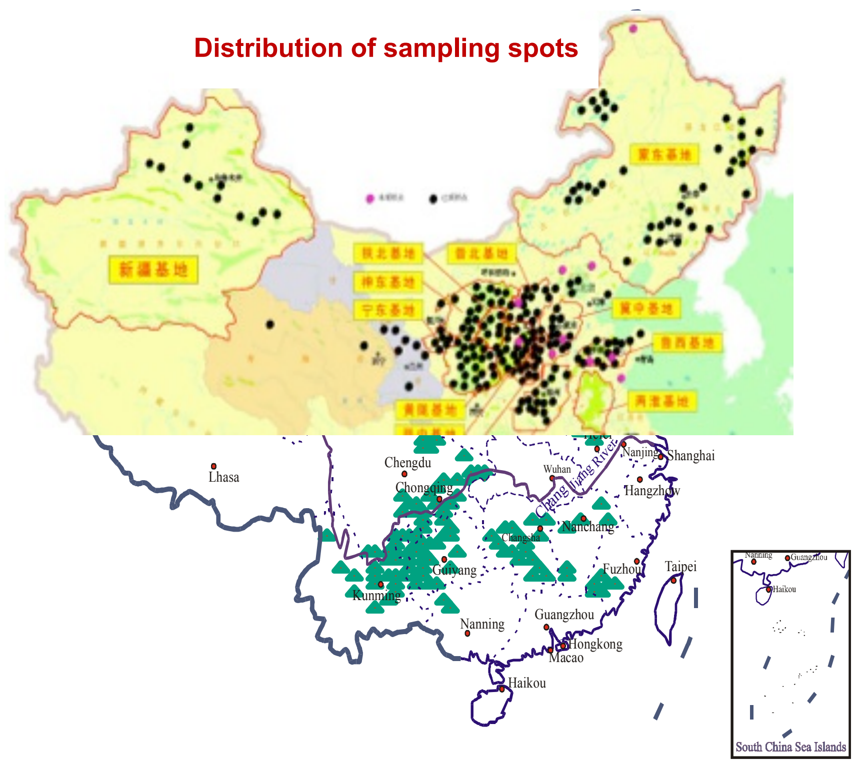
□□□□□□□□□□□

➢ Obtain systematical carbon content of different energy sources□

- We investigated 602 sets of coal samples which collected from 105 coal mine districts in 2012□

- The annual production of 105 coal mine districts is 96.7% of total coal production in 2011.

- Meanwhile, results of 448 coal samples from United States Geology Survey (USGS) were used for comparison.



Carbon content of China Coal

Table. Comparison of carbon content between coal in China and US.

	China	US
No.	602	129
Average	55.42 / 54.21%	61.41
Standard Deviation	11.08	12.17
Mean deviation	2.26	1.07
Confidence level	0.95	0.95
Degree of freedom	601	128
T value	1.96	1.98
Error range	4.44	2.12
Lower limit	50.98	59.29
Upper limit	59.86	63.53

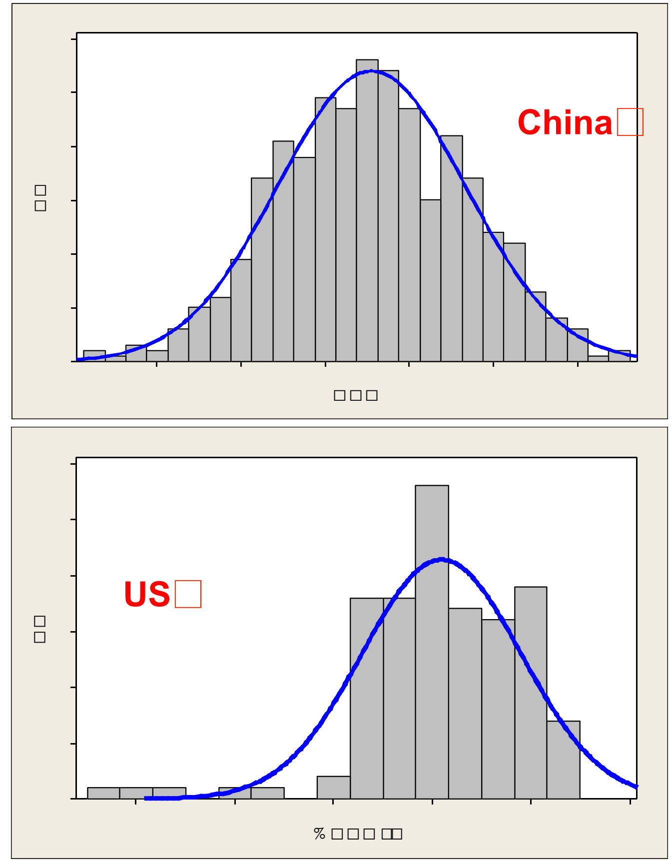
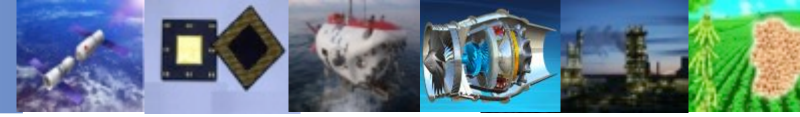


Fig. Distribution of carbon content

- **The carbon content of Chinese coal is much lower than that of US coal.**
- **The distribution of carbon content in China is wider .**



1、排放任务群

成果（1）：科学评估能源消费与水泥生产过程的排放量

- 对于煤炭消费量进行了较为准确修正。

运输损失5-6‰

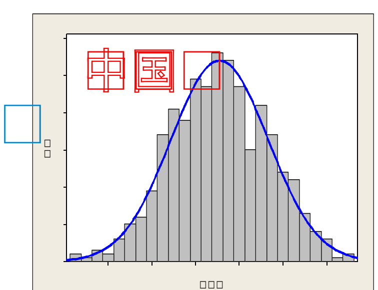
洗选损失1.8%

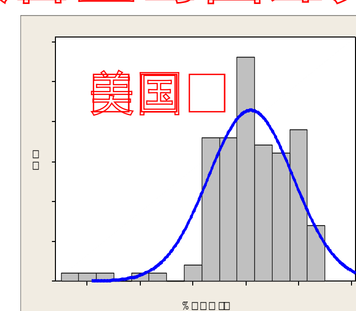
	,%	Cd,%	Mad,%	Ad,%	Qgr,d (MJ/kg)
		68.08	0.56	24.96	6182
	68	81.90	0.60	10.64	7650
	10	32.74	0.69	57.83	2858
	6	30.14	0.81	59.53	2554
	16	7.51	0.87	84.53	287

- 系统得到了能源种类的燃料碳含量，尤其是煤碳含量与国外数据存在较大差距。

➢ 与美国煤炭相比，我国煤炭的碳含量偏低。

➢ 我国煤炭的平均碳含量为55.42%，考虑产量的碳含量为54.21%。





- 系统形成了能源利用各行业的碳氧化因子，较IPCC的默认值1存在较大差距。
- 建立了完备的数据库系统

> 系统、定量获得了我国能源排放的基本参数。
> 能源碳排放可能低10-15%。
> 为我国各行业、地区节能减排提供参考依据。
> 已经发表了20篇论文，预计2015年完成40篇左右论文发表。

□□□	2014□8□	□□□□
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□□	□□	□□□□0.94□□
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□□□□□	□□	□□□□0.1-0.7
□□□□□	□□	□□□□0.57-0.88
□□□	□□□□	□□□□0.77-0.95
□□□□	□□	□□□□0.13-0.3
□□□□	□□	□□□□0.99
□□□□□	□□	□□□□0.001-0.1
□□□	□□	□□□□0.98-1.0
□□□	□□	□□□□0.75-0.99
LNG	□□	□□□□0.98-1.0
□□□	□□	□□□□0.1-0.99
□□	□□	□□□□□10-15%

Project 2 CH_4 and N_2O emissions from land use and livestock
土地利用与畜牧业的甲烷和氧化亚氮排放

- Established a network of measuring CH_4 and N_2O emissions from land use across China

Total 13 sites

Each site has 3-5 treatments

3-year consecutive measuring.

The TanSat Mission of China

[illegible]

全球二氧化碳监测科学实验卫星

[illegible]

[illegible]

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碳卫星的研制计划

2011.02 kick off of project

2013.03 PDR-Preliminary Design Review

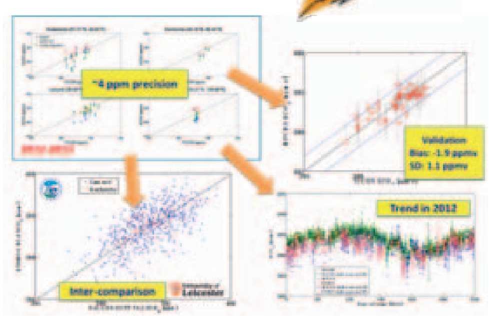
2013.06: Kick off phase C

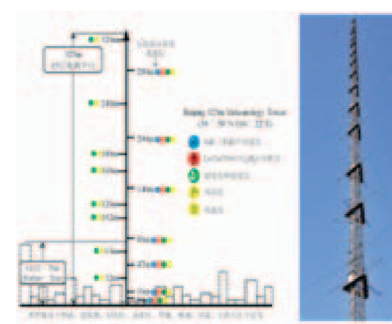
2014.12 CDR- Critical Design Review

2015.10 CO2 Spectrometers Finish

2016.04 SRR- Satellite Readiness Review

2016.12 Launch





Instrument design, Retrieval algorithm, Validation observation

Major missions (2)

Projects on ecosystem carbon fixation

To synthetically study and quantitatively assess the carbon sequestration rate and potential increment of carbon sink of various ecosystems in China.

构建了陆地生态系统碳收支清查体系，评估了生态系统固碳现状及潜力

- **Current status, rate, mechanism and potential of terrestrial ecosystems in china**
- **Assessment on carbon sequestration of National Key Ecological Restoration Programs**
- **Develop and disseminate techniques of enhancing ecosystem carbon sink in typical** regions

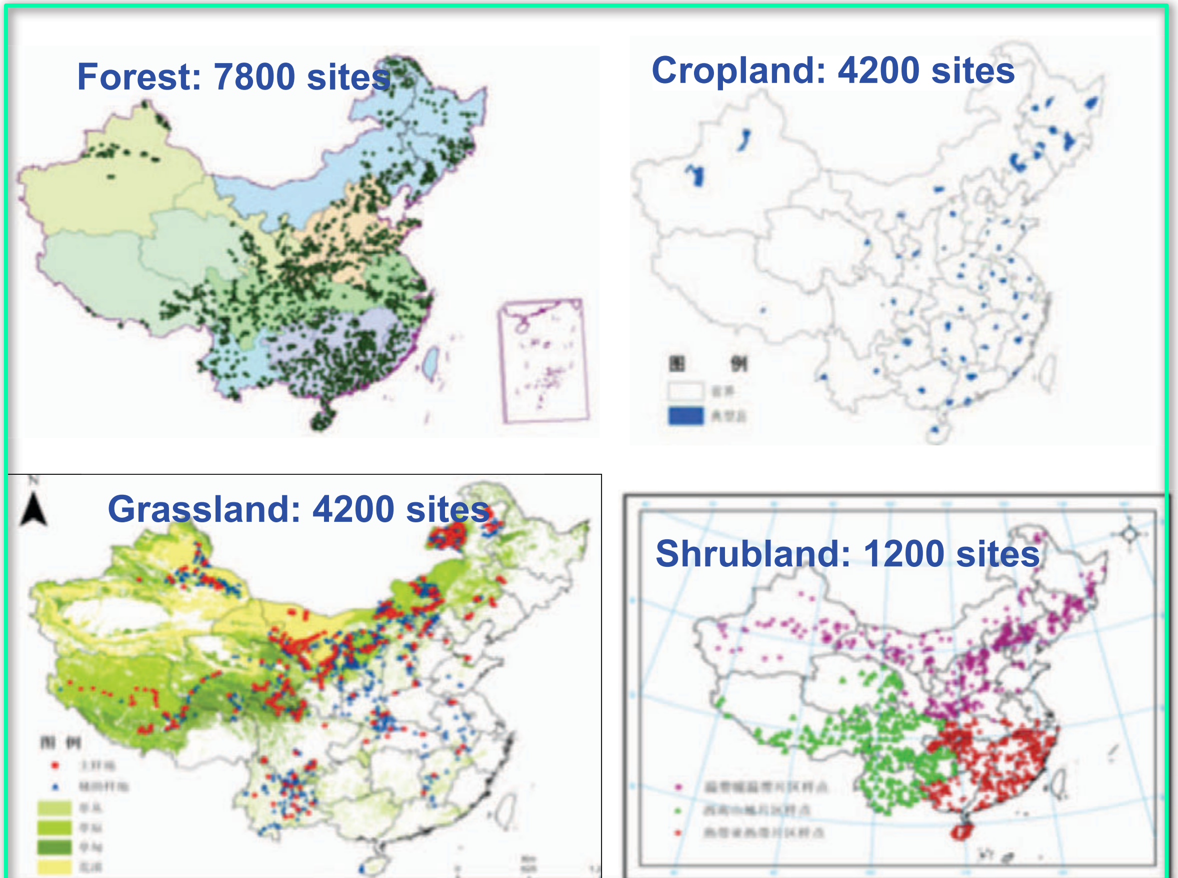
- 我国陆地碳库现有总量
- 生态系统固碳速率和潜力
- 我国重大生态工程已固碳量
- 增加碳汇的技术体系

Content 内容

- Aims
- The methodology and project design
- The pattern and dynamic of C pools
- Effects of 6 national eco-projects on C sink(on going)
- Technologies of enhancing C sink
- Driving forces and implications
- Summary

- 目标
- 全国覆盖清查体系和数据库建设
- 碳库格局和动态
- 正在执行的六大生态工程固碳量
- 几个固碳技术
- 机制和建议
- 总结

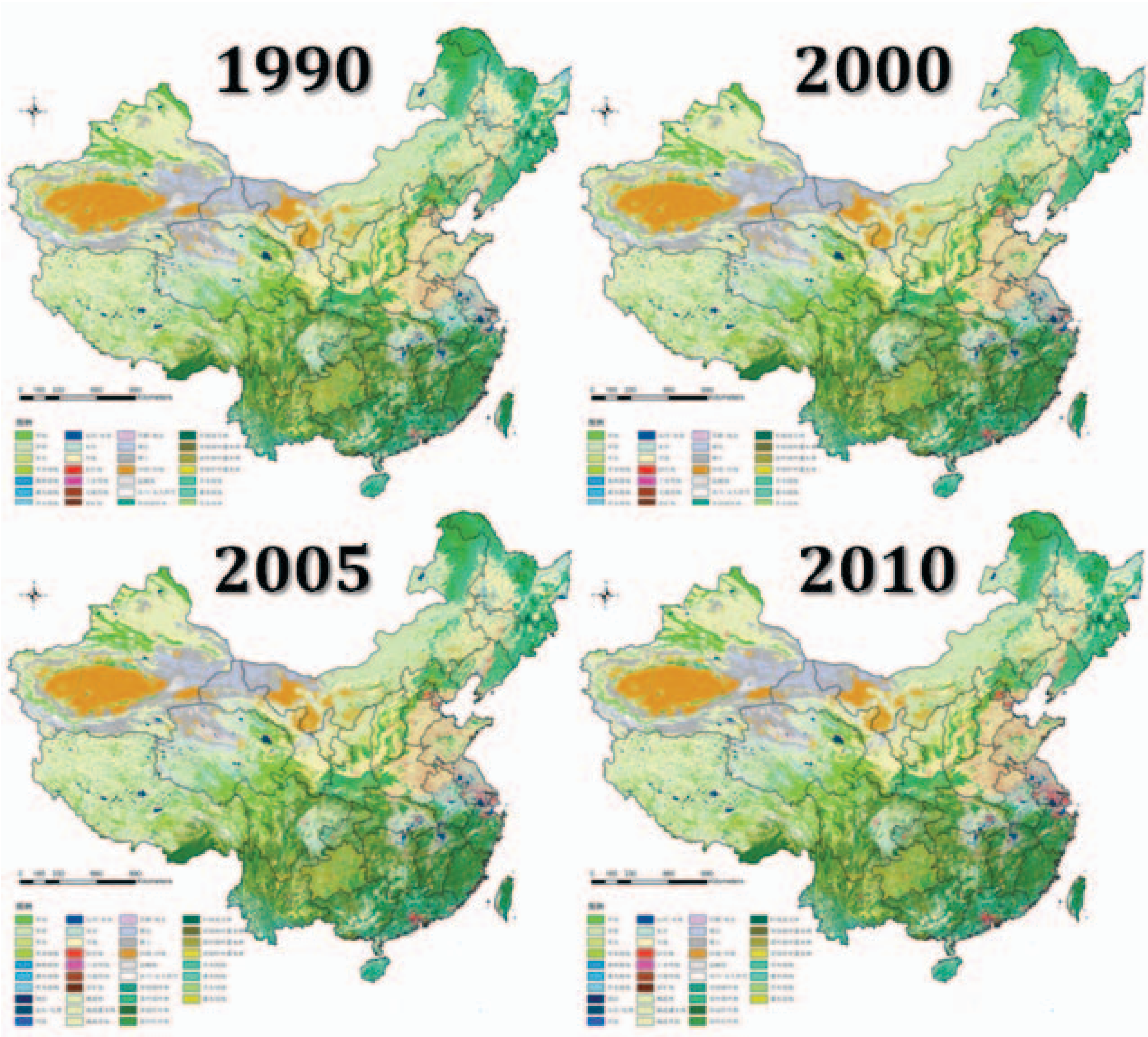
1 Inventory systems-site distribution 样地分布



Inventory sites 清查样地

Eddy-covariance sites
通量网点

建立了全国土地覆被数据系统及分布图



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1990, 2000, 2005, 2010

2 Accomplished database relating to ecosystem carbon sequestration 完成陆地生态系统固碳数据库

Pattern, dynamic and mechanism of C pools

↑

Analysis and comparison among multi-ways

- Based on survey
- Based on models
- Based on IPCC ways
- Based on eddy-covariance way

↑

Structure of the database

M)N □□□□□□碳贮量评估(不同土壤容重传递函数的影响)□□

(8种PTFs□7000个土壤剖面数据)

No.	SOC density (kg C m^{-2})			Area (×10^4 km^2)	SOC storage (Pg C)		
	0–20 cm	20–100 cm	0–100 cm		0–20 cm	20–100 cm	0–100 cm
M1	4.17±2.65^{bf}	5.68±3.08^{d}	9.85±5.48^{bc}	938.79	39.14	53.29	92.43
M2	2.85±1.63^{g}	4.31±2.16^{e}	7.16±3.62^{e}	938.79	26.78	40.45	67.19
M3	3.69±1.89^{d}	5.97±2.77^{ab}	9.62±4.45^{bc}	938.79	34.66	56.00	90.62
M4	3.30±1.58^{f}	5.54±2.54^{d}	8.84±3.95^{d}	938.79	31.01	51.99	82.96
M5	3.58±1.67^{de}	6.07±2.85^{a}	9.63±4.32^{b}	938.79	33.64	56.98	90.37
M6	3.85±2.16^{c}	5.83±2.83^{c}	9.67±4.77^{bc}	938.79	36.10	54.69	90.79
M7	4.27±2.63^{a}	5.95±3.12^{bc}	10.22±5.49^{a}	938.79	40.09	55.88	95.97
M8	3.57±1.77^{de}	5.85±2.72^{bc}	9.43±4.29^{c}	938.79	33.53	55.04	88.53
Average	3.66±0.46	5.65±0.57	9.31±0.95	938.79	34.37±4.29	53.04±5.33	87.36±8.93
CV (%)	–	–	–	–	12.48	10.05	10.23

- 0-100cmSOC□ □ 87.36±8.93 Pg□
- □ □ SOC□ □ □ □ □ □ □ □ □ □ SOC□ □ □ □ □ □ □
- 0-100cm□ PTFS□ □ □ □ □ □ □ (CV)□ 10.23%□

Xu et al., 2015, JGR

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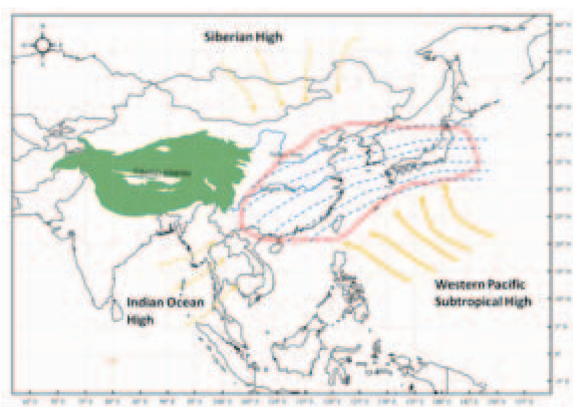
3、□□□□□□□完成了中国区域陆地生态系统固碳速率评估□

M□N 中国为主体的亚洲东部亚热带森林是W一个巨大碳汇功能区□

(NEP)

362±39 g C m^{-2} yr^{-1} NEP 0.72±0.08 Pg C yr^{-1}

NEP 8%



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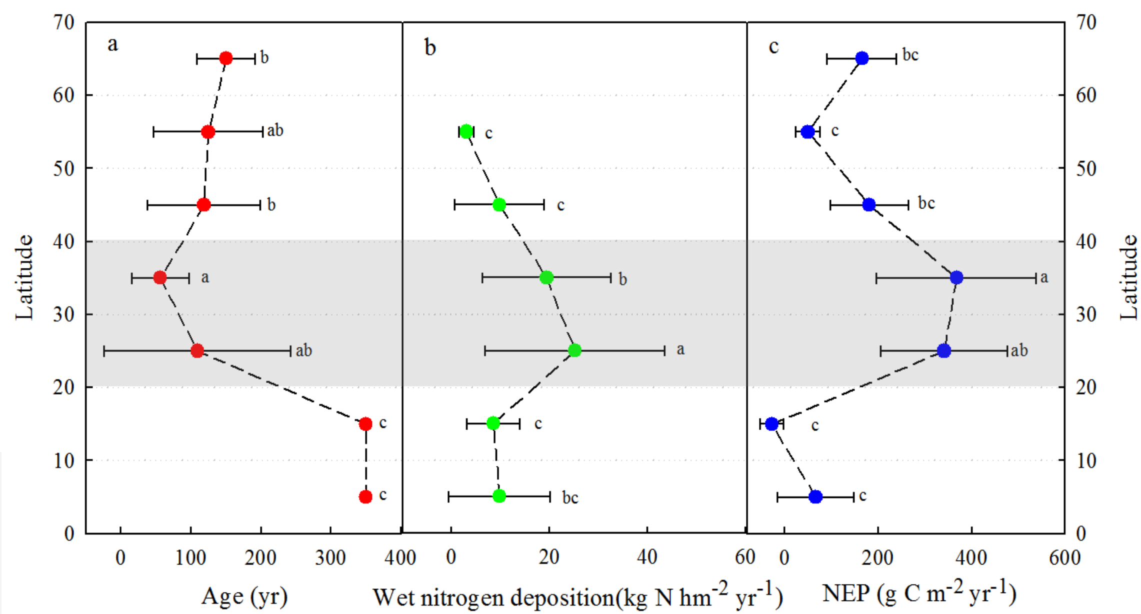


于贵瑞等，2014，PNAS

[illegible] C [illegible] °C [illegible] R [illegible] A3 [illegible] B [illegible] A3 [illegible]

1980-2010

	[illegible] (10^8 hm^2)		[illegible] (t/hm^2)		[illegible] (Pg)		[illegible] (Pg yr^{-1})
	1980s	2010s	1980s	2010s	1980s	2010s	
[illegible]	1.38	1.75	57.97	59.54	8.00	10.42	0.12
[illegible]	1.38	1.75	13.55	13.84	1.91	2.27	0.02
[illegible]	1.38	1.75	53.13	57.14	7.33	10.00	0.13
[illegible]	1.38	1.75	125.65	129.66	17.38	22.69	0.27

1980-2010

Region	Change of Area/ 10^4 km^2	Change of C storage/ Pg			
		AGBC†	BGBC	SOC	Ecosystem C
Northeast	-1.397	0.000	0.034	-0.101	-0.066
Inner Mongolia	-0.650	0.015	0.098	-0.338	-0.224
Northwest	-1.668	0.009	0.064	-0.100	-0.028
Qing-Tibet	0.382	0.024	0.380	-0.100	0.305
Total	-3.333	0.048	0.575	-0.638	-0.014

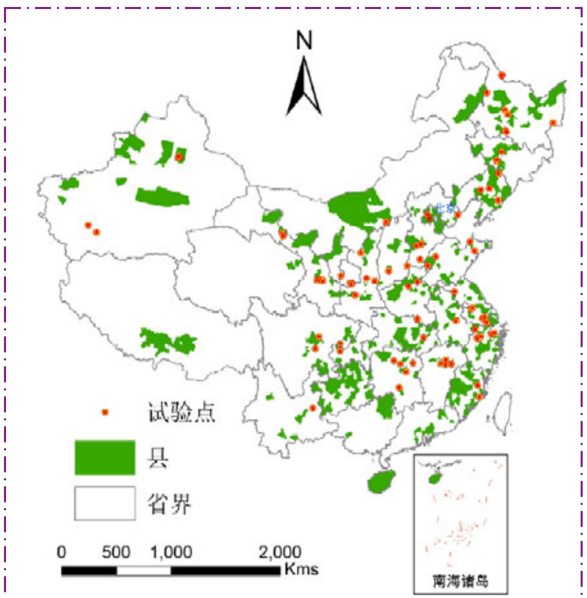
于贵瑞团队,已完成

M）N 保护耕作制度使中国农田土壤具有较大的固碳速率□

(0-20cm) 1980s

28.51 Mg C ha^{-1} 2010s 32.6 Mg C ha^{-1} (Mg C = 10^9 g C)

0.13 Mg C ha^{-1}

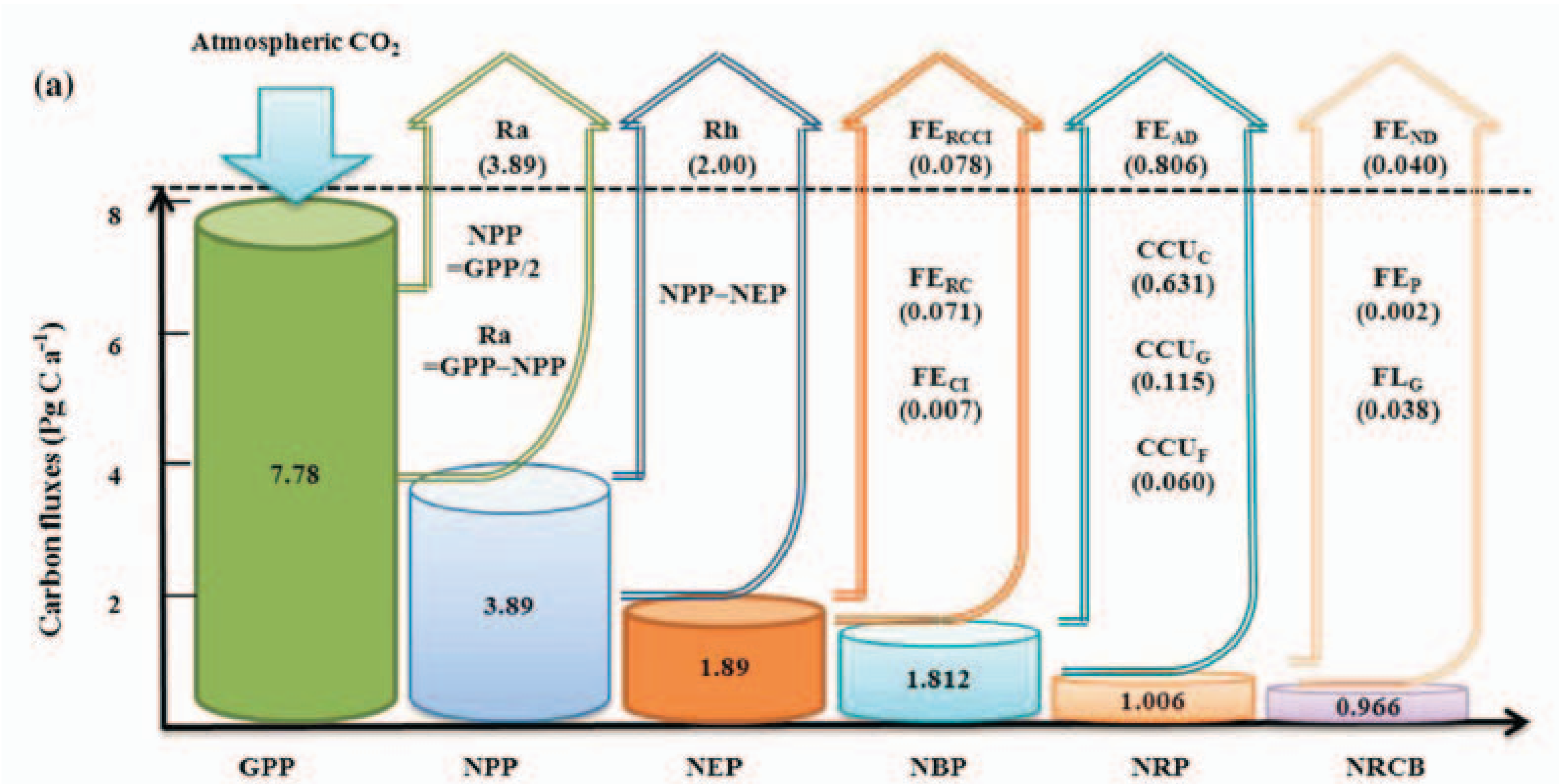


Meta分析□□□□534□ (378□□/□/□)
□□□ 144 kg C/ha/yr (72□216)

DNDC/Century□□
□□□□ 116 kg/ha/yr
□□□□ 120 kg/ha/yr

60□□□□□□□□□□
SOC□□ (□□□□ 1.9□)
□□□□□ 132 kg/ha/yr □ -5.2□ 267□

史学正团队,拟在PNAS专辑发表



Wang et al, 2015, Science Bulletin

M 5N □□□□□□□□□□□□□□□□□□□□□□□R □□11.25 TgC yr-1□

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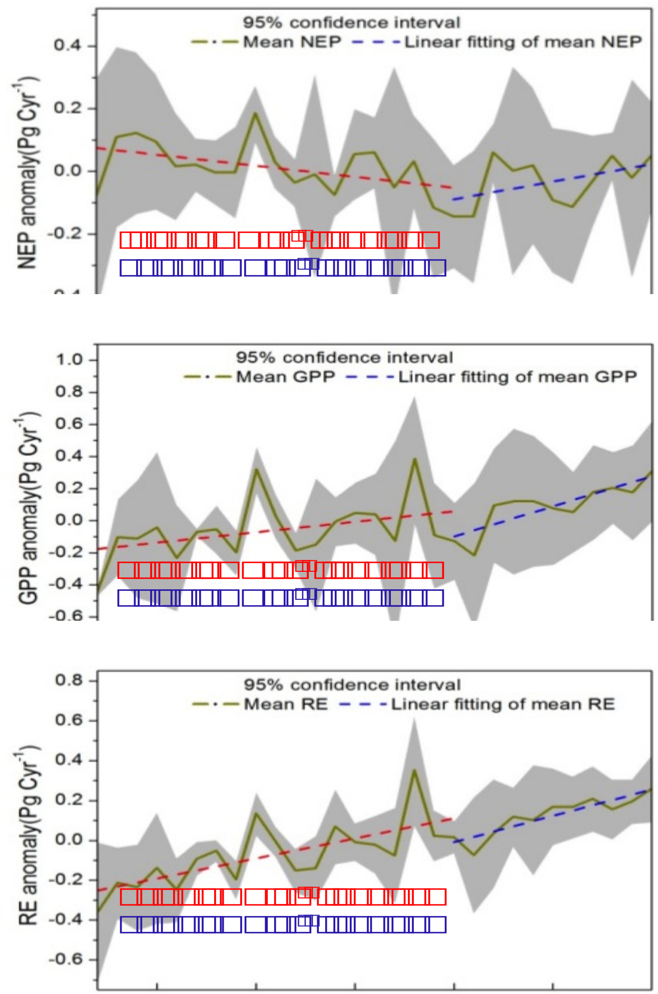
- □10□ □2000-2010□ □□□□□ □□□□NEP□ □□□□20□ □1982-2000□ □□□□□□□□ □□□□□□□□□□□□□□□□
- NEP□ □□□□□□□□ □□10□ GPP□ □□□□RE□ □□□□□□ □NEP□ □20□ □ -7.04 Tg C yr^{-1}□ □□□□□□10□ □11.25 Tg C yr^{-1} □□□□□



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3	□□□□□□□□□	1204	Landset□□□□□□□□SPOT□□□□□□□□□□□□□□□□□□□□□□□□□□□
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5	□□□□□□□□□	1307	□□□□□□□□□□□□□□□□□□□□□□□□□□
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□□□□□□□□		□□□□□□ (□hm²)□	□□□□□□ P Tg C□□	□□□
1	□□□□□□□□□□	6937□	474□	1998-2010
2	□□□□P□ □□□□	1784□	413-901	2000-2010
3□	F□□ G □□□□□□	1204□	2080	1978-2008□
4□	□□□□□□□□□ □□□□□□	992□	446.8□	1990-2010
5□	□□□□□□□□□□	1307□	194±43.5□	2001-2010
6□	□□□□□□□	5995□	101-149.6□	2003-2010
7□	□□□	18219□	3666-4289□	平均增加 20.1-23.5 t C/ hm²

中国6大生态工程总面积约182万km²，占国土面积的18.9%，□程实施后增加固碳量3.66-4.29 Pg C□

Major missions (3)
---Climate sensitivity □ □ □ □ □ □ □ □

To develop a more integrated new generation climate system model, quantitatively project greenhouse gas concentration corresponding to future global warming scale, understand the relationship between anthropogenic aerosols and climate change, and reduce uncertainties in the relationship

气候敏感性任务群基于观测的温度变化和气候系统模式模拟等获得对气候变化及其机制的新认识。

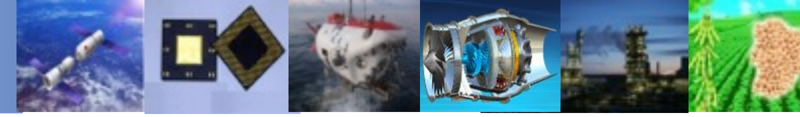
1、研发出先进的关键物理过程参数化方案，实现与CAS气候系统模式耦合，建成国际先进的中国科学气候系统模式。

研发出可考虑地表水、地下水耦合及人类活动影响的陆面水文分系统模式。

研发出云-辐射-气溶胶集合模拟参数化方案。

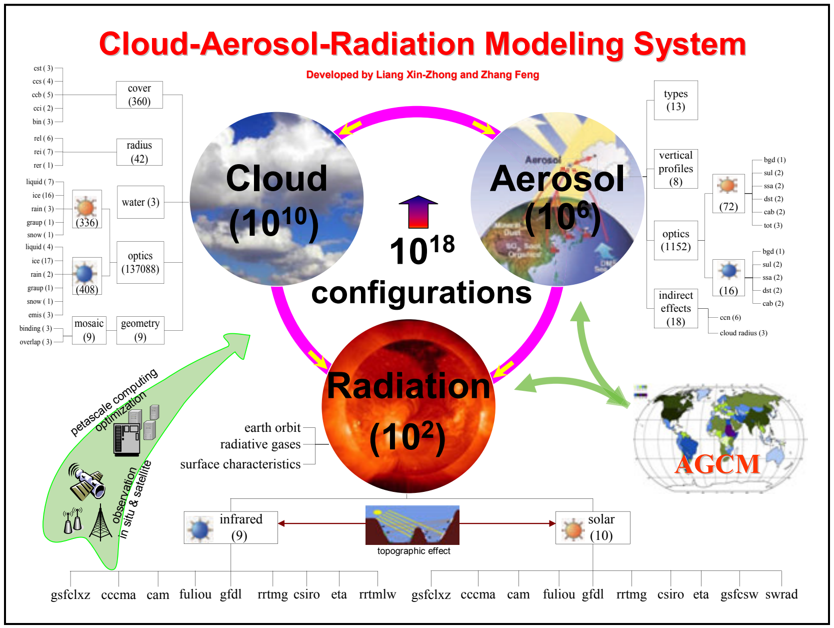
研发新一代CAS动力学植被模型，可考虑自反馈的萌衍方案、个体高度的光竞争方案，以及人类干扰模块等。

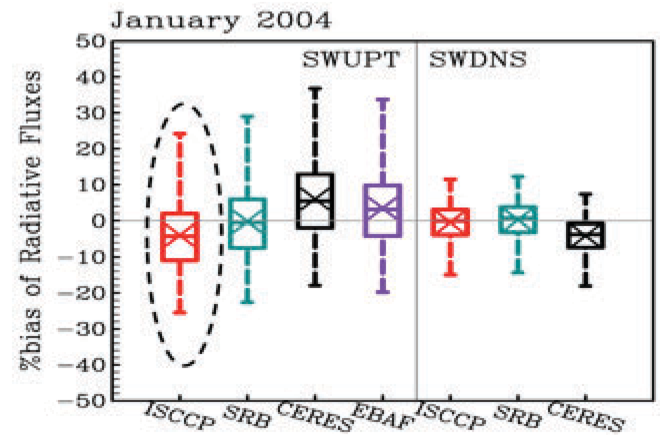
发展针对稳定边界层通量参数化的新方案。

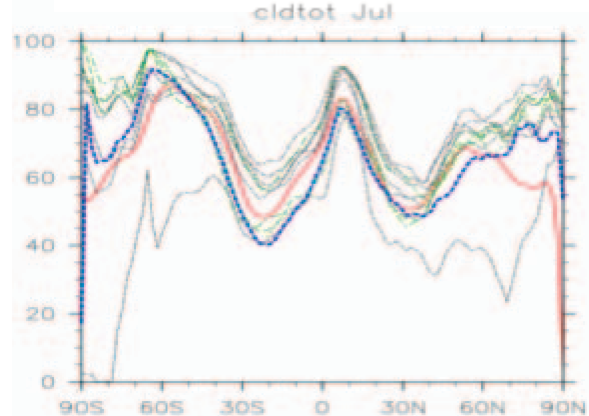


建成国际先进云-气溶胶-辐射集合模拟系统P(CAR系统)□?

云-气溶胶辐射强迫是未来气候变化预估不确定性的最重要来源□







红色实线：观测；

蓝线：耦合CAR系统前的模拟结果（与观测偏差较大）

黑线和绿线：耦合了CAR系统后的不同集合样本的模拟结果

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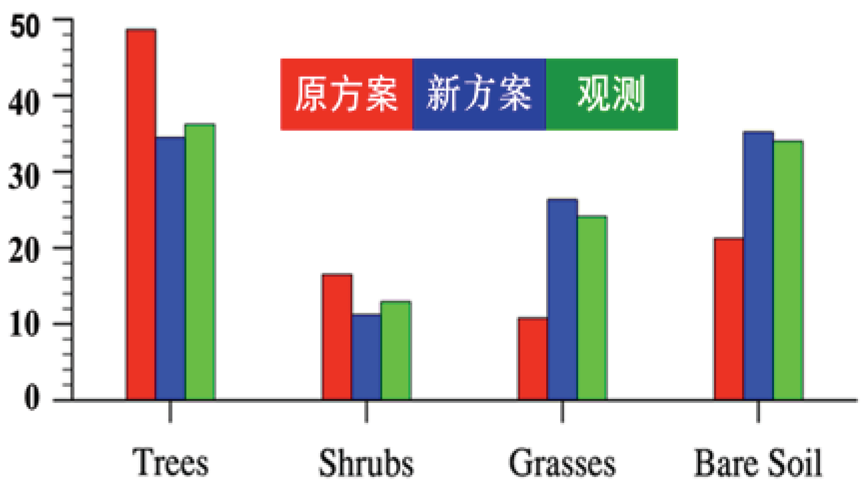
- CAR系统参加国际气溶胶比较计划P(AeroCom)□
- CAR系统已被耦合到国际知名区域模式CWRF中□
- 应邀在AGU年会做口头报告□

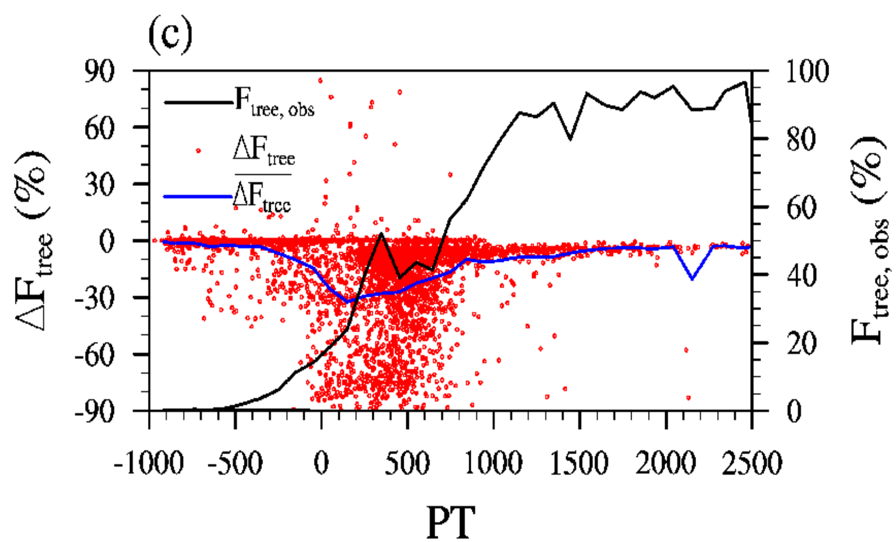
耦合了CAR集合方案后的CAS气候模式的集合模拟R其变化范围可很好地包含了观测结果□

建成全球植被动力学模式ʊ 萌衍S—竞争参数化方案?

□□□IAP-DGVM□□□□□不同植物类型g之间的萌衍竞争R s□ 气候/环境条件对萌衍的影响;□优于国际同类模式。□□



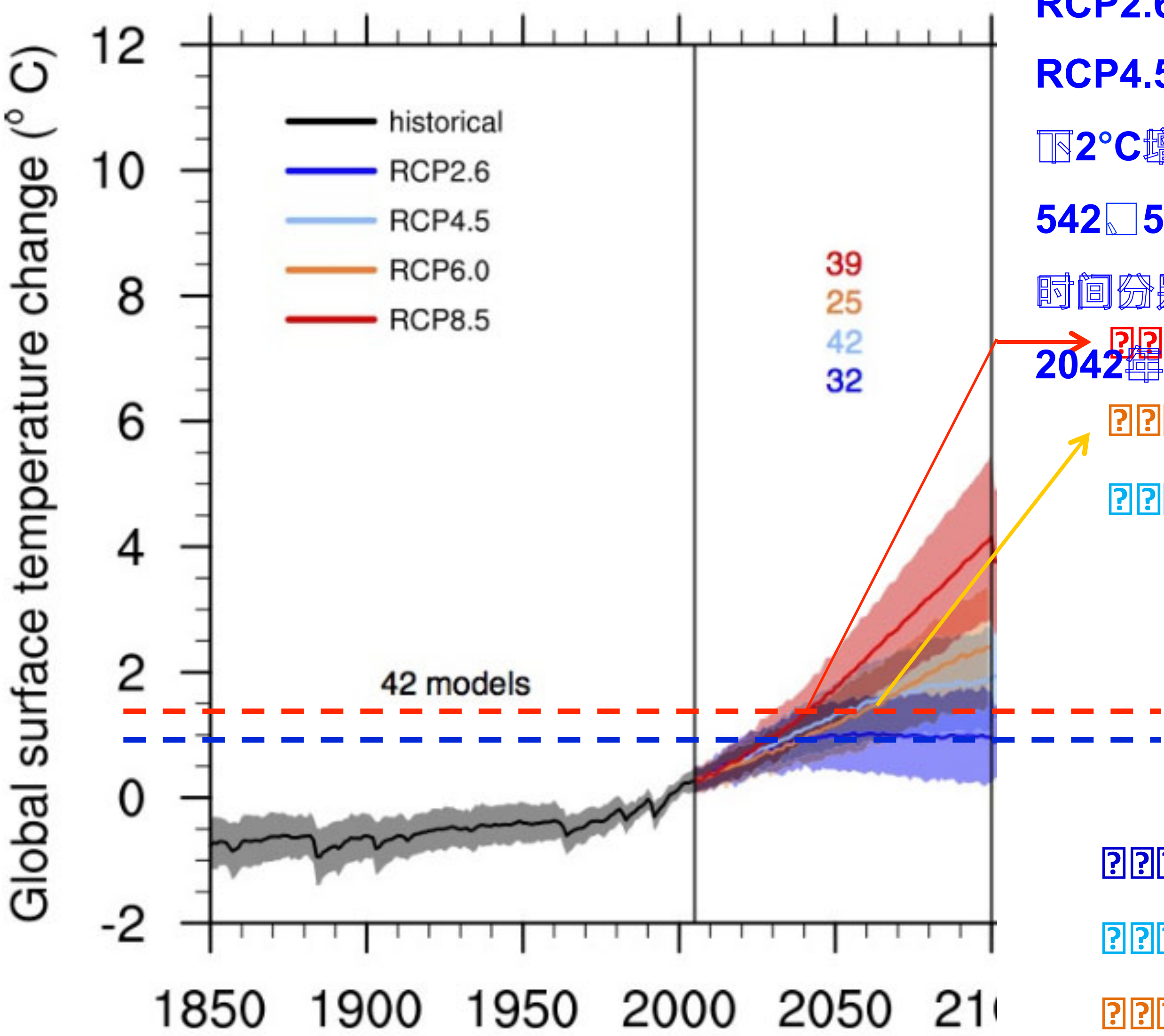
建成的DGVM可更好模拟出观测的全球主要植被类型覆盖面积（单位$10^6 km^2$）



研发出新的植被萌衍方案R 可更好模拟出树覆盖度差异随气候因子的变化。□□

尤其对生态过渡带（对气候变化的敏感区域）模拟的改进更为显著

模拟未来不同情景下增温2℃P（1.5℃）对应的CO^2e



RCP2.6不会达到2°C阈值，RCP4.5、RCP6.0和RCP8.5情景下2°C增温对应的 CO_{2-e}分别为542、560和563 ppm，出现的时间分别是2056年、2063年和2042年。

????B(- ?? AM i e ?HPpdPg

????A(p?? Api i e ?HPpAMg

????d(- ?? dPi i e ?HPp- Ag

2℃阈值

1.5℃阈值

???P(A??d- Ai i e ??HPpdPg??

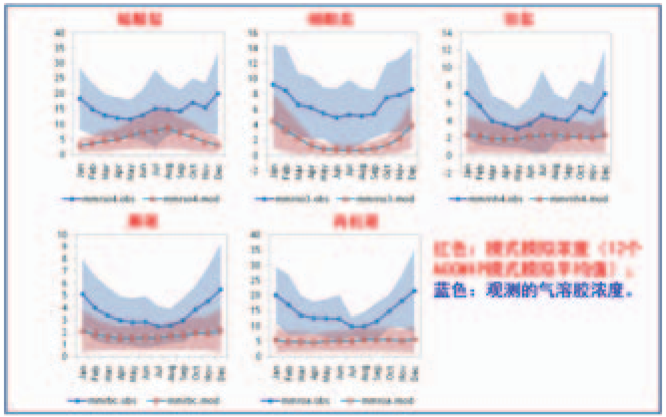
???d(- ??dABi i e ??HPpMMg?

???A(p??dAM i e ??HPpM g?

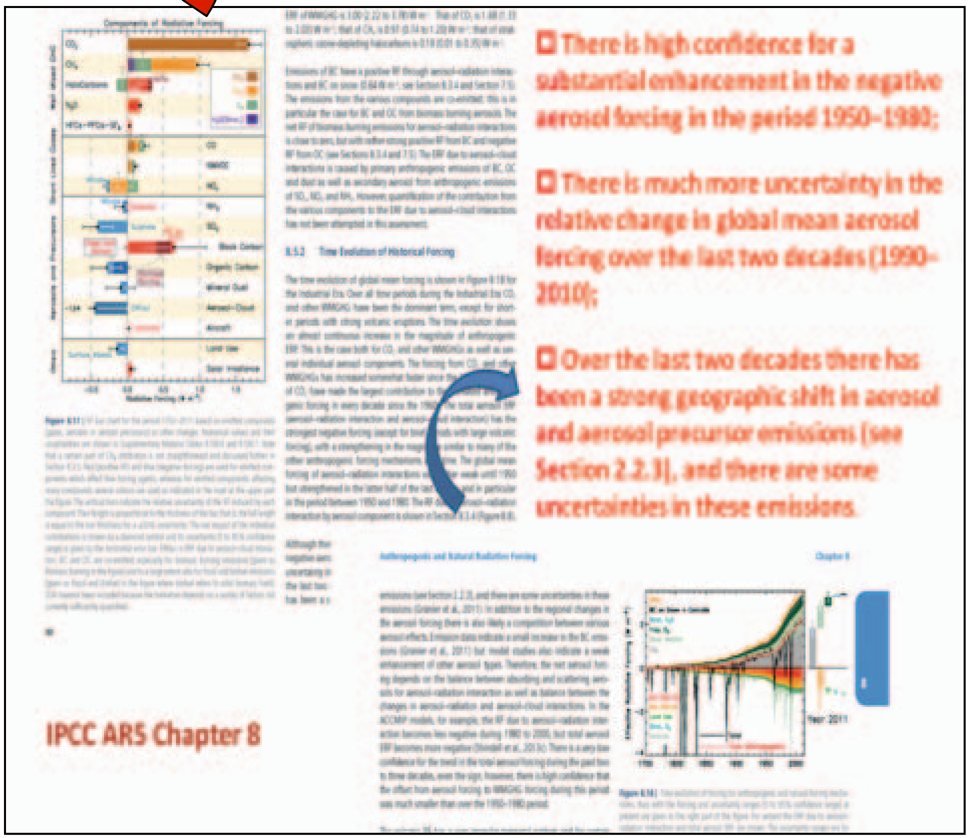
???B(- ??dAui i e ??HPpPBg?

6、发现气溶胶浓度和光学厚度高于国际多模式模拟值

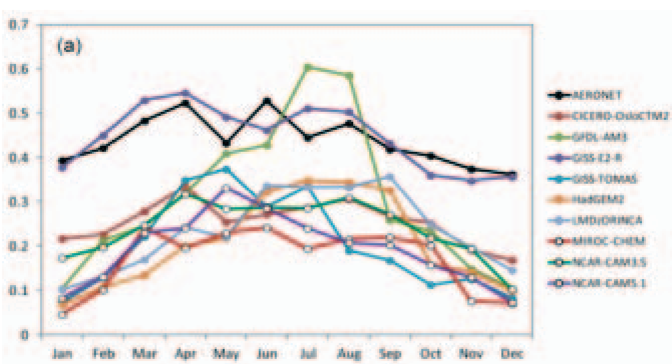
ACCMIP模式气溶胶浓度与观测值比较



IPCC AR5 认识基础上的提高

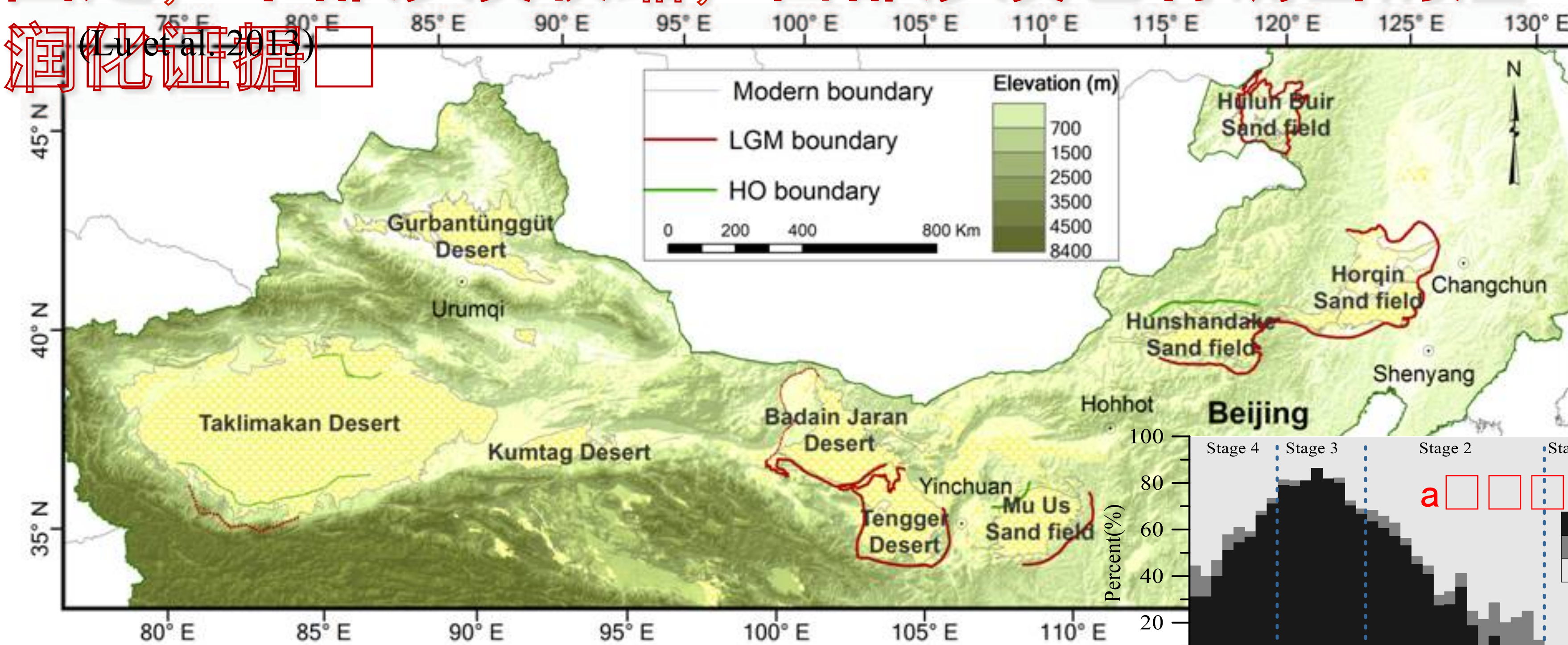


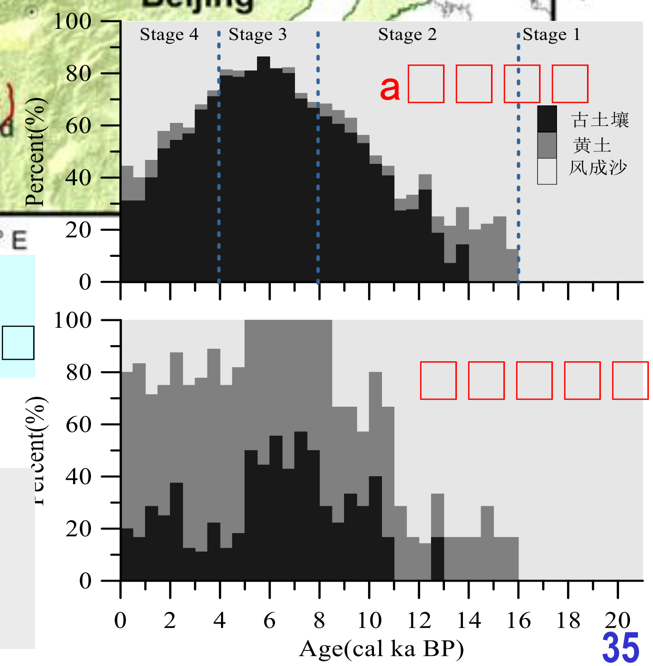
ACCMIP模式气溶胶光学厚度与观测值比较



1、□全新世大暖期六盘山s以a东沙地几乎全部固定R 中部沙漠收缩R 西部沙漠也有确凿的湿润化证据□

(Lu et al. 2013)





- □□□□□(21±2ka)□□□□□R □□□□;
- □□□(6±0.5ka)a□□□□□□□ R □□ s□□□□

(□□s□□ □□□□□□□

(Li et al.

全球增温将可能导致我国北方沙漠区收缩、□草原植被扩张□

Major Accomplishments

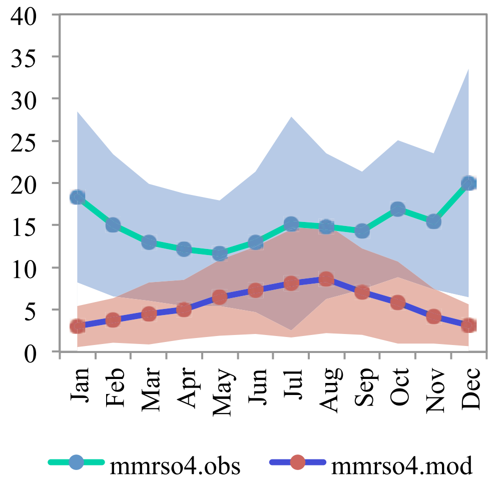
主要研究成果□

- Examined the amplitude, rate, periodicity, abrupt change, and mechanism of climate change over the past 2000 years
- Quantified the warming in China during the last hundred year on the basis of homogenized observations
- Implemented key parameterizations schemes in CAS Climate System Model and performed future projection of climate
- Improved understanding of climatic effect of aerosols by nationwide measurements

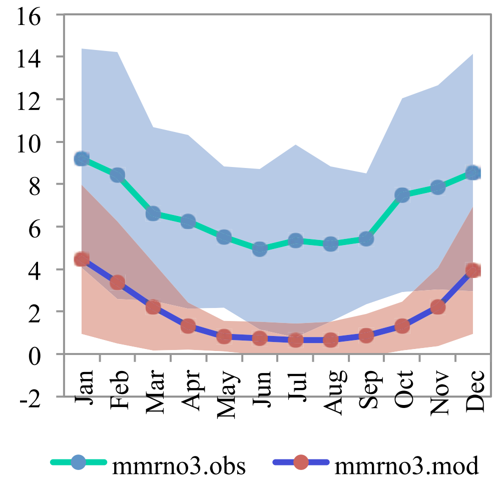
Evaluation of ACCMIP Simulated Aerosol Concentrations in China

利用观测的气溶胶浓度评估ACCMIP模拟的气溶胶

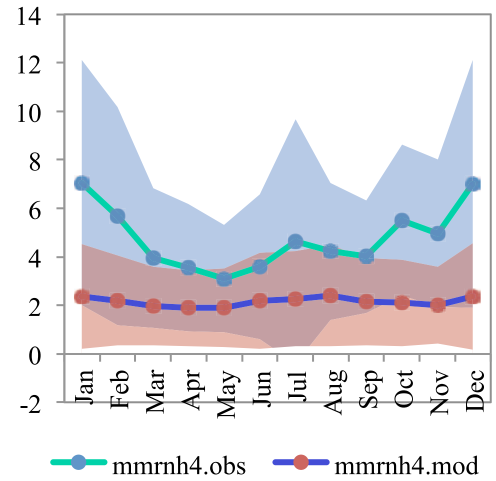
Sulfate



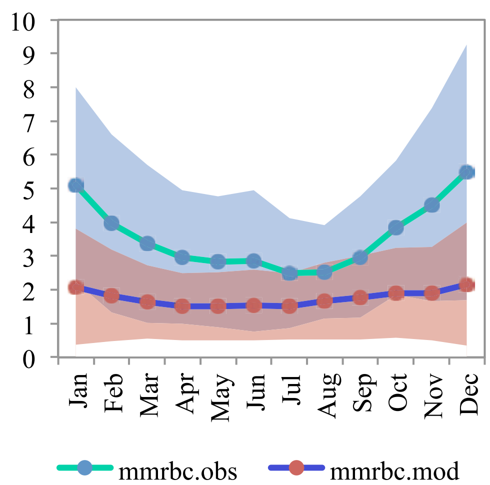
Nitrate



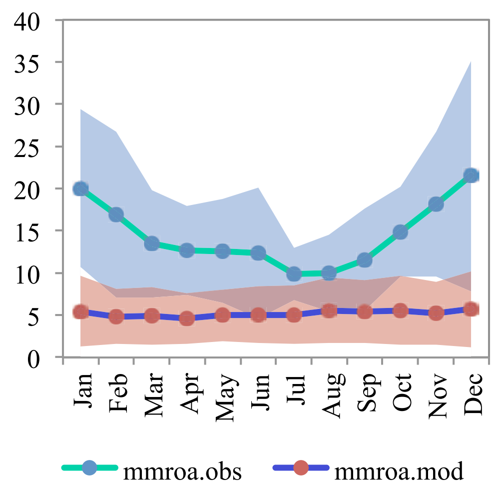
Ammonium



BC



OC



Red: Modeled Conc.;
Blue: Observed Conc.;
12 ACCMIP models considered

□□□□□□□□
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□□□

Major missions (4)

Projects on green development 绿色发展任务群

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- 为国内制定低碳发展的战略、政策、路径提供重大咨询建议。
- 研究我国未来碳排放轨迹和达到峰值的情景。

Presentation-4

--Green low-carbon Development Strategy for China. by Wang Yi

Main scientific/application objectives

主要研究、应用目标

Support climate policy decision making through:

- **Data collecting and information system developing**
- **Climate simulation and GHG reduction roadmap designing**
- **Analyzing of historical emissions and their impacts**

Prospects 展 望

Provide observation network, mothed and technique
Develop earth system models

Provide observational datasets, scientific understanding and support to the nation's mitigation and adaptation to climate change

Building comprehensive research teams
support to the nation's green policy to climate change

TanSat → CO2 Flux

Model → Climate Projection

Policy →Sustainable Development

[illegible]

TanSat Science Team

Institute of Atmospheric Physics, Chinese Academy of Sciences

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(3) Strategic Priority Research Program –

Space Science: Scientific Research Satellite

(CAS)

(2015-2016)

--- Organization of TanSat Mission

--- [illegible]

Term-1(2011-2017)
Measurement Goals
XCO2
1~4 ppmv
Monthly
500 x 500 km^2

Term-2(2013-2015)
Measurement Goals
CO2 Flux
Relative flux error
20%
Monthly
500 x 500 km^2

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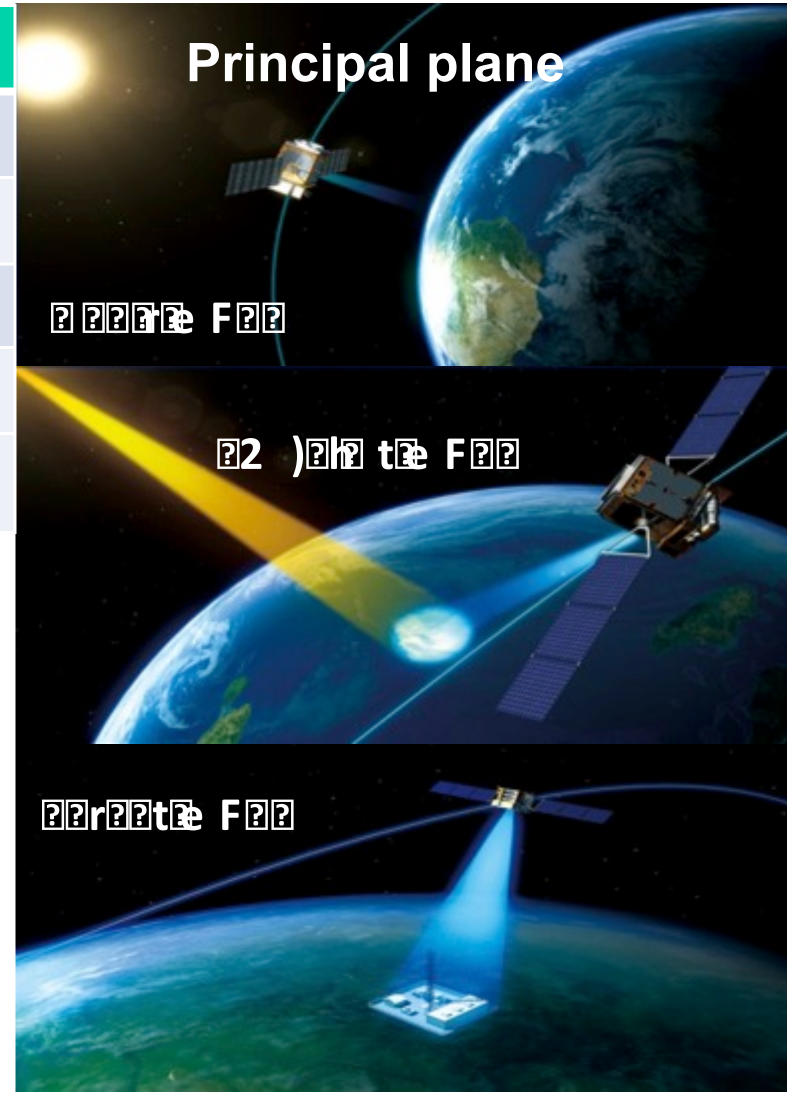
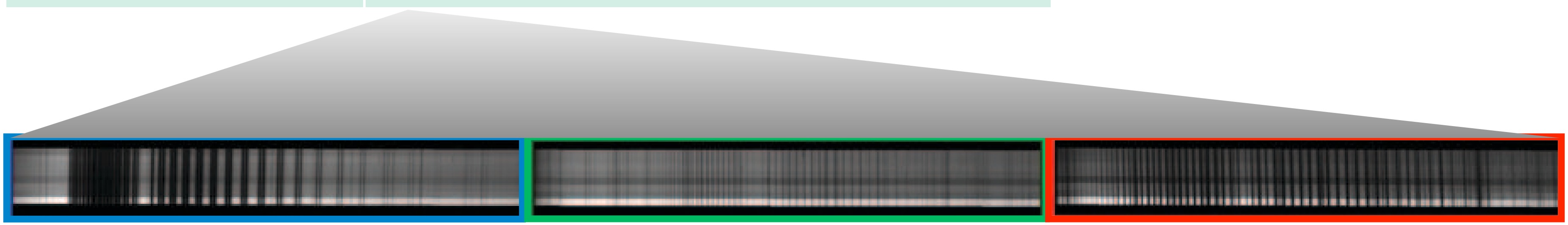


Cloud and Aerosol Polarization Imager (CAPI)

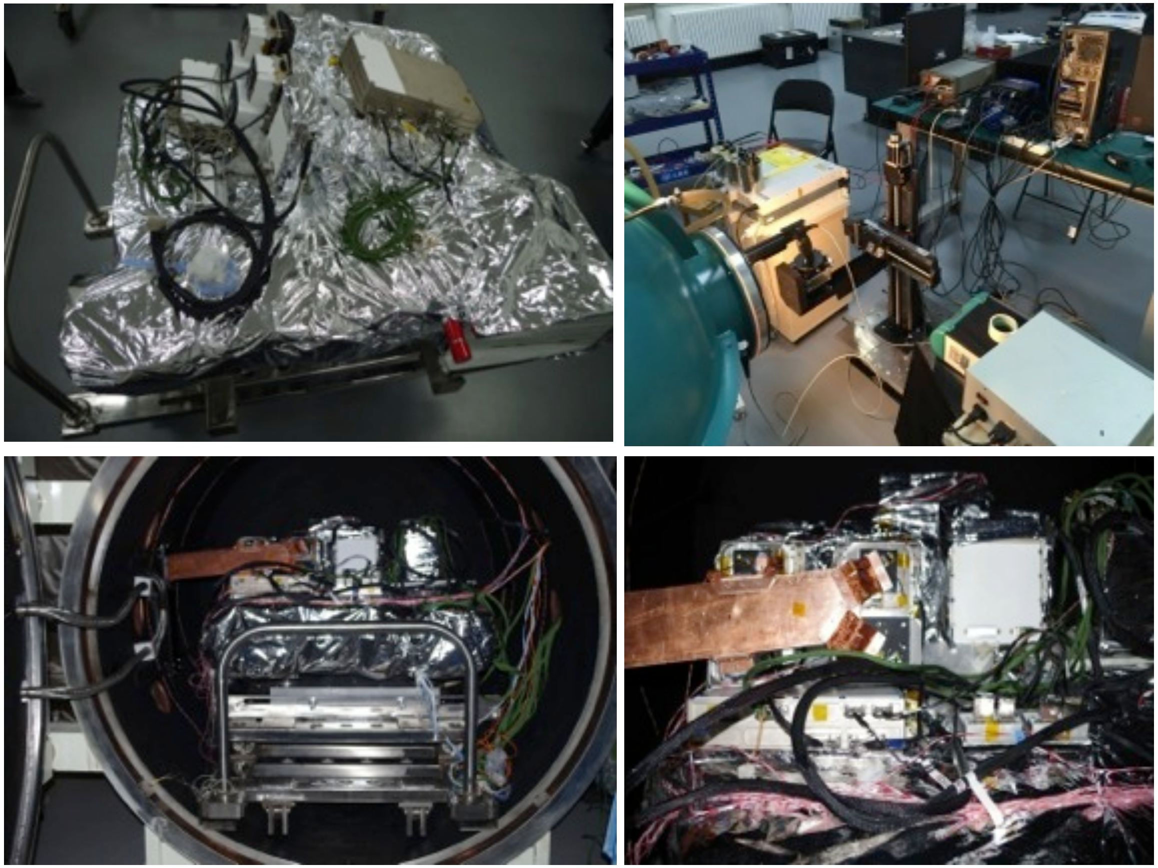
	O_2 A	CO_2 Weak	CO_2 Strong
Spectral Range (nm)	758-778	1594-1624	2042-2082
Spectral resolution (nm)	0.038-0.047	0.120-0.142	0.160-0.182
SNR	360	250	180
Spatial resolution	2kmx2km		
Swath	20km		

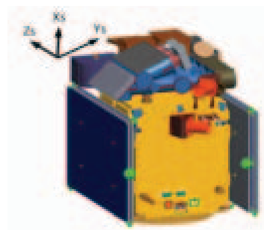
Carbon Dioxide Sensor (CDS)



Preflight calibration 2015-2016

- Radiometric Cal.
- Spectral Cal.
- Polarization Cal.
- Geometric Cal.
- SNR

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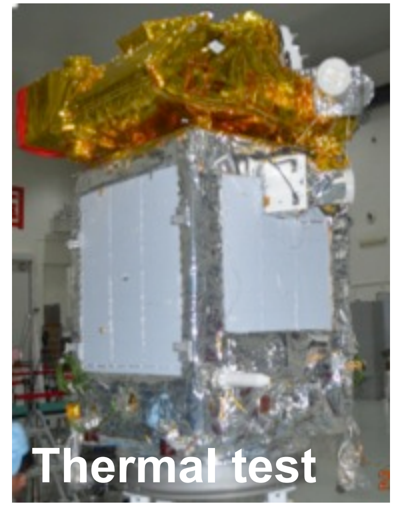
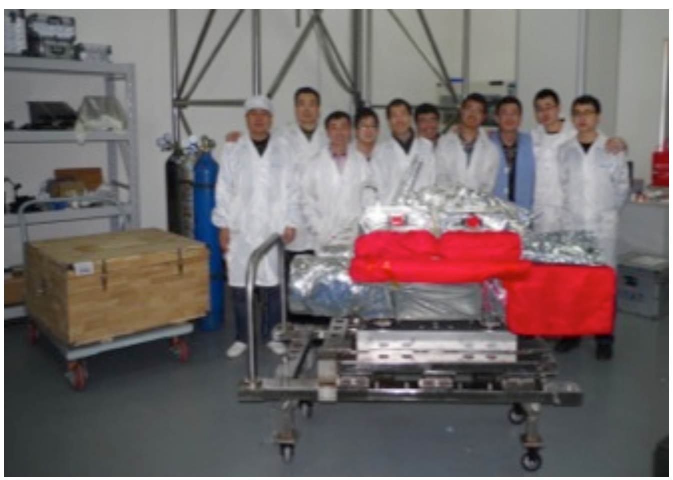
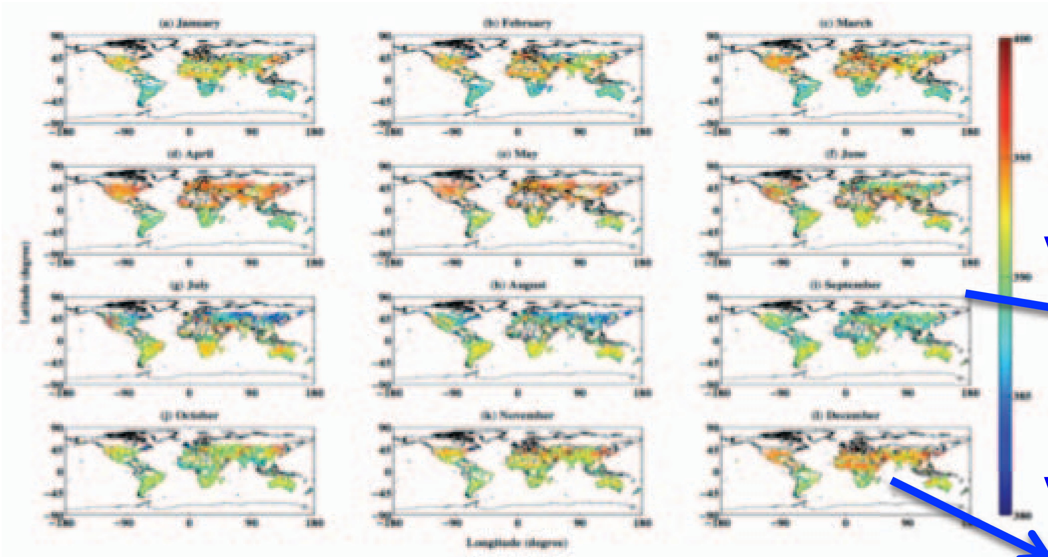
Xs
Ys


Thermal test

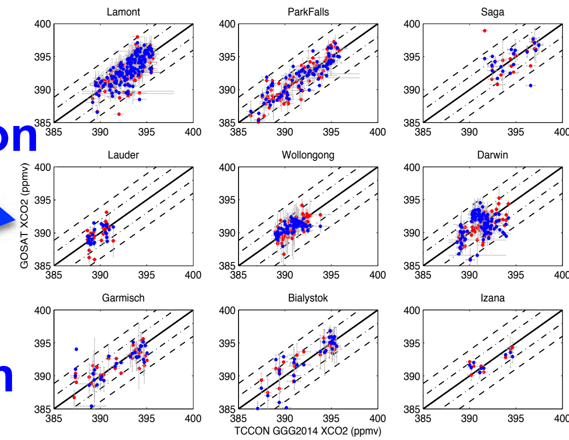



Electronics integration


Mechanical tes

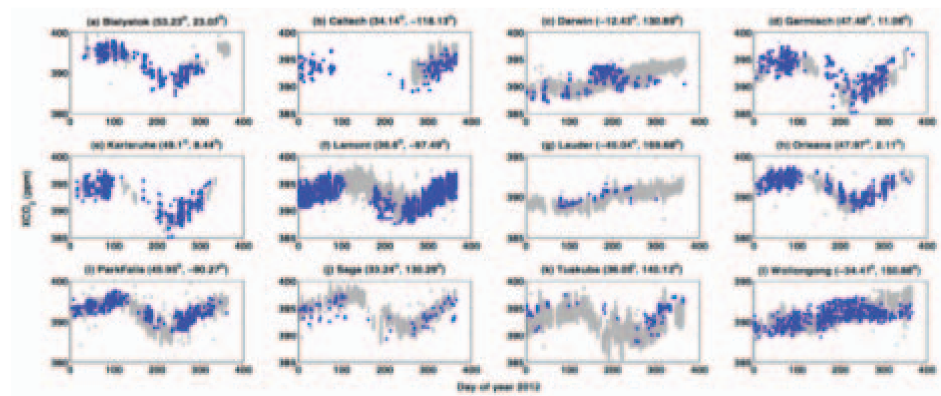


Validation



Variation

TCCON site	Latitude (°)	Longitude (°)	IAPCAS-GOSAT	
			Bias (ppmv)	RMSE (ppmv)
Lamont, USA	36.60	−97.49	−0.58	1.41
Park Falls, USA	45.95	−90.27	0.29	1.29
Saga, Japan	33.24	130.29	1.13	2.08
Lauder, New Zealand	−45.04	169.68	−0.11	0.90
Wollongong, Australia	−34.41	150.88	−0.77	0.95
Darwin, Australia	−12.43	130.89	0.62	1.99
Garmisch, Germany	47.48	11.06	2.02	1.89
Bialystok, Poland	53.23	23.03	0.01	1.50
Izana, Tenerife	28.30	−16.50	−1.22	1.31
Mean	–	–	0.15	1.48



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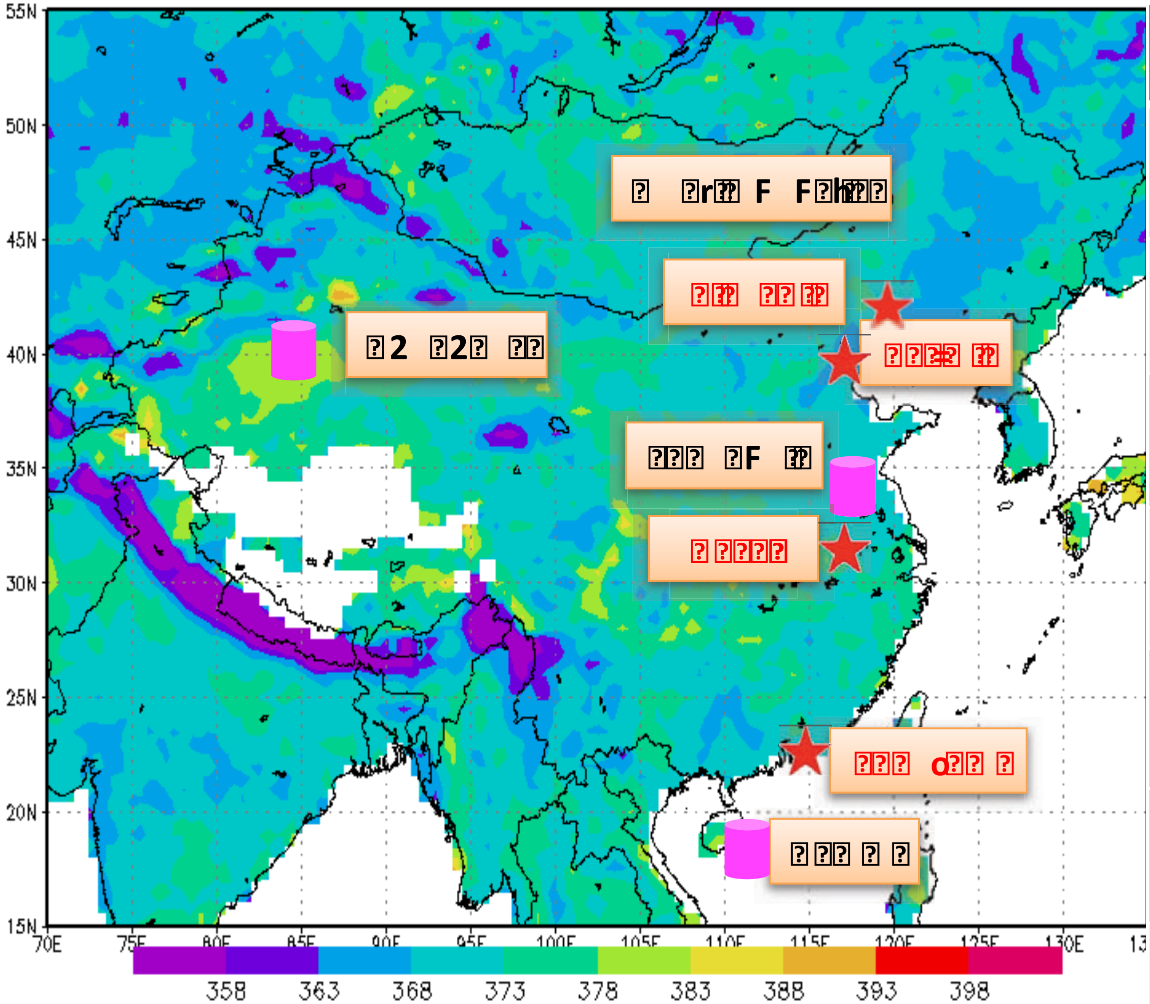
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CHINESE ACADEMY OF SCIENCES

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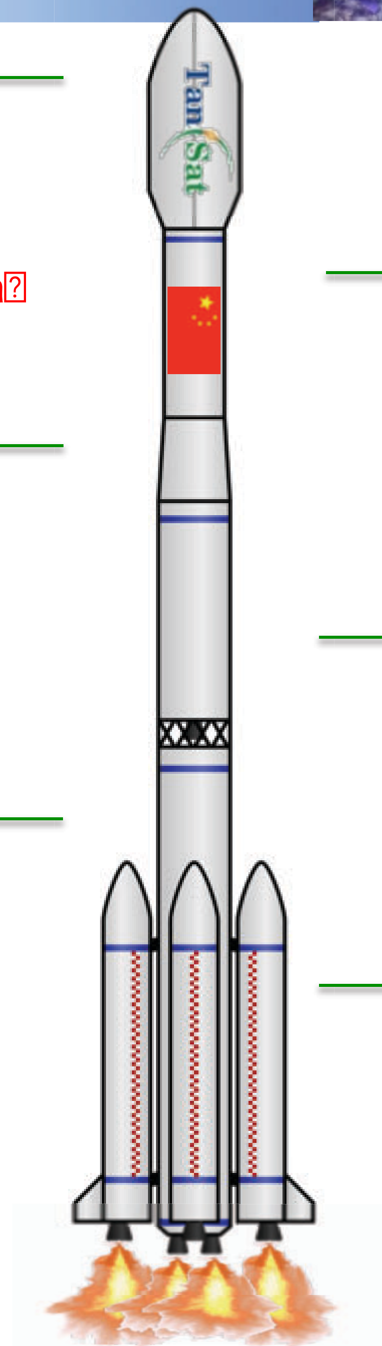

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Present Status

- Well operating
- Has made preliminary test
- Need ~6 months for regular operation and products

- International cooperation considered

Thank You!