A comparative study on multi-model numerical simulation of black carbon in East Asia

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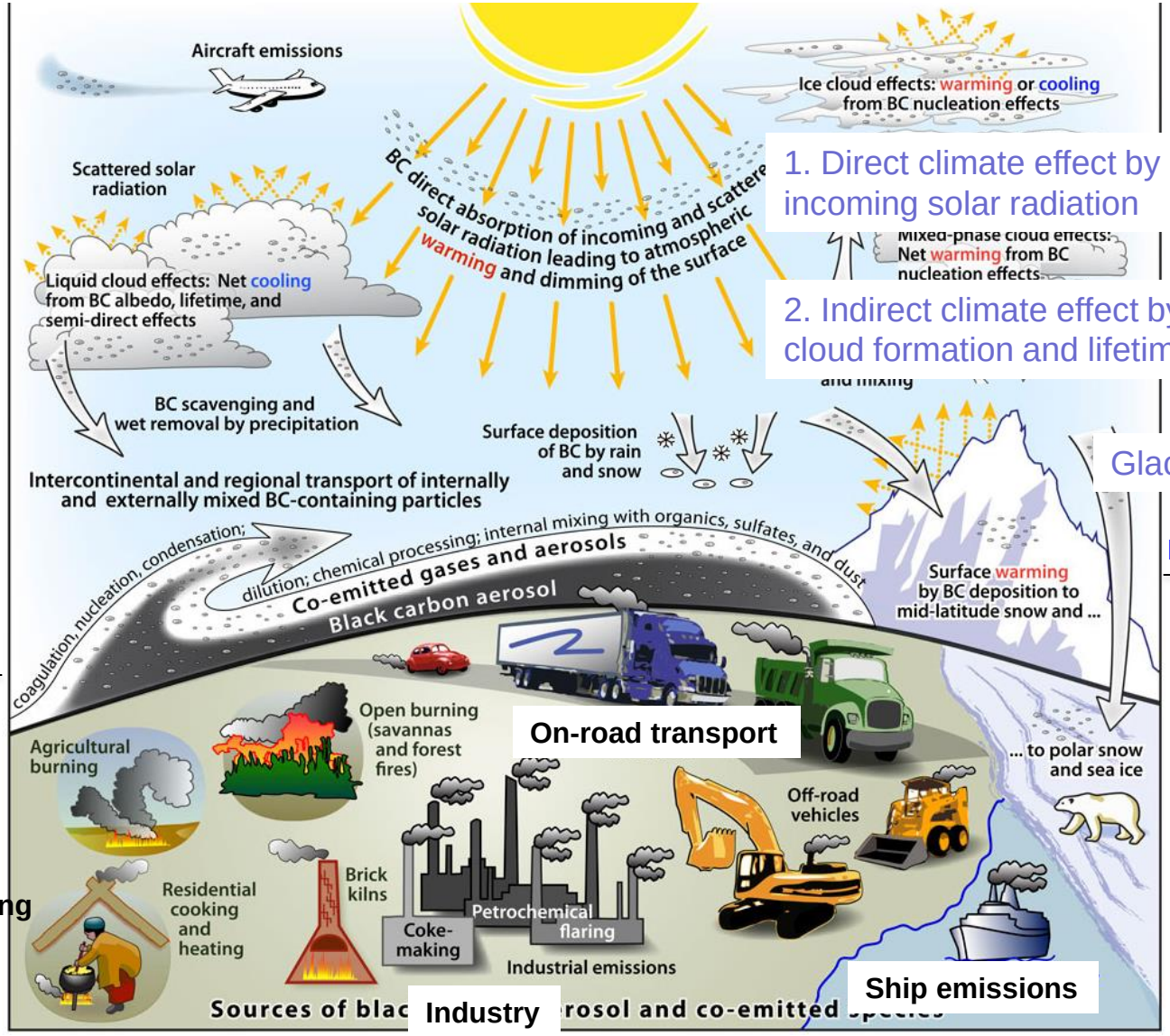
Black carbon in the atmosphere

Definition by EPA: Black carbon (BC) is the most strongly light-absorbing component of particulate matter (PM), and is formed by the incomplete combustion of fossil fuels, biofuels, and biomass.



1. Direct climate effect by absorbing incoming solar radiation

2. Indirect climate effect by influencing cloud formation and lifetime

Glacier melting

Environmental effect

Emission

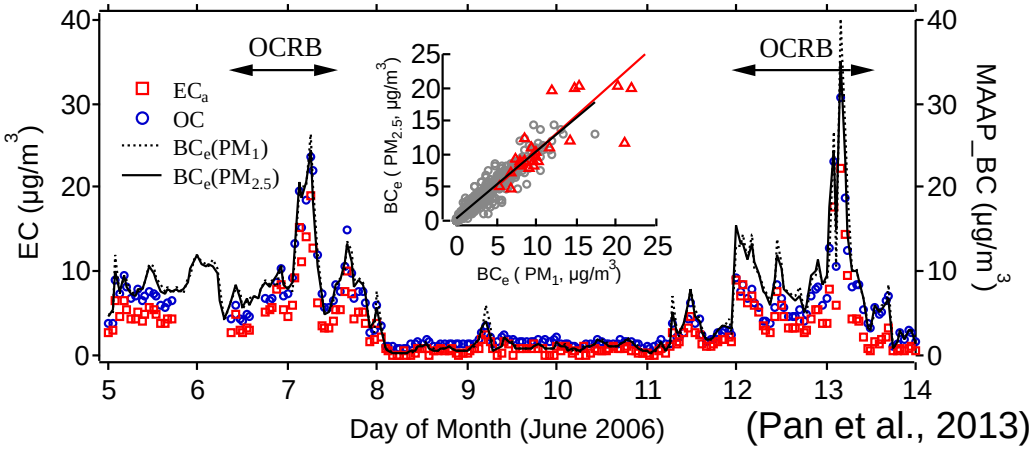
Biomass burning & wild fires

Cooking & heating in rural area

(Bond et al., 2013)

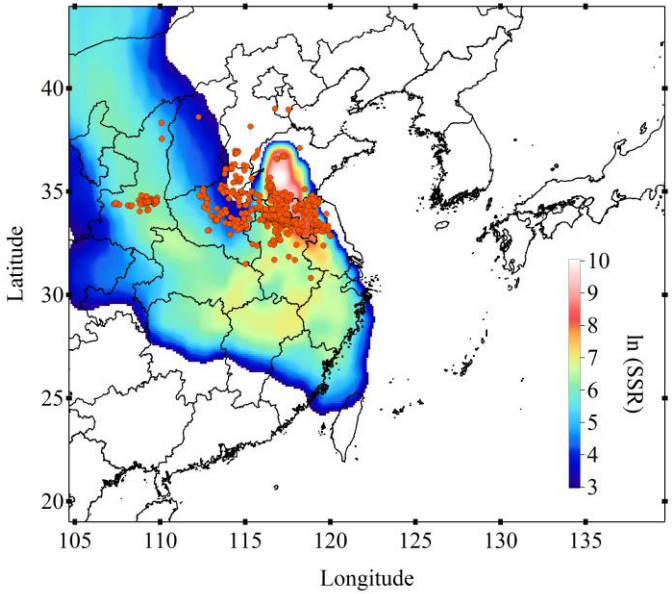
Biomass burning cases during Mt.Tai (1534 m) Campaign

High BC concentration (10~30 ug/m^3)

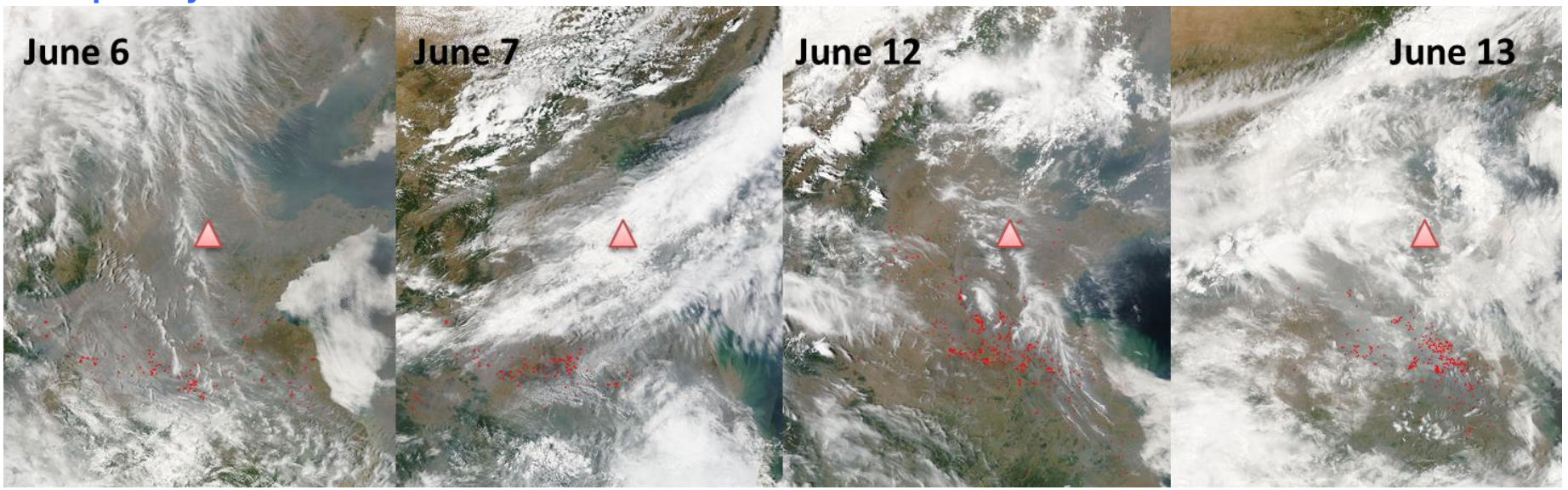


(Pan et al., 2013)

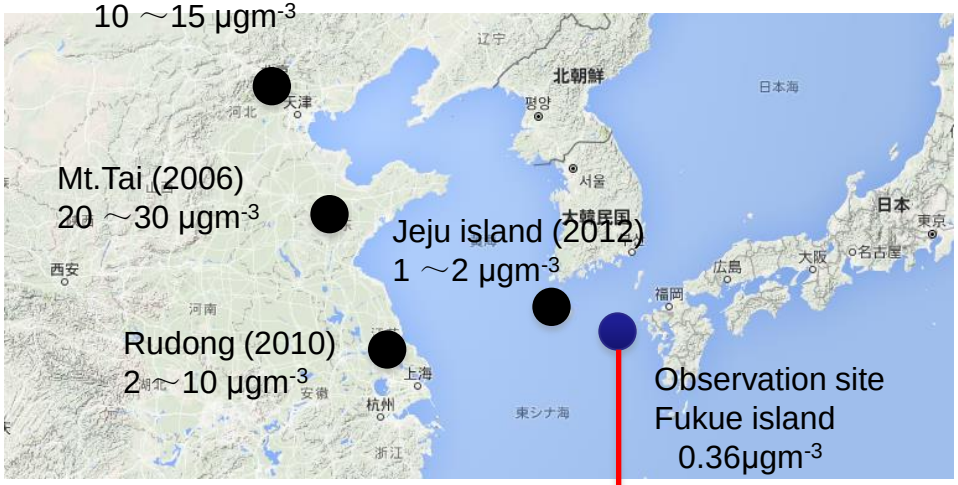
Footprint calculated by FLEXPART model



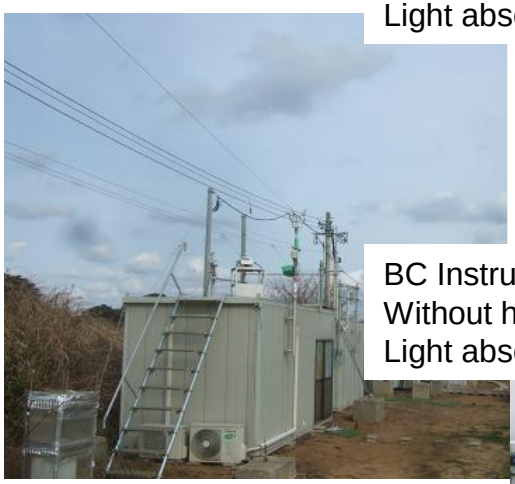
Hotspots by MODIS observation



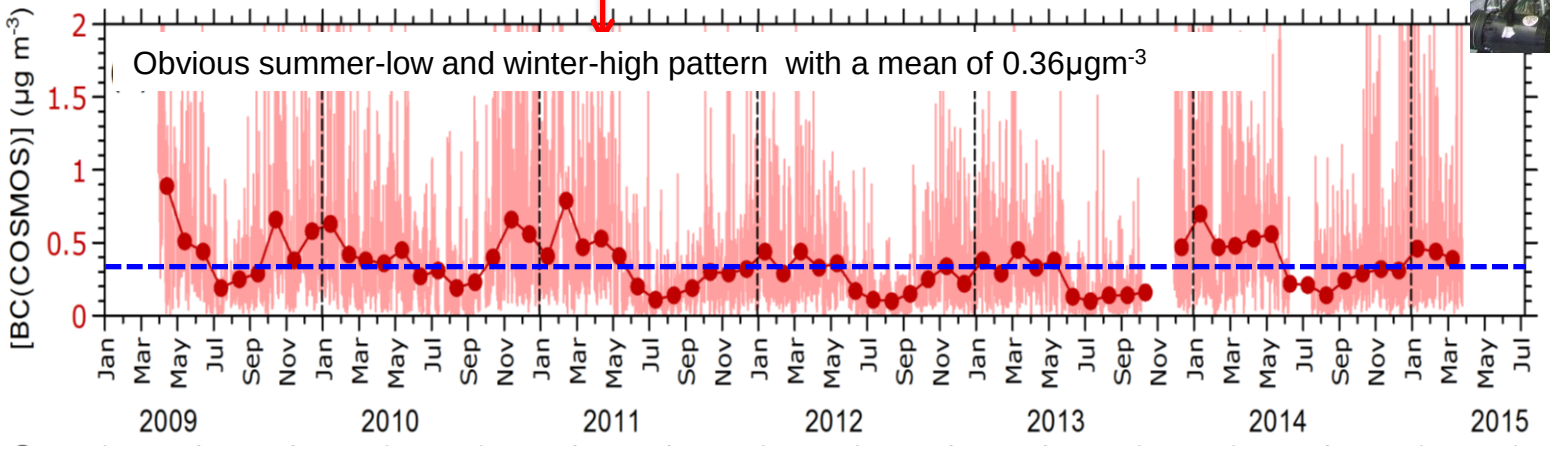
Long term observation (2006 - 2015) of BC mass concentration in East Asia



BC Instrument 1: COSMOS
Inlet flow is heated to 300℃
Light absorbing method

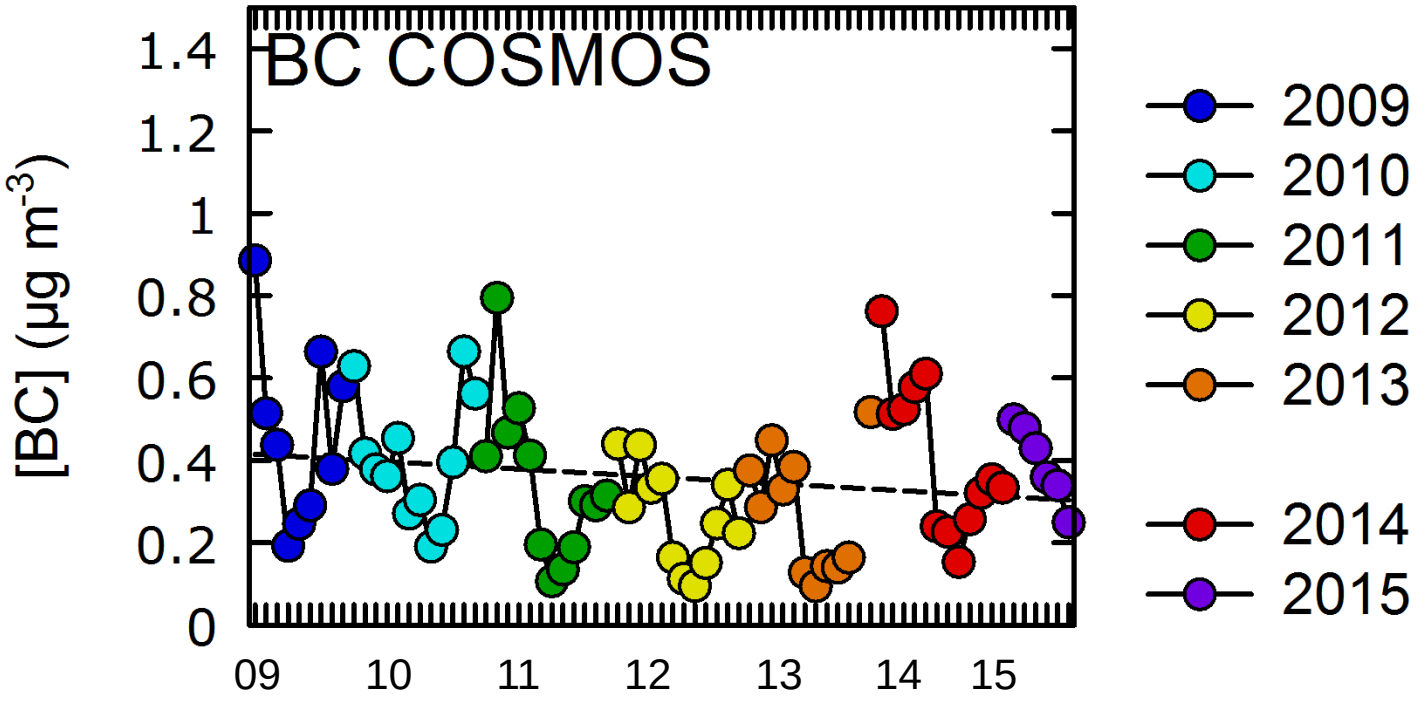


BC Instrument 2: MAAP
Without heating,
Light absorbing method



Significant decrease of BC concentration along the transport pathway indicates that the long range transport ability of BC from Asian continent is very limited!

BC concentration in Fukue island showed decreasing trend in the past 7 years.



How about the ability of different air quality models?

The Model InterComparison Study for Asia

MICS-Asia Phase I and II

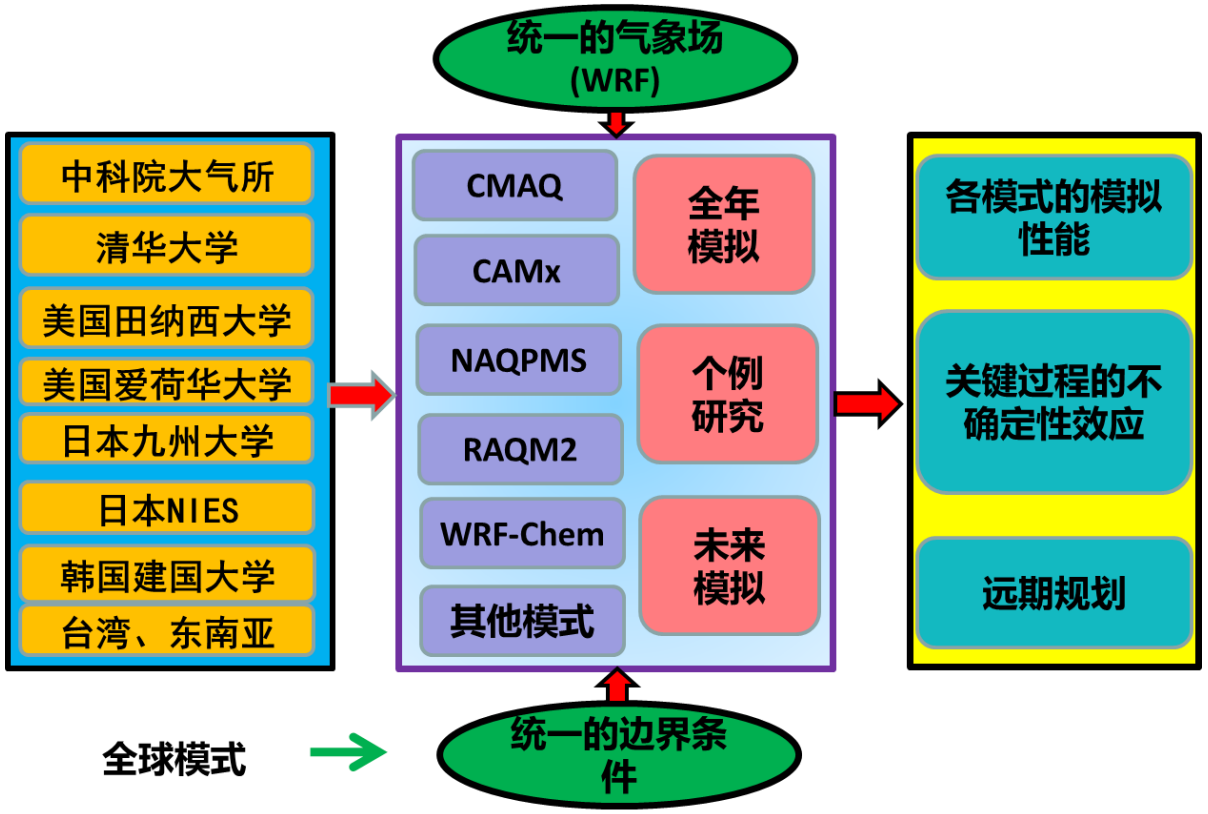
- To obtain common understanding of model performance and uncertainties in Asia.
- MICS-Asia Phase I (1990-2000), long-range transport and deposition of sulfur.
- MICS-Asia Phase II (2001-2009), taking into account more species than Phase I.

  sulfur, nitrogen compounds, ozone and aerosols

Achievement of MICS-Asia II were published in AE in 2008

MICS-Asia III and HTAP

20 groups from China, Japan, USA, Korea and Countries in South Asia added the MICS-Asia III, and had Joint with HTAP for hemispheric study



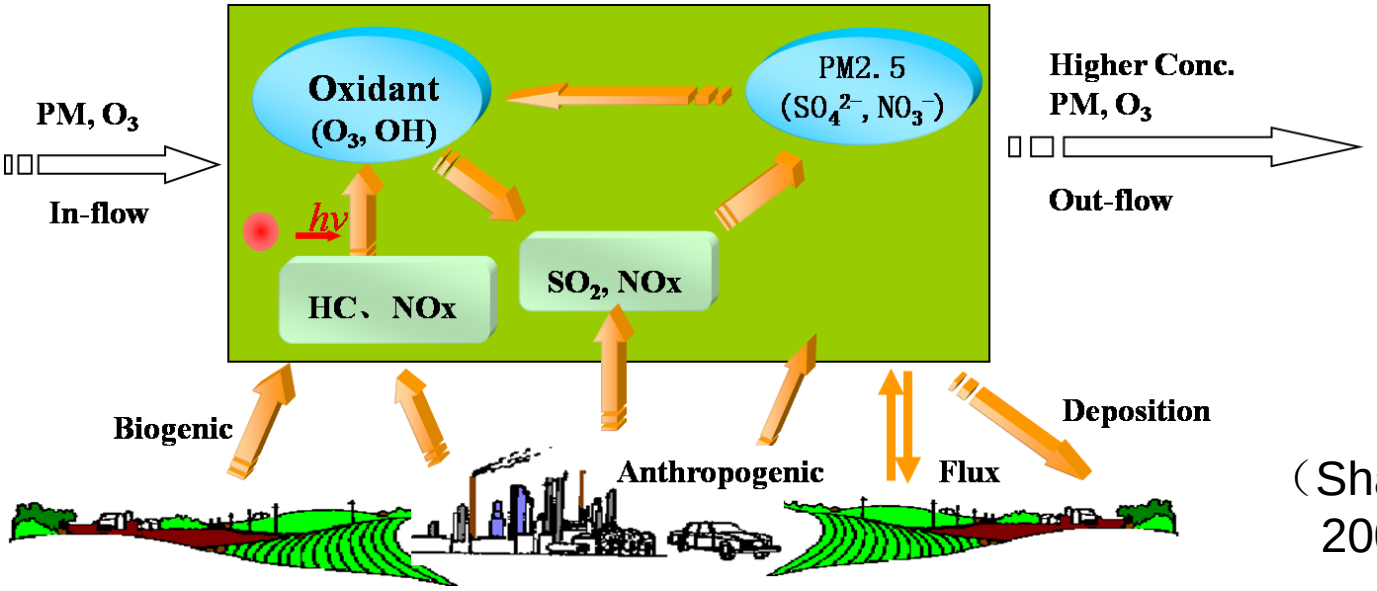
HTAP& MICS-Asia workshop，
Beijing，2015

OBJECTIVES of MICS-Asia III

- To **evaluate strengths and weaknesses** of current multi-scale air quality models and provide techniques to **reduce uncertainty** in Asia
- To develop a **reliable anthropogenic emission inventories** in Asia and understand uncertainty of bottom-up emission inventories in Asia
- To provide multi-model **estimates of radiative forcing** and **sensitivity analysis** of short-lived climate pollutants

Model Intercomparison

Air Pollution Complex in Asia: Regional Haze and High Ozone

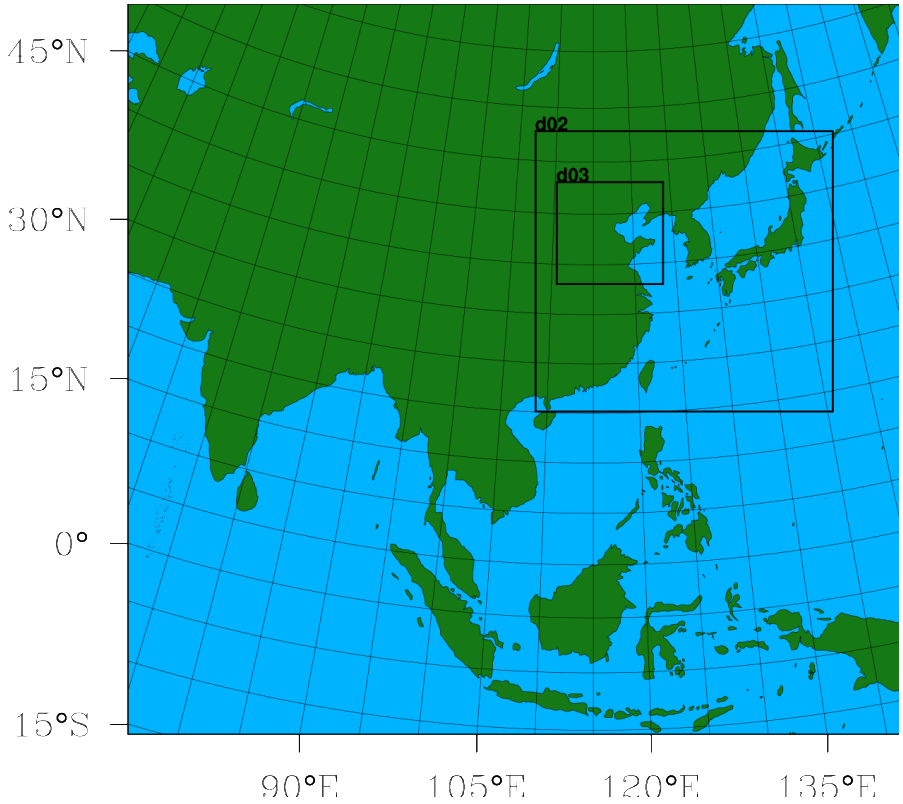


（Shao et al, 2006)

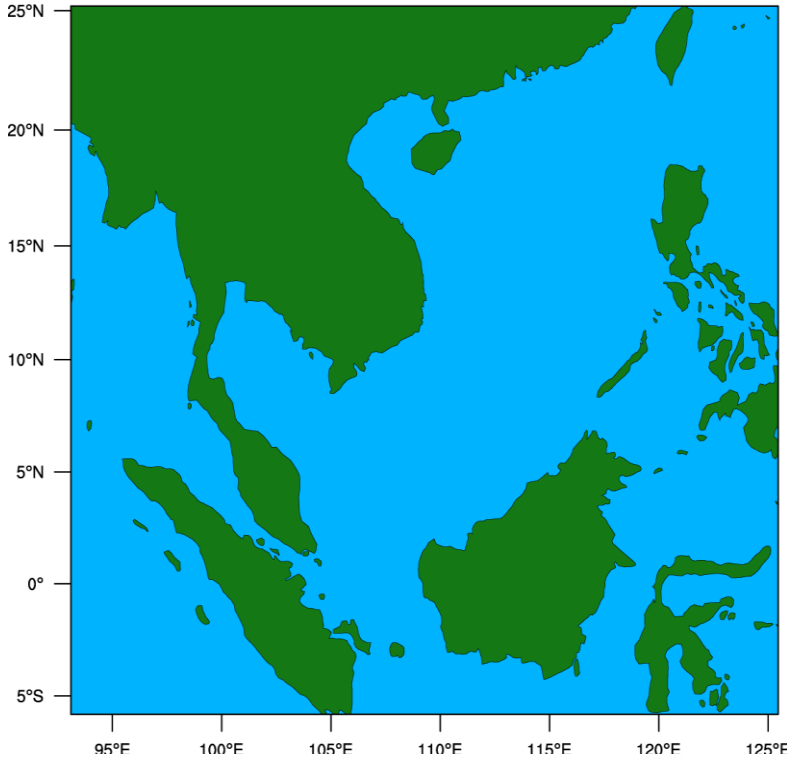
To understand and improve air quality models, we need to

- **Assessing the ability of models to reproduce pollutant concentrations under highly polluted conditions (Regional Haze and High Ozone);**
- **Quantifying uncertainties of each process (phys and chem), model resolutions (hori and vert) and key boundary layer parameters.**
- **Investigating the air quality responses to specific emissions perturbations in a common case.**

Model domains



Model domains (D1, D2, and D3) for Northeast Asia



Model domain (D2) for Southeast Asia
D1 for Southeast Asia is exactly the same as that for Northeast Asia.

Prepared inputs for all the participated models

- **Gridded emission**

Anthropogenic emissions datasets:

Mosaic national emission inventories of China, Japan, Korea, India ,Thailand.

Other anthropogenic emission, such as aircraft and shipping emissions

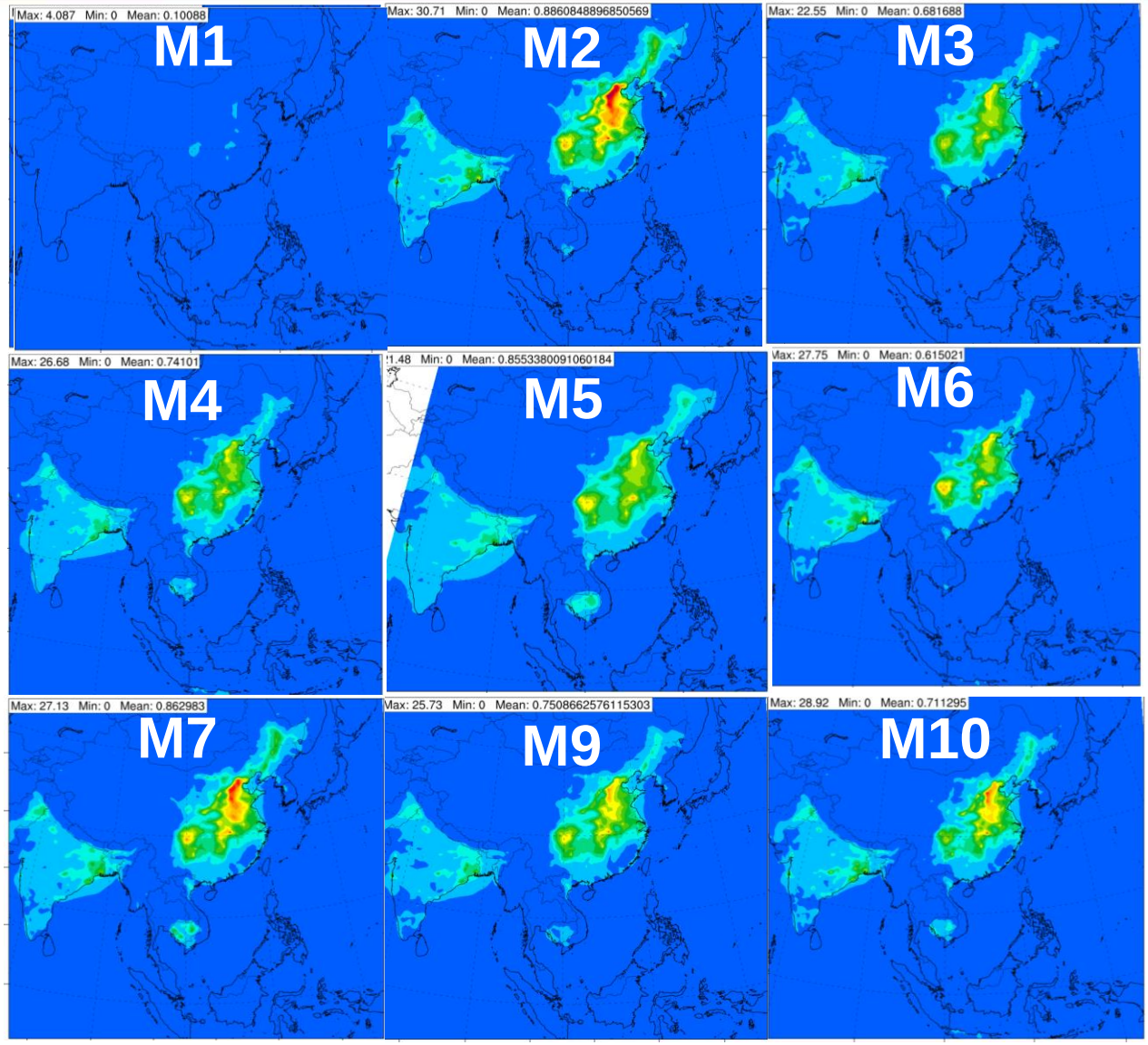
Natural emissions datasets:

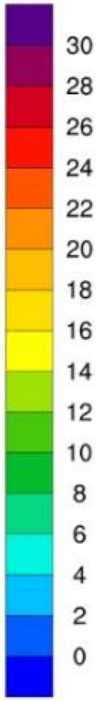
Biomass burning, Biogenic, Volcano, Dust, Sea-salt, Soil Nox and HONO, Lightning NOx

- **Meteorological fields**

Prepared the same meteorological model (WRF or other models) to drive air quality models.

Multi-Model comparison of BC (Jan.2010)

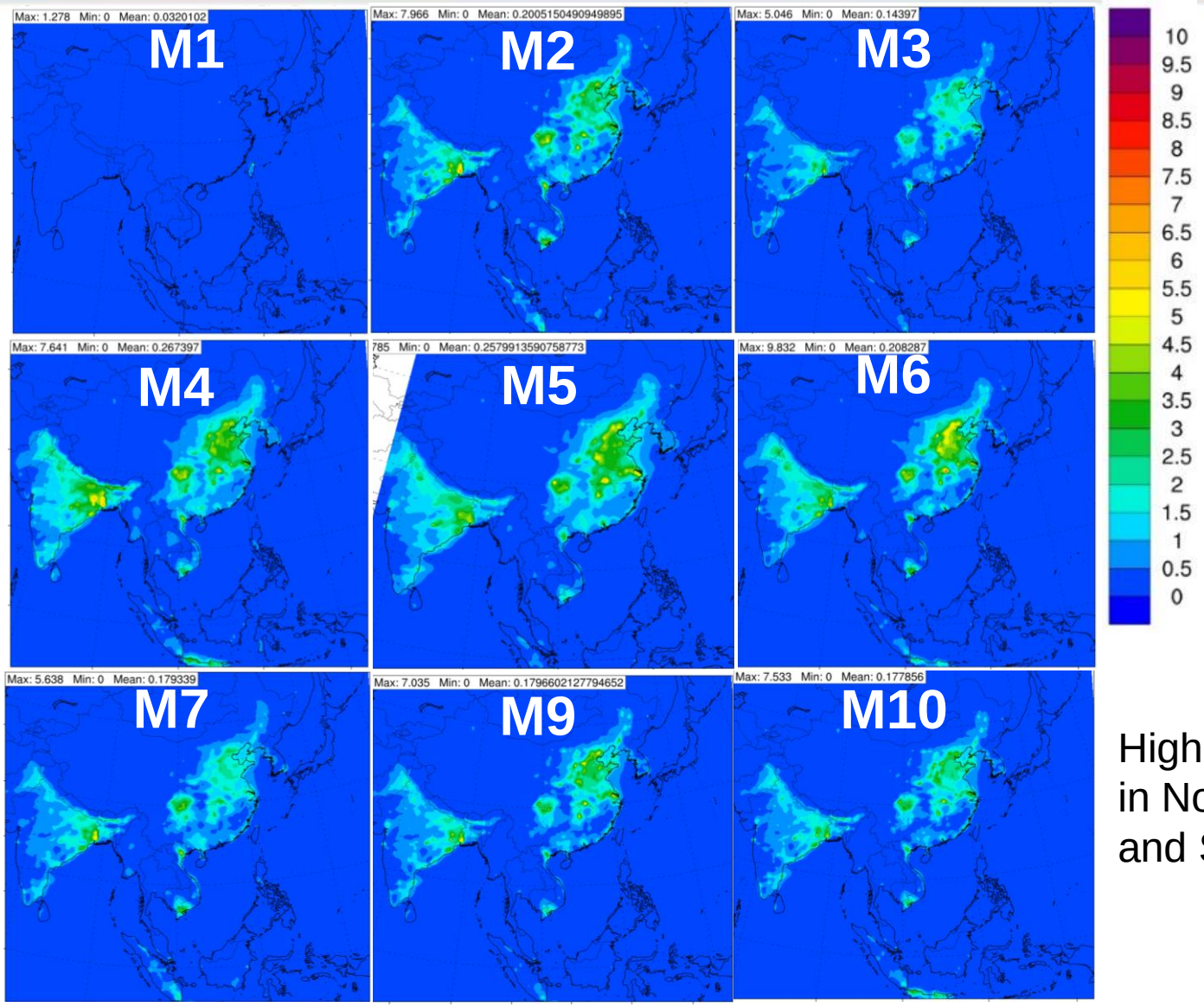




The simulation performance on BC are almost the same except M1 in Jan.,2010.

Higher BC concentration in North China Plain (NCP) and South Tibetan Plateau

Multi-Model comparison of BC (Jul.2010)

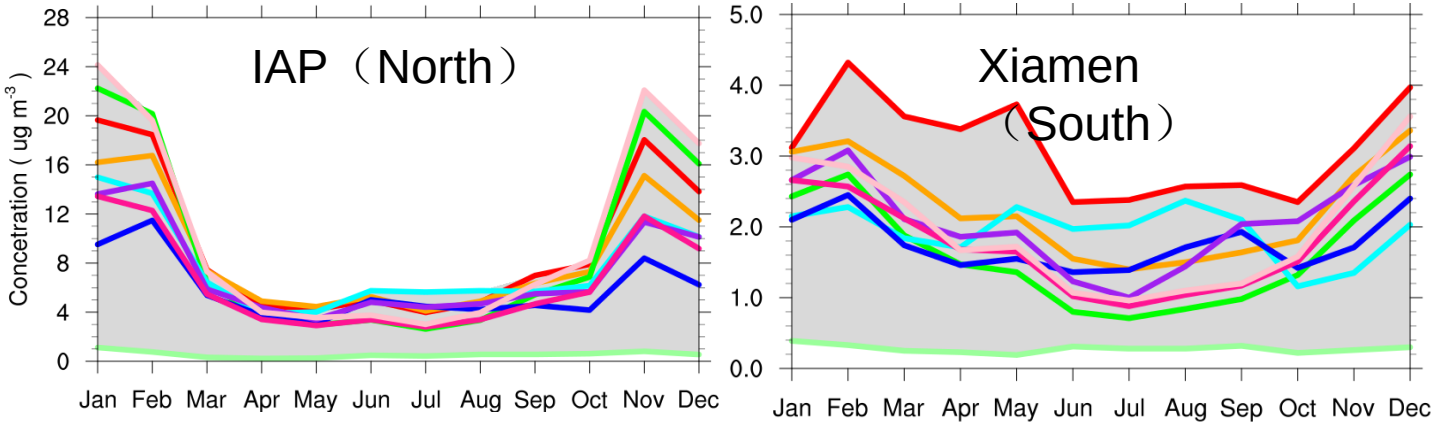


The simulation performance on BC are almost the same except M1 in Jul.,2010.

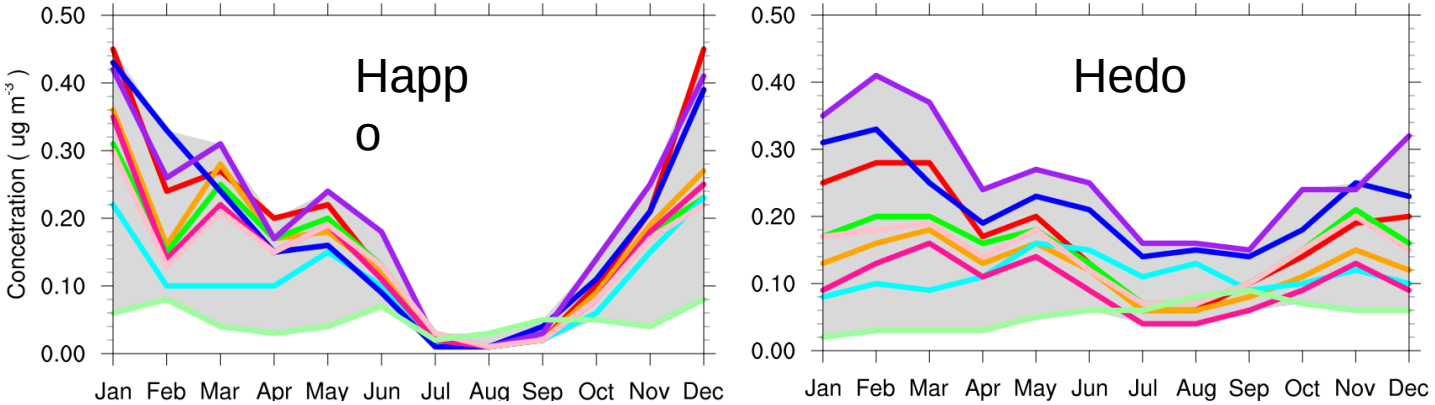
Higher BC concentration in North China Plain (NCP) and South Tibetan Plateau

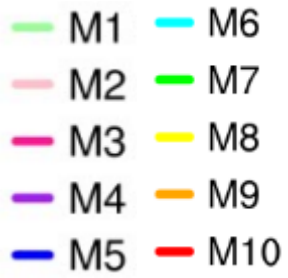
BC simulation in different regions

China



Japan



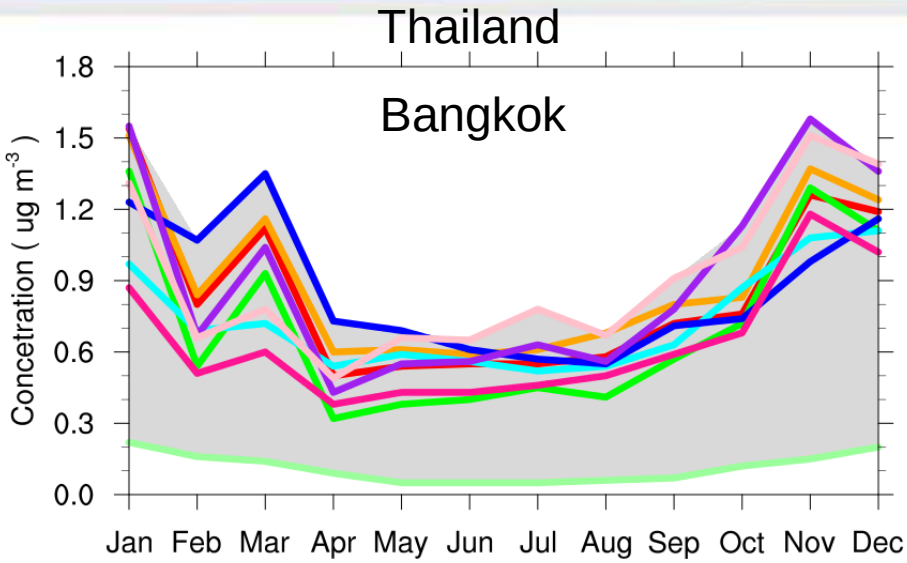


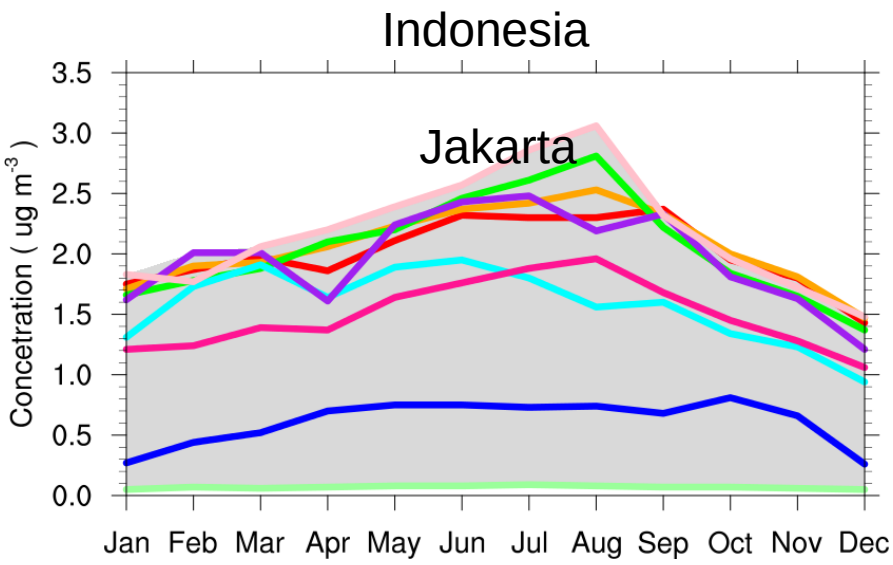
Significant seasonal variation occurs in NCP

Higher concentration distributes over China, especially in the north

Higher concentration appered in winter and lower in summer

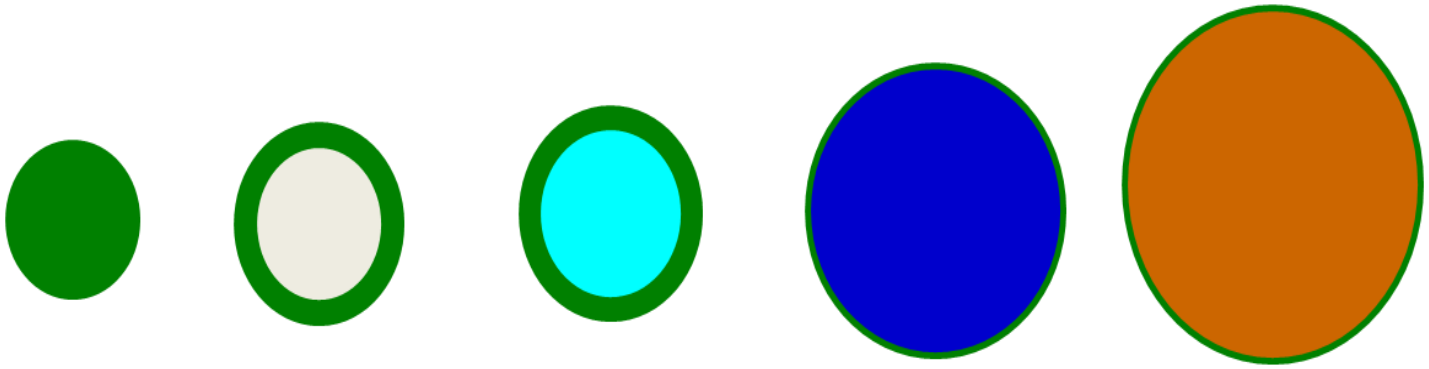
BC simulation in different regions





Higher consistency of multi-model in Summer (Northern Hemisphere）

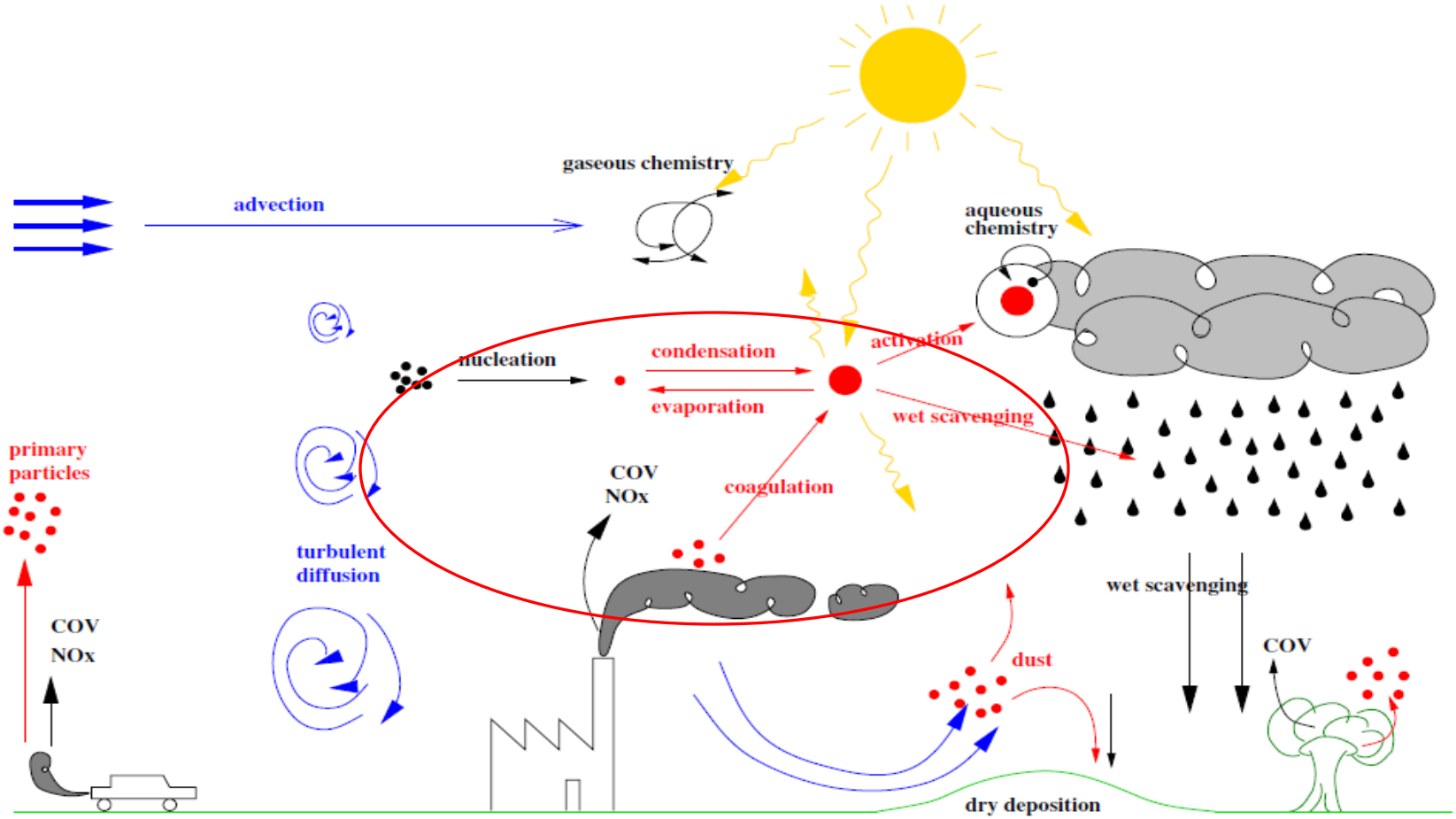
Aerosol (soot) climate and environmental effects depend on



- Concentration
- Composition
- Size
- Mixing state

- Emission
- Transport, deposition
- Microphysics
- Chemical reaction

NAQPMS+APM



NAQPMS+APM describes nucleation, condensation/evaporation, coagulation and size-resolved deposition.

Introduction to APM

■Mixing state: semi-external

•Secondary particles

•Primary particles + coating

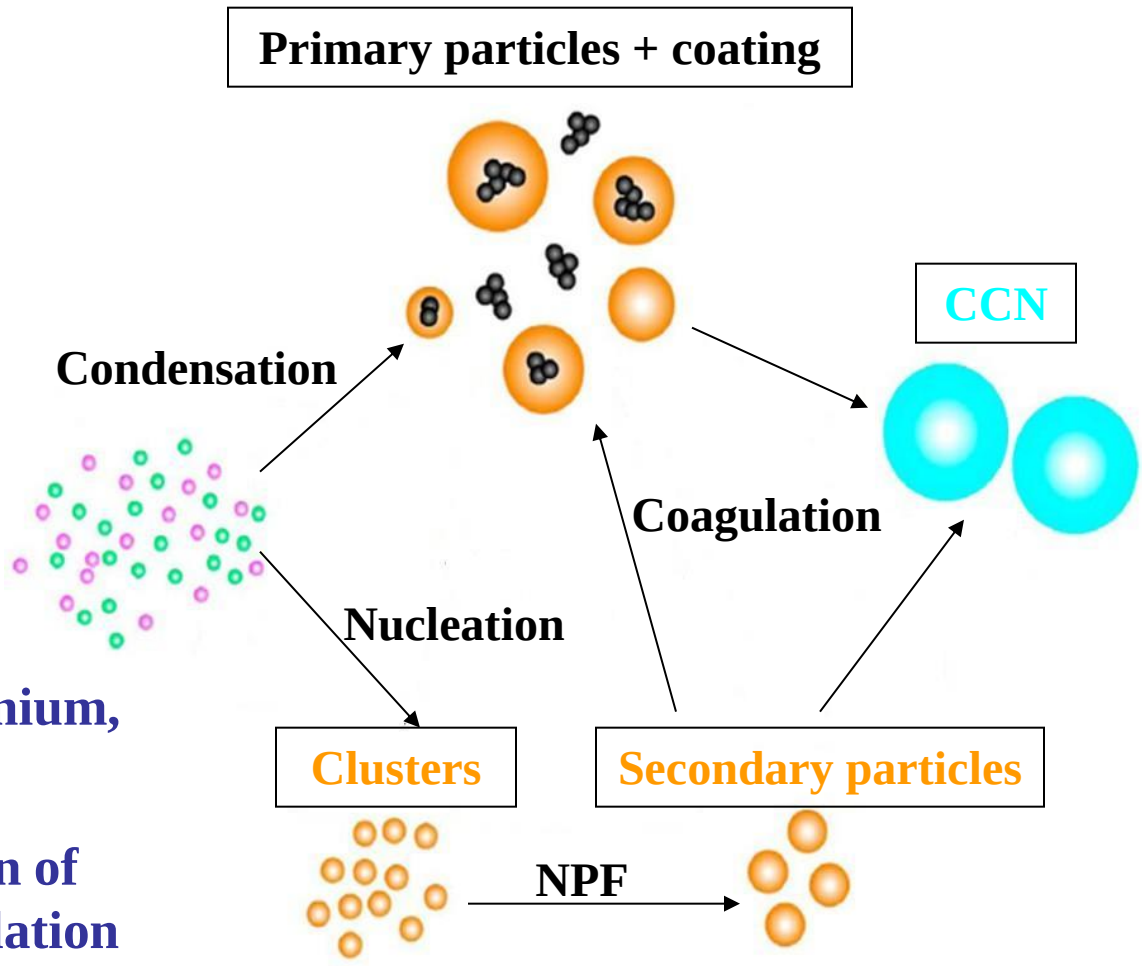
■微物理过程：

•Nucleation： IMN or other

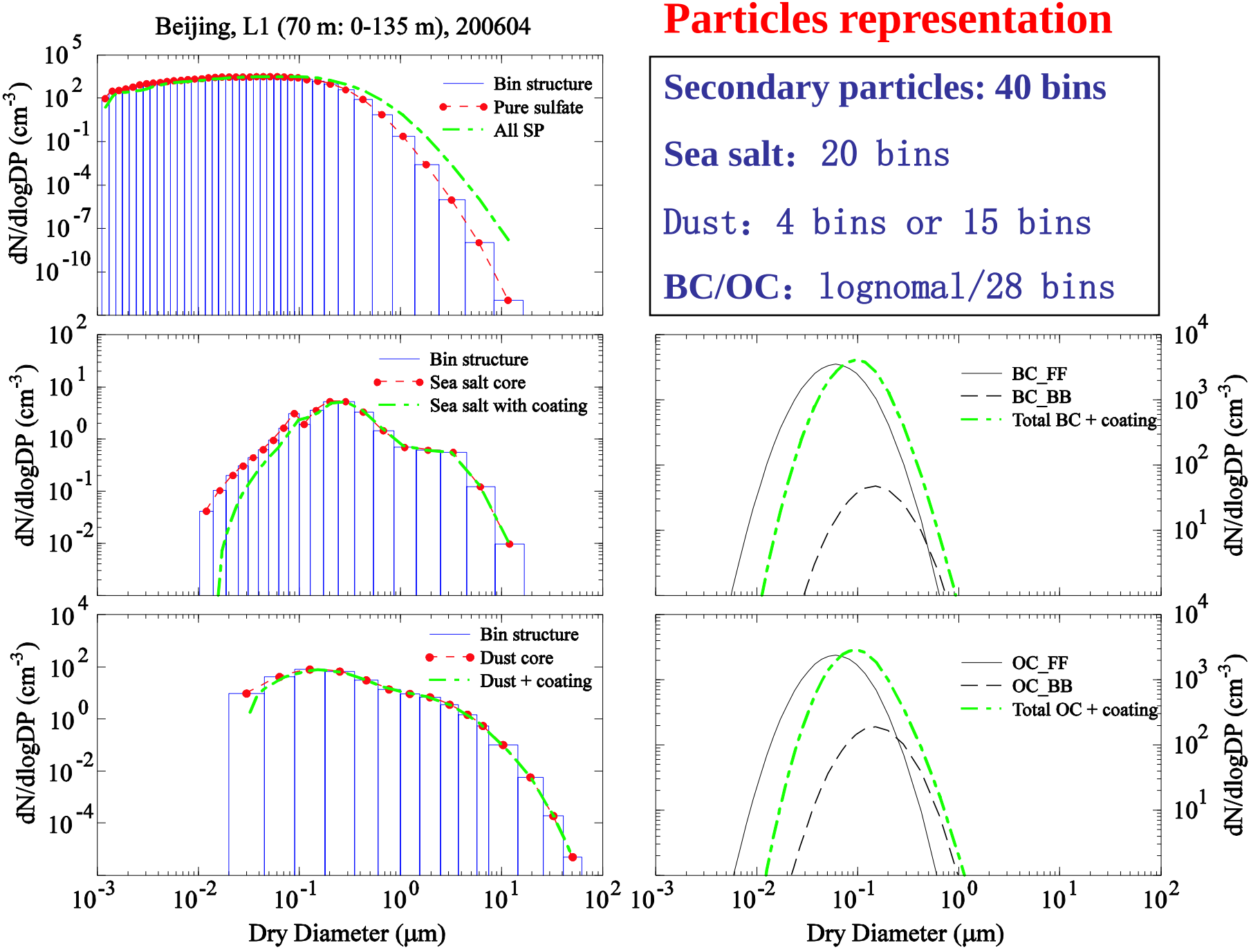
•Condensation： sulfuric acid

•Equilibrium： Nitrate, ammonium, SOA

•Coagulation： Self-coagulation of secondary particles and coagulation scavenging by other particles



Particles representation



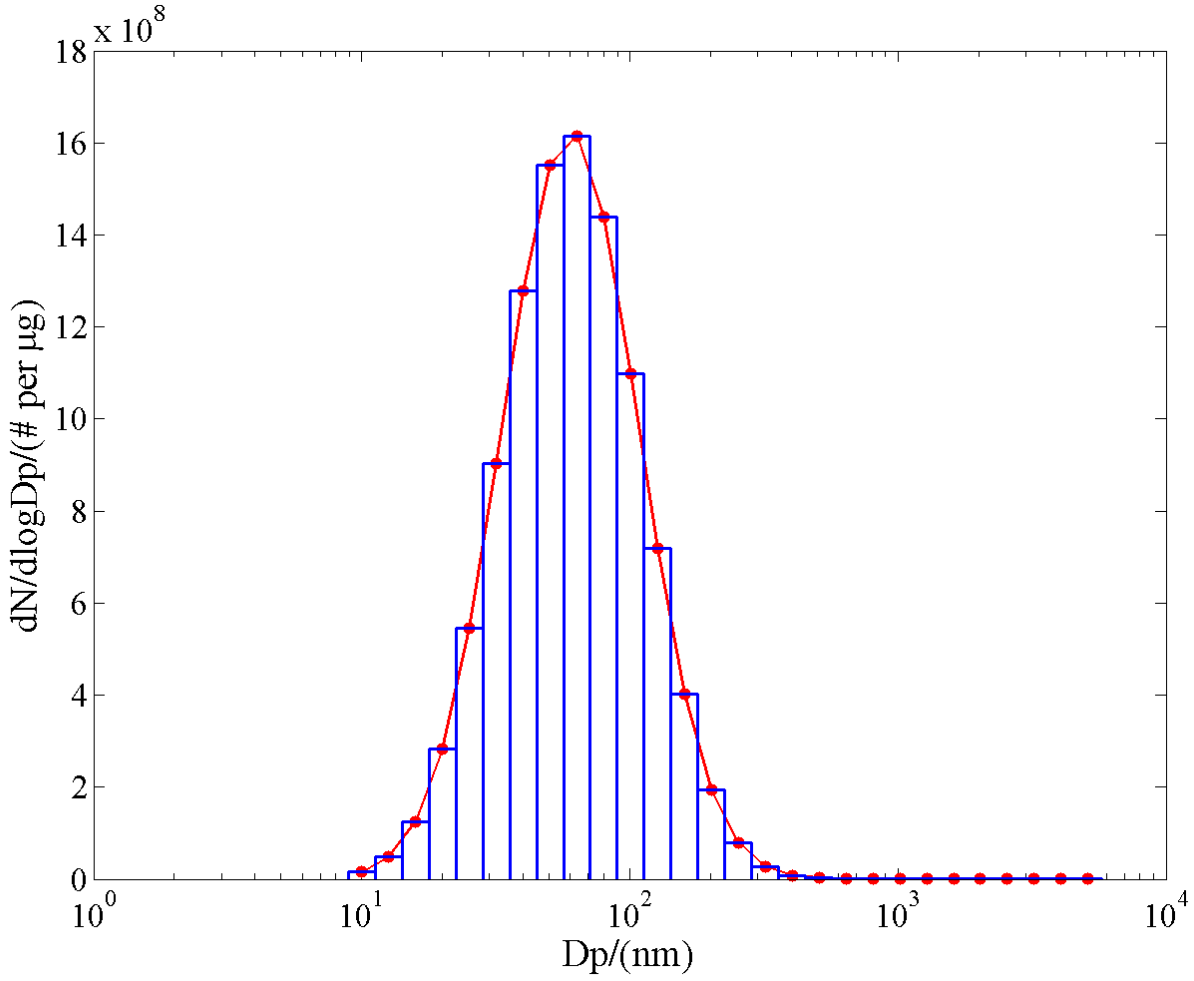
Secondary particles: 40 bins

Sea salt: 20 bins

Dust: 4 bins or 15 bins

BC/OC: lognomal/28 bins

Carbonaceous particles size bins



■**Size bins:**

10nm-10μm, 28 bins

■**Coagulation:**

Jacobson（1994）

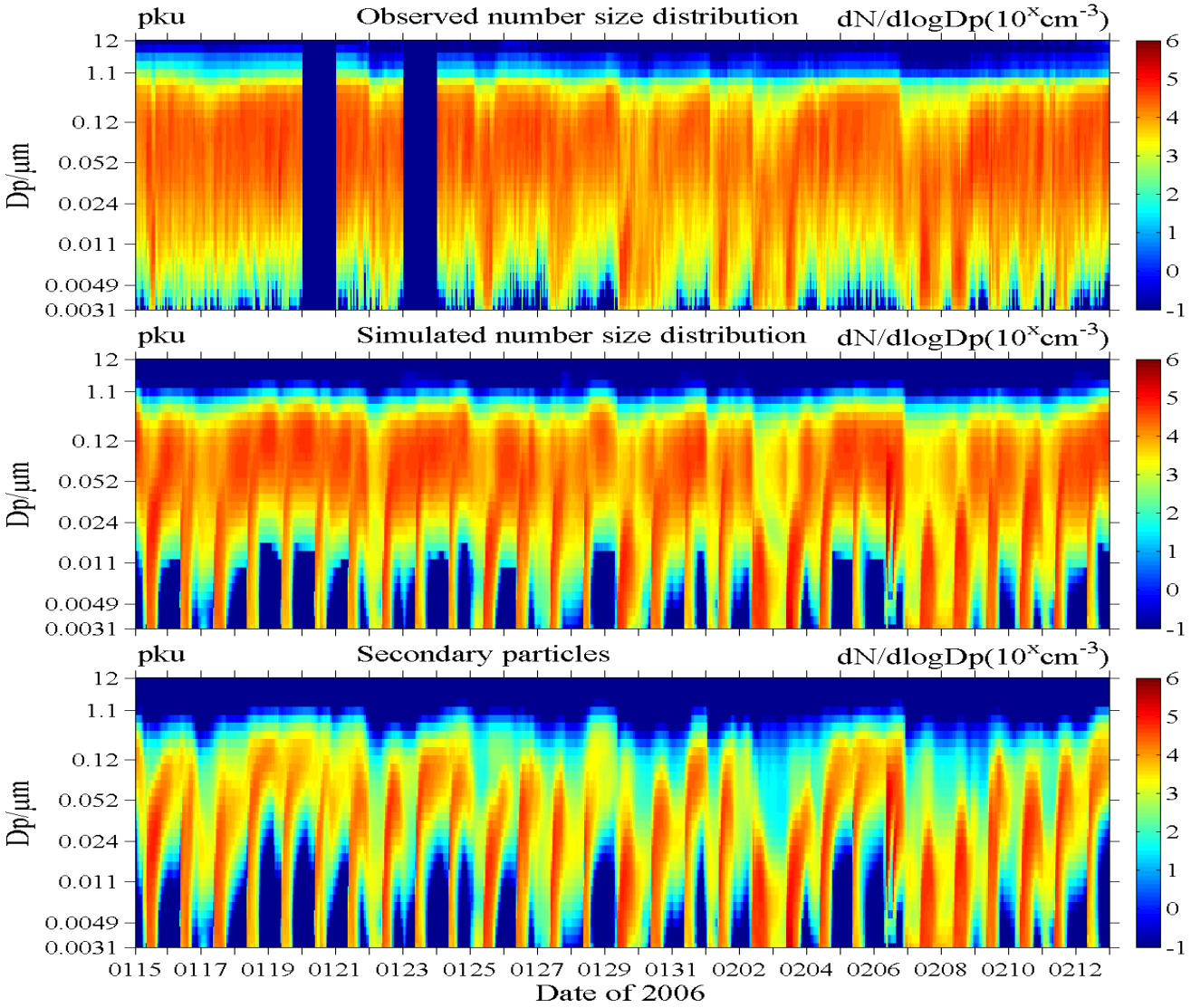
■**Ageing**

e-folding time: 1.2 day

✓**Coagulation can be considered;**

✓ **Model can be constrained by observed BC size distribution.**

Particles number size distribution in Beijing

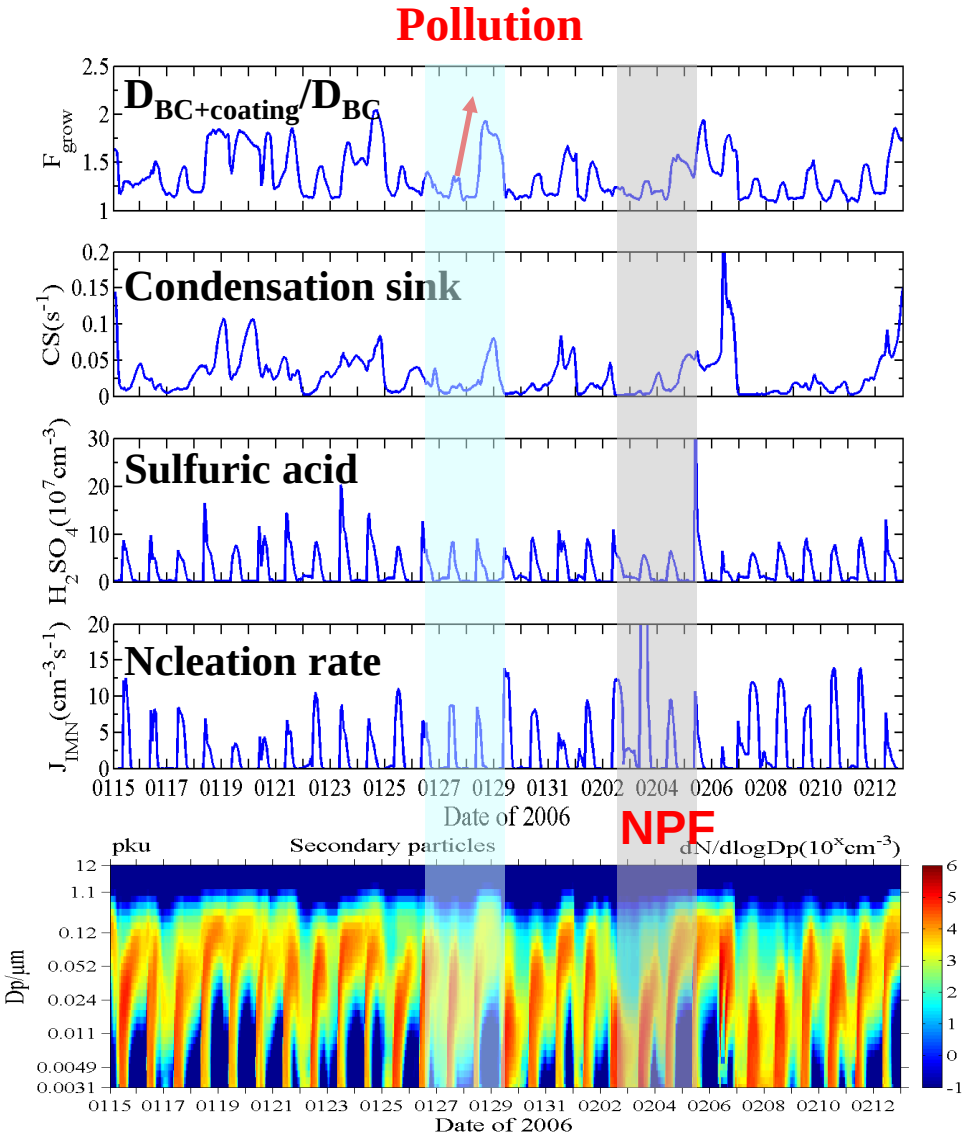


Observed

Simulated

Secondary particles

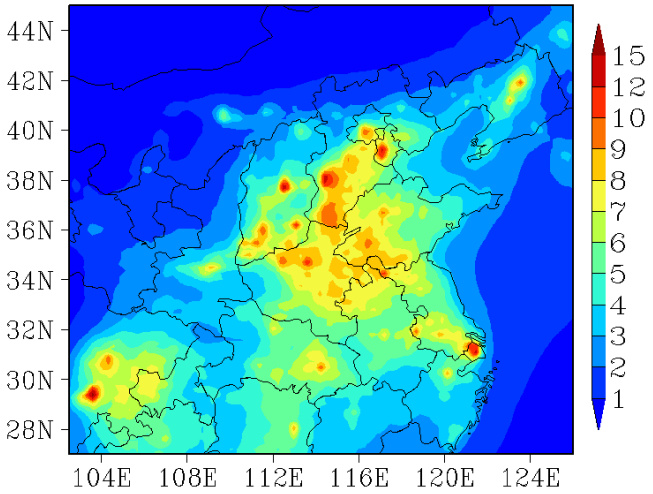
Evolution of microphysics parameters



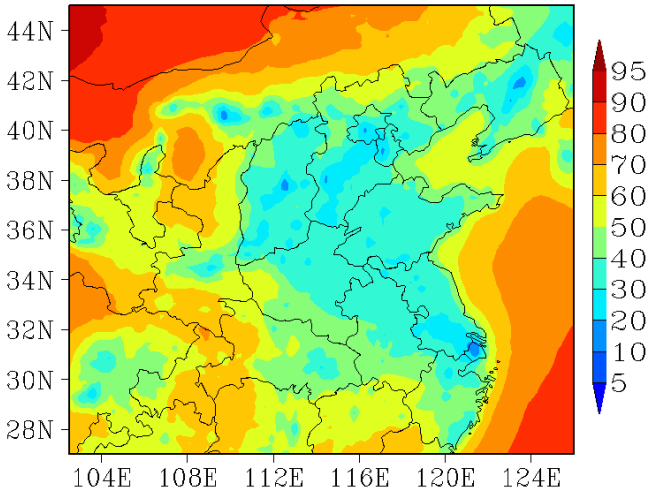
- $D_{BC+coating}/D_{BC}$ can be as high as 1.5 or obove, BC mixing state was changed;
- Condensational sink was higher in pollution episodes;
- Sulfuric aid concentration showed a evident diurnal variation;
- Nucleation rate was higher in NPF event;
- NPF can be identified and reproduced by NAQPMS+APM.

Key parameters of BC in central-eastern China

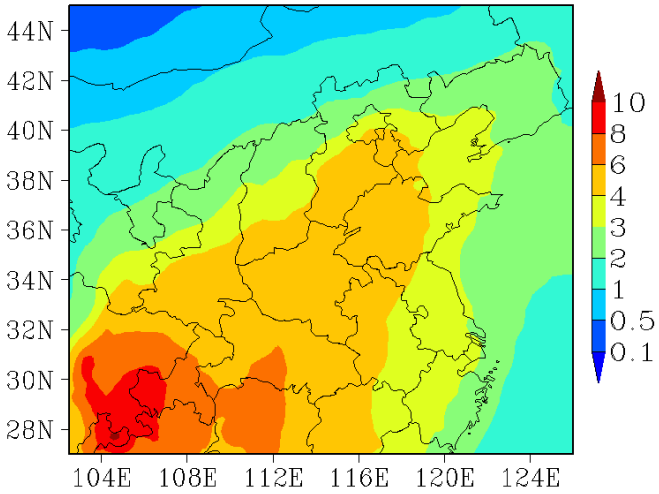
BC conc(ug/m^3)



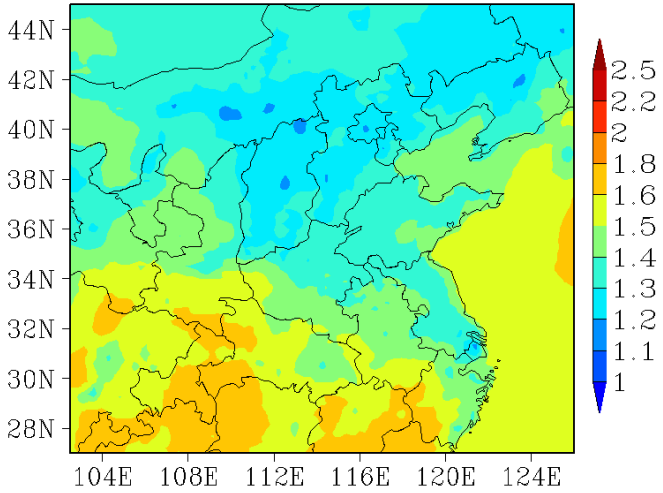
Hydrophilic BC frc(%)



Sulfate on BC(ug/m^3)

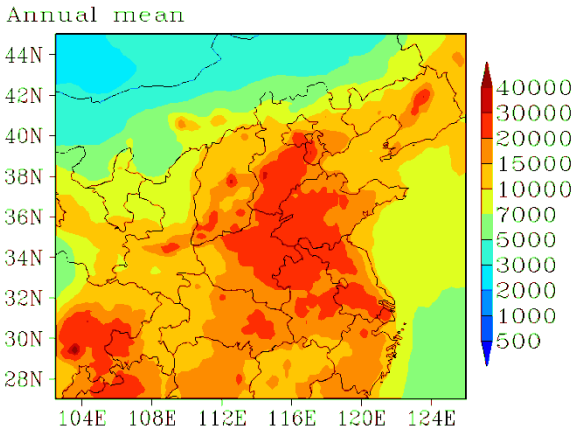


$D_{BC+coating}/D_{BC}$(-)

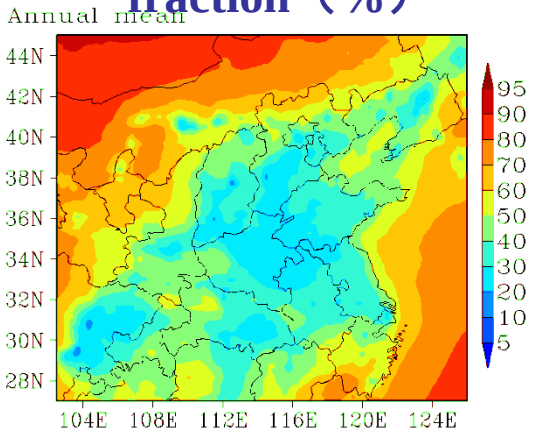


Microphysics parameters in central-eastern China

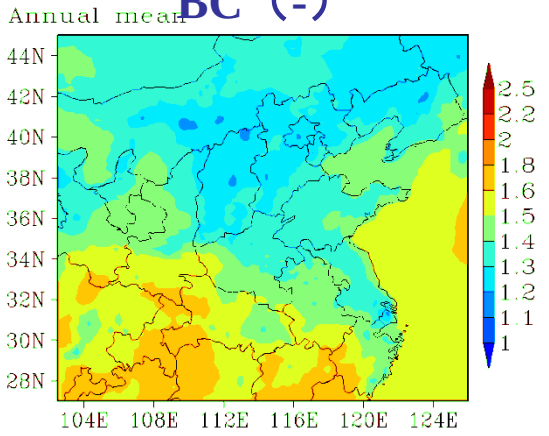
CN10nm（cm^{-3}）



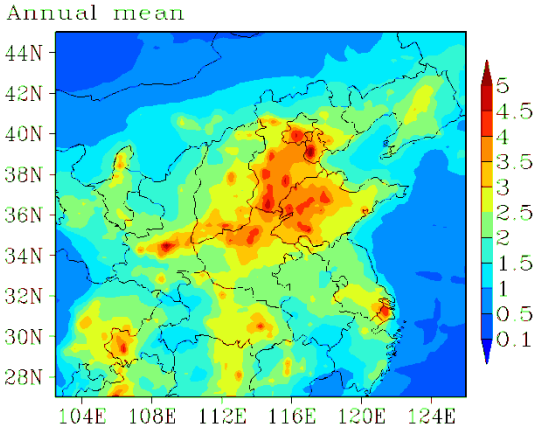
Secondary particles fraction（%）



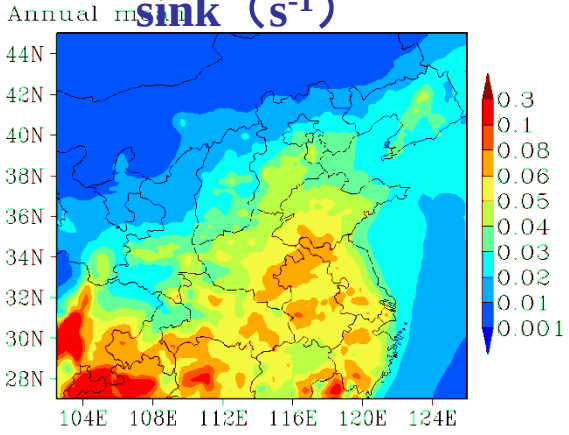
Growth factor of BC（-）



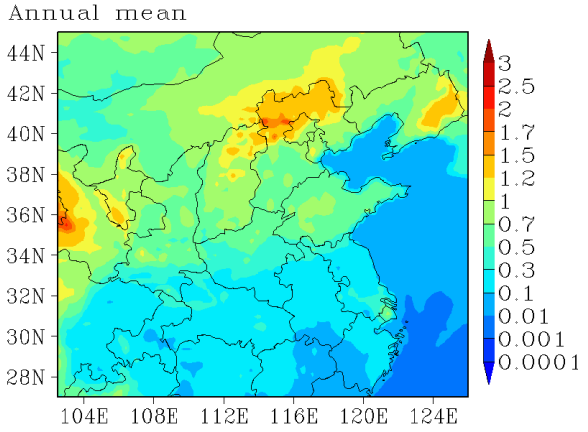
H_2SO_4(g)（$10^7 cm^{-3}$）



Condensational sink（s^{-1}）

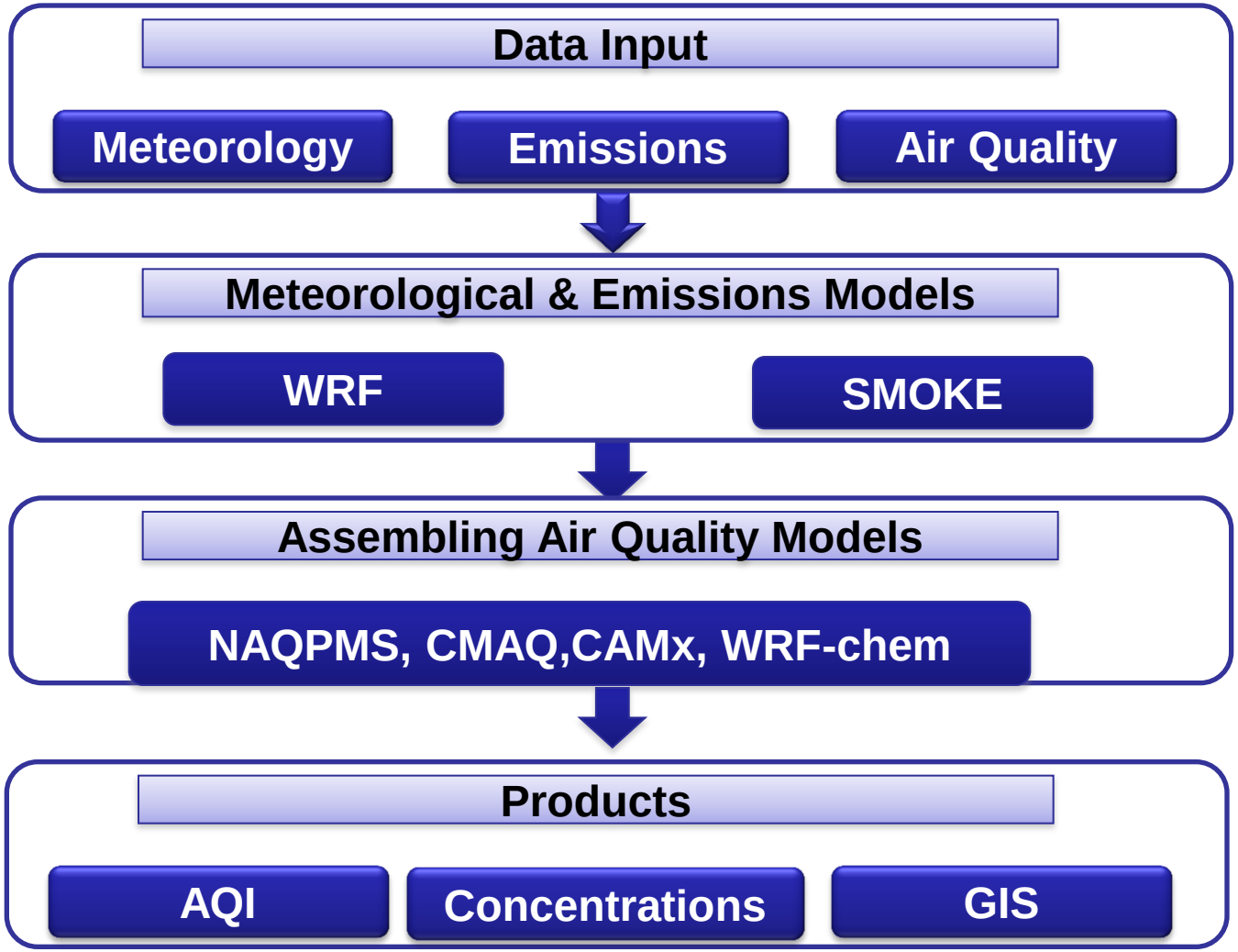


IMN（$cm^{-3}s^{-1}$）



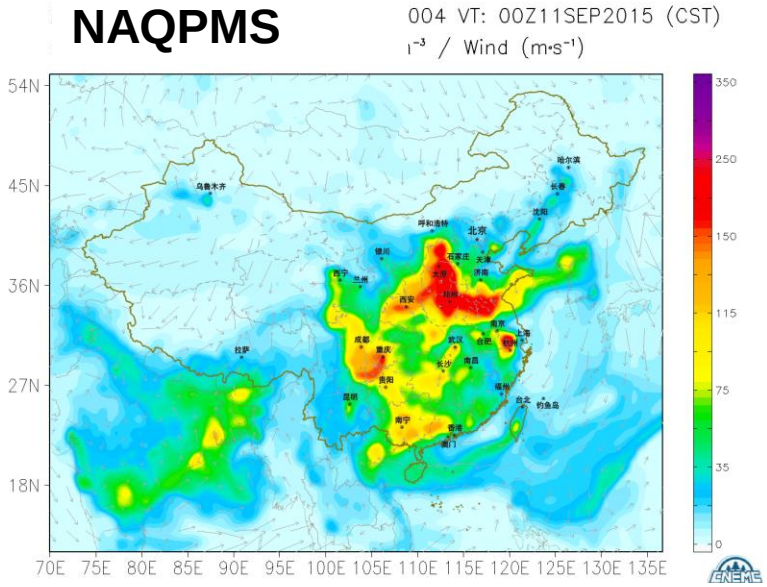
National Air Quality Operational Platform

- **Scheme of the national forecasting model system**

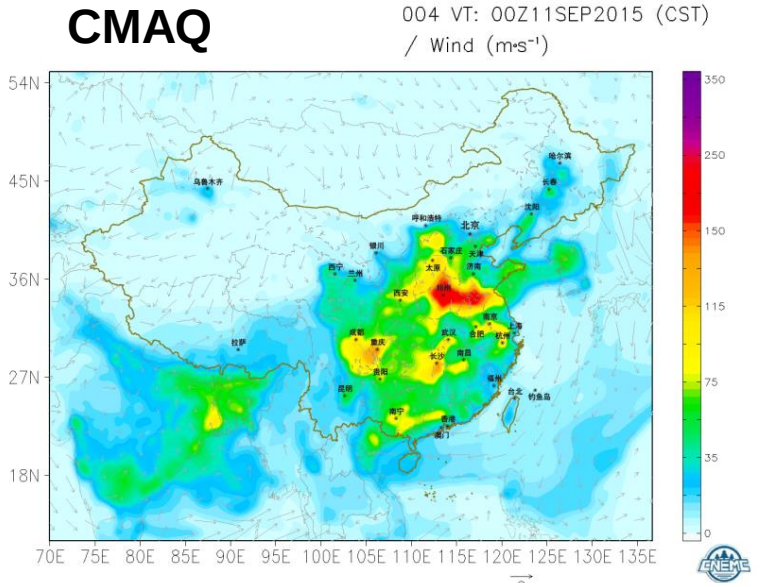


Regional forecast operation system

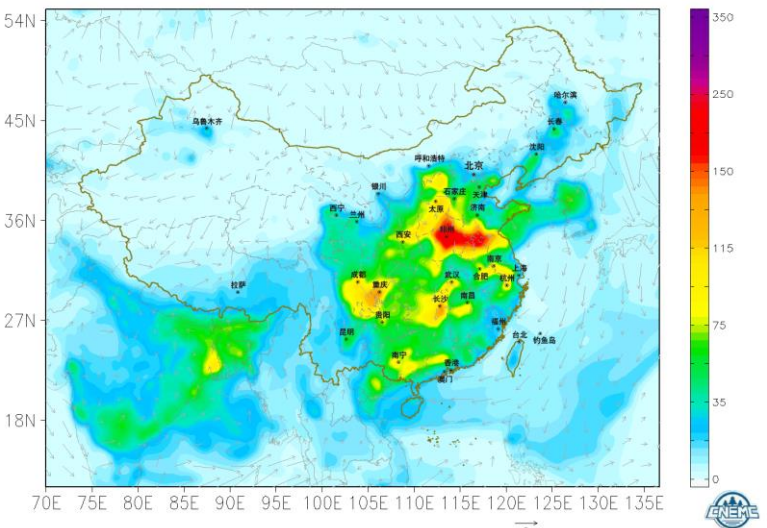
NAQPMS



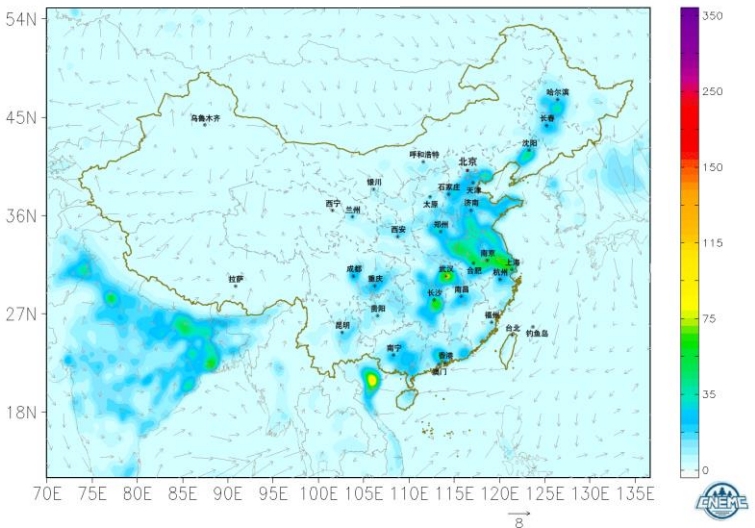
CMAQ



CAMx



WRF-CHEM



Regional forecast operation system

京津冀区域中心预报预警业务系统
Regional forecast operation system

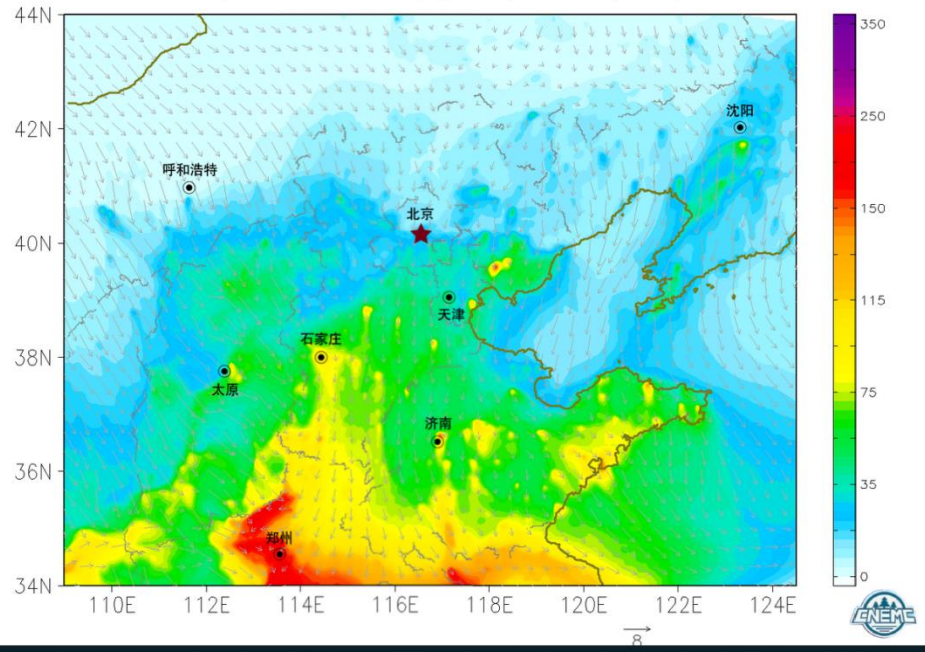
首页 预报工作流程 预报日志 预报评估 Sept 11 2015 滚动预报 您好,朱莉莉 注销

2015-09-11 播放跨度：2015-09-11 至 2015-09-17 快

11SEP2015 (CST) Forecast t+000 VT: 11SEP2015 (CST)
NAQPMS Daily Surface $PM_{2.5}$ $\mu g \cdot m^{-3}$ / Wind ($m \cdot s^{-1}$)

预报分析流程
- 模式分析
- 城市预报分析
- 分层数据查看
- 大气条件分析
- 污染来源追因分析
- 后向轨迹图
- 实况分布图
- 同化再分析图
- 站点污染物
- 城市污染物
- 同比分析

预报参考流程
预报决策流程



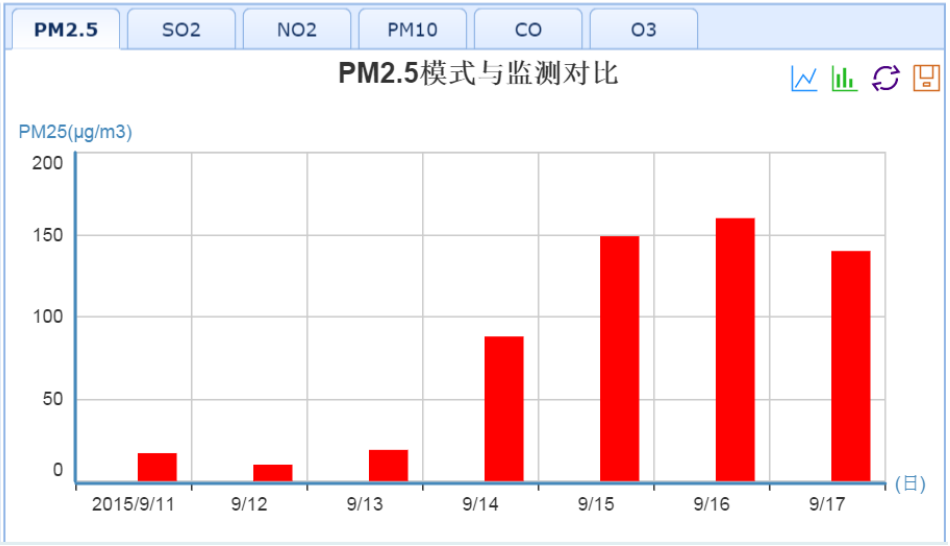
预报日期 2015-09-10 20时
模式 NAQPMS CMAQ CAMx WRF-Chem
时间类型 小时 日均
区域 全国 中东部 京津冀及周边
产品 PM2.5 PM10 SO2 CO NO2 AQI O3-8h
查询

技术支持：中国科学院大气物理研究所 曙光信息产业(北京有限公司) 北京融昭普瑞科技有限公司

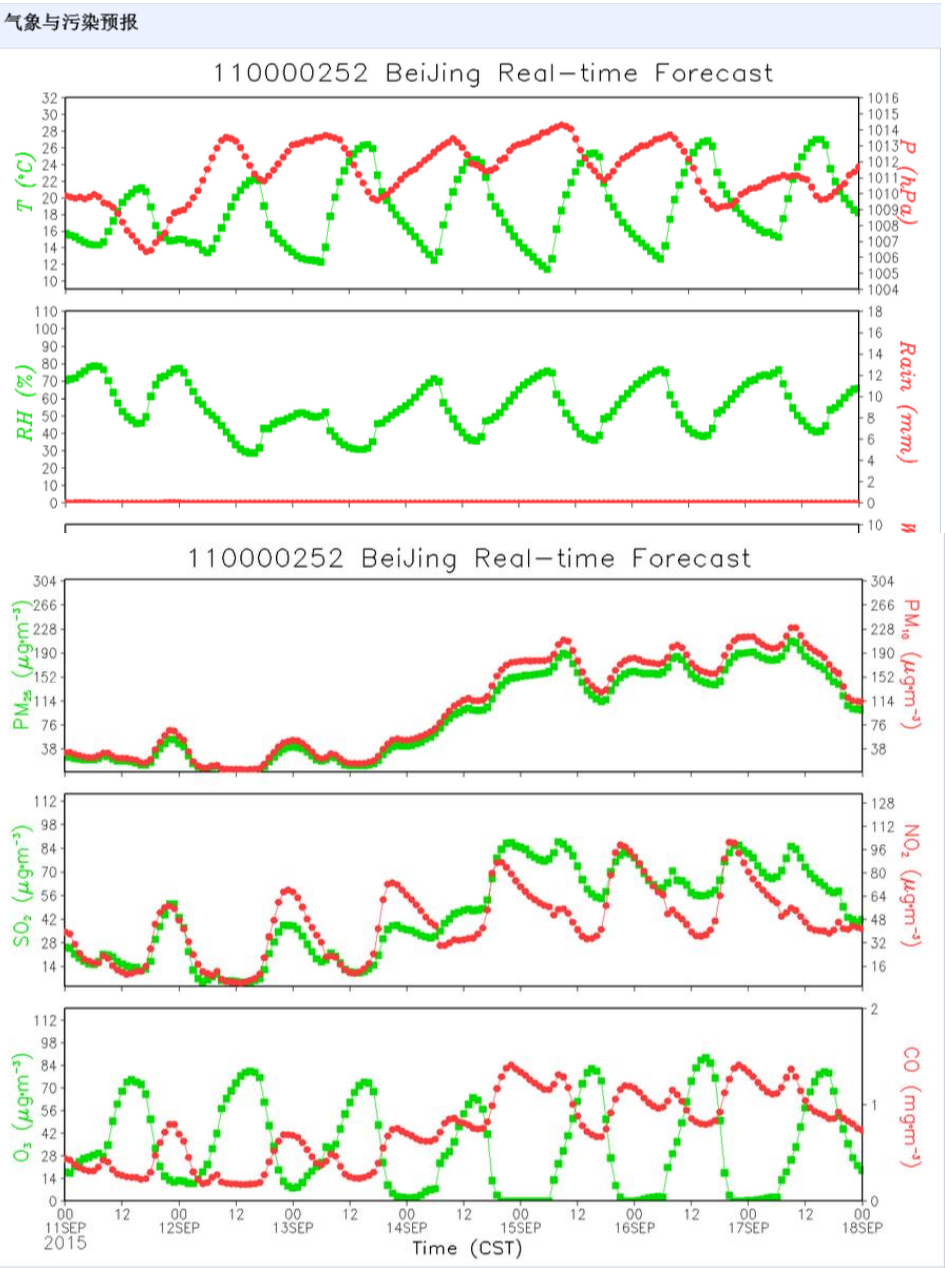
Regional forecast operation system

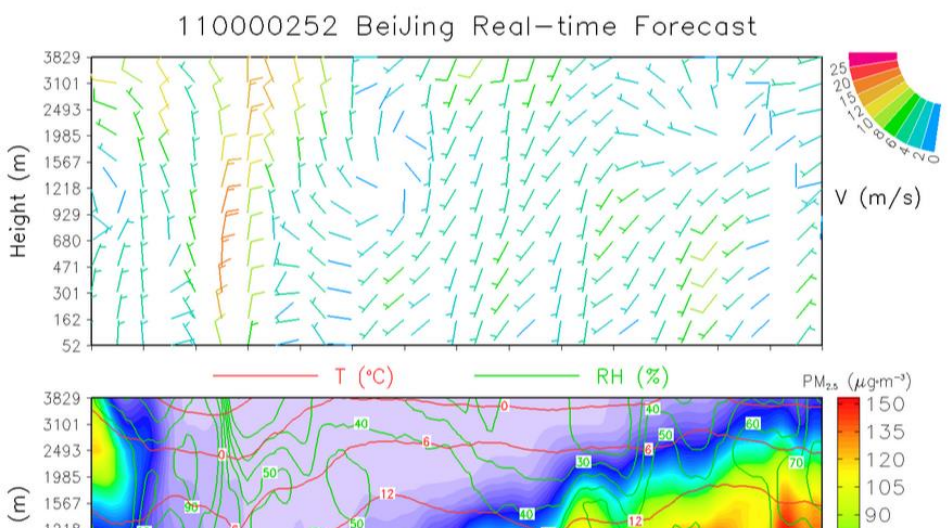
日期	SO2	IAQI	NO2	IAQI	PM10	IAQI	CO	IAQI	O3-1h	IAQI	O3-8h	IAQI	PM2.5	IAQI	AQI	首要污染物	指数级别
20150911	13	13	13	16	19	19	0.252	6	79	25	75	38	17	24	38		1
20150912	9	9	13	16	12	12	0.224	6	87	27	83	42	10	14	42		1
20150913	15	15	25	31	23	23	0.335	8	73	23	68	34	19	27	34		1
20150914	46	46	49	61	101	76	0.785	20	77	24	67	34	88	116	116	PM2.5	3
20150915	68	59	56	70	166	108	0.983	25	91	28	81	41	149	199	199	PM2.5	4
20150916	63	57	58	73	178	114	0.971	24	101	32	92	46	160	210	210	PM2.5	5
20150917	52	51	37	46	155	103	0.849	21	92	29	83	42	140	186	186	PM2.5	4

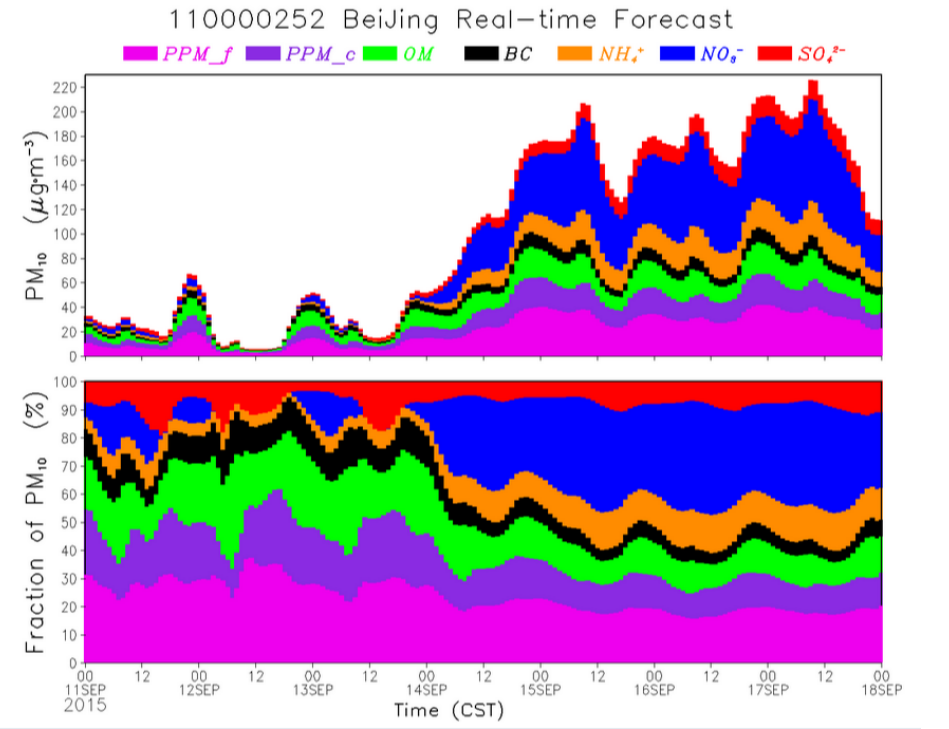
优 良 轻 中 重 严重



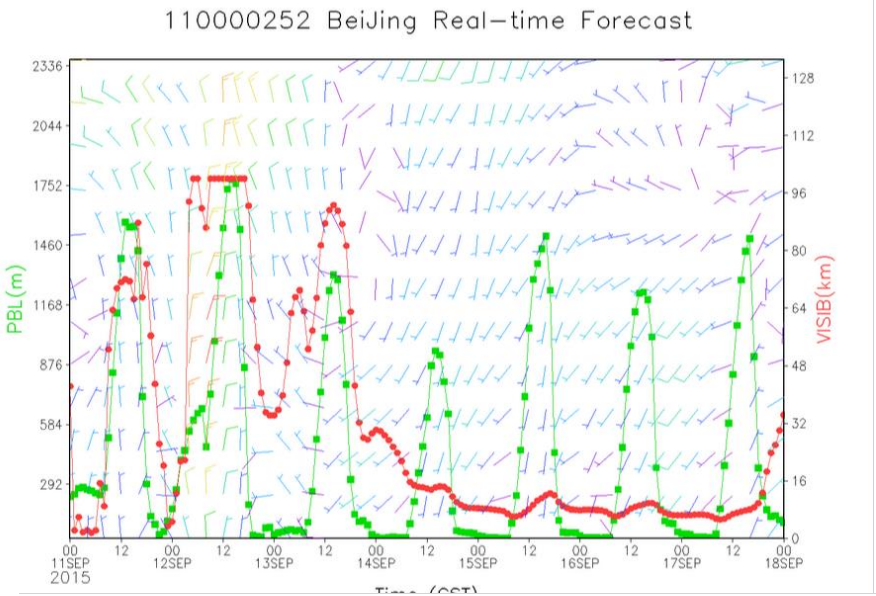
Regional forecast operation system

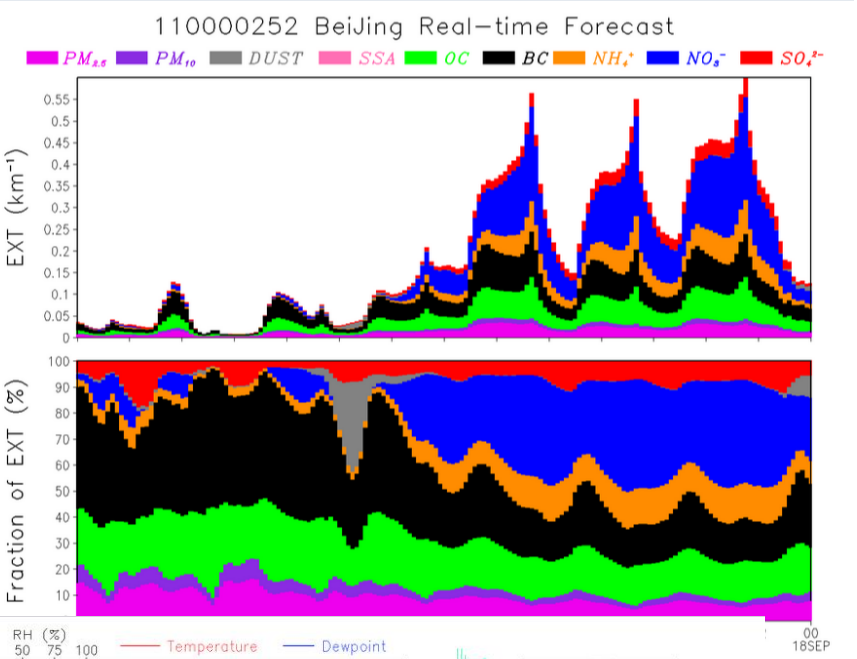


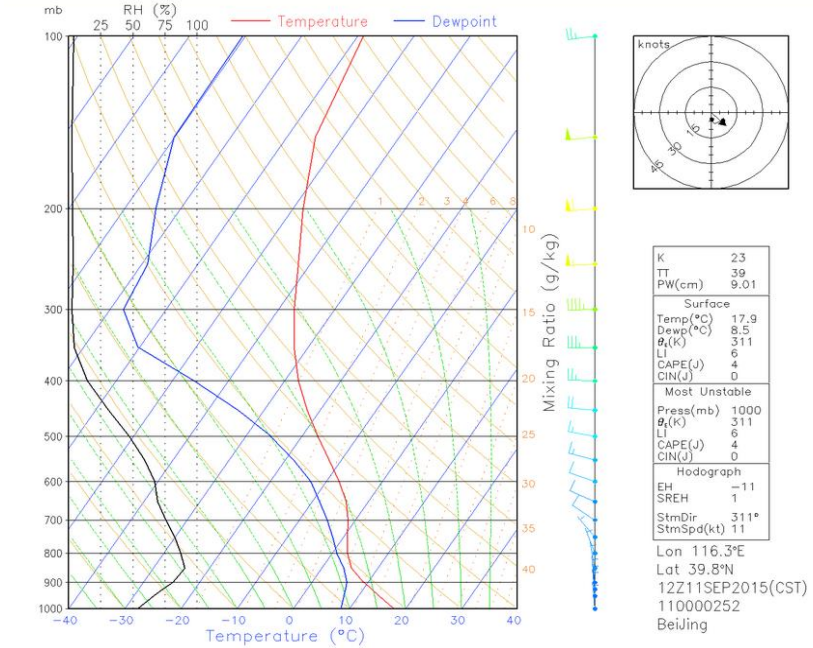


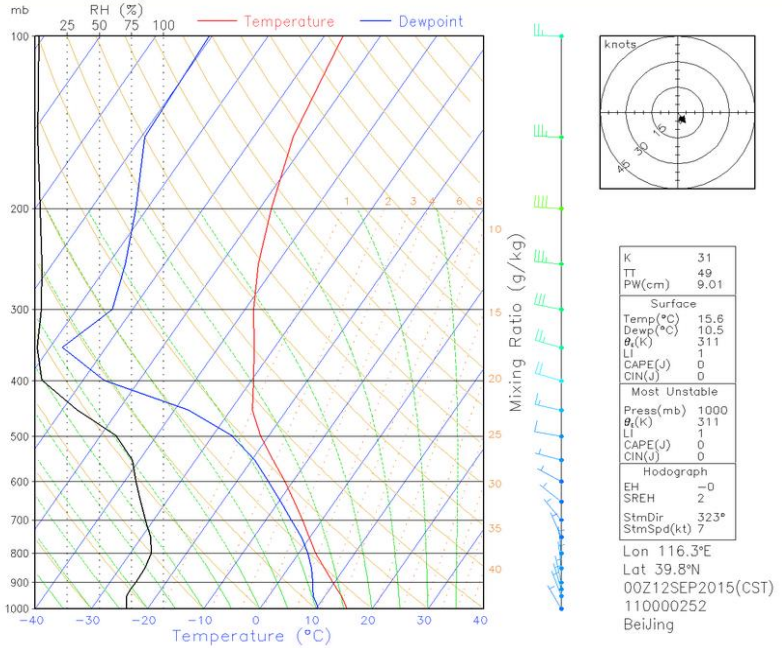


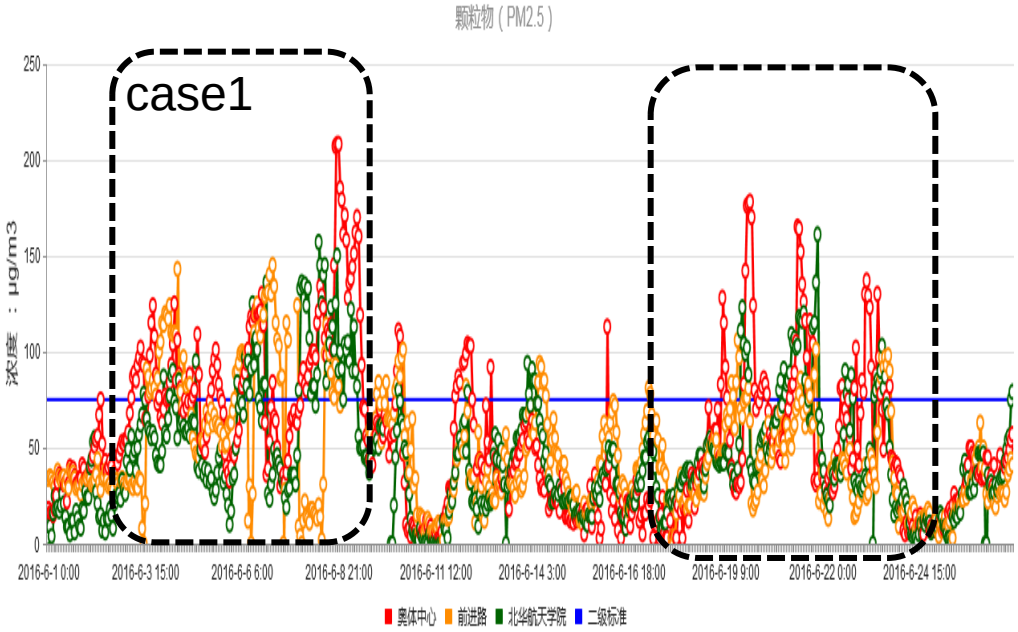
Regional forecast operation system

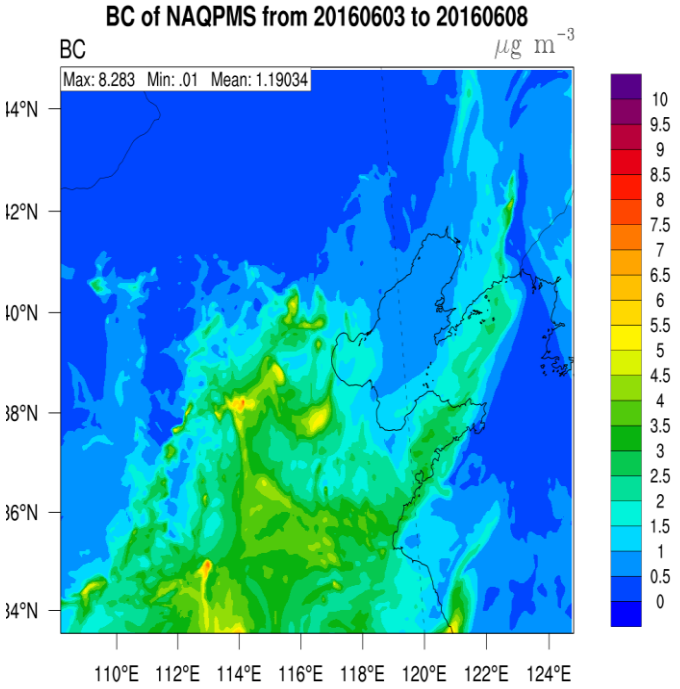


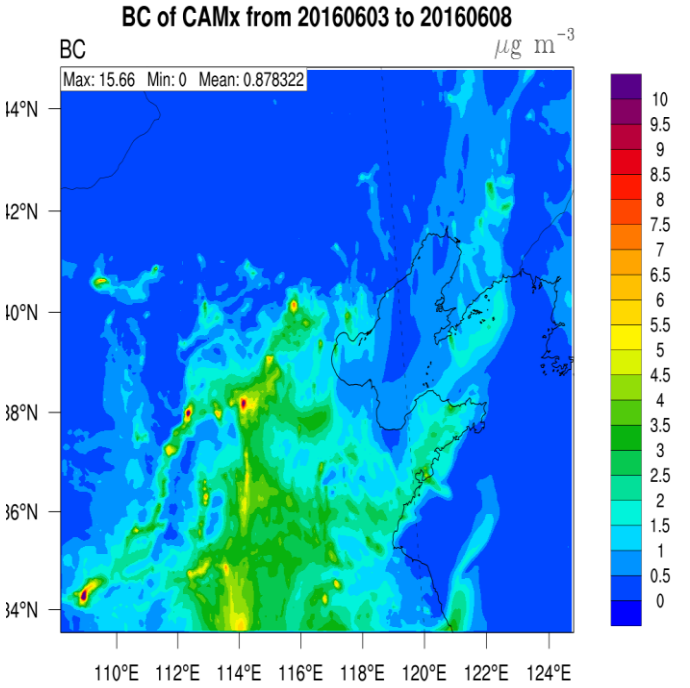


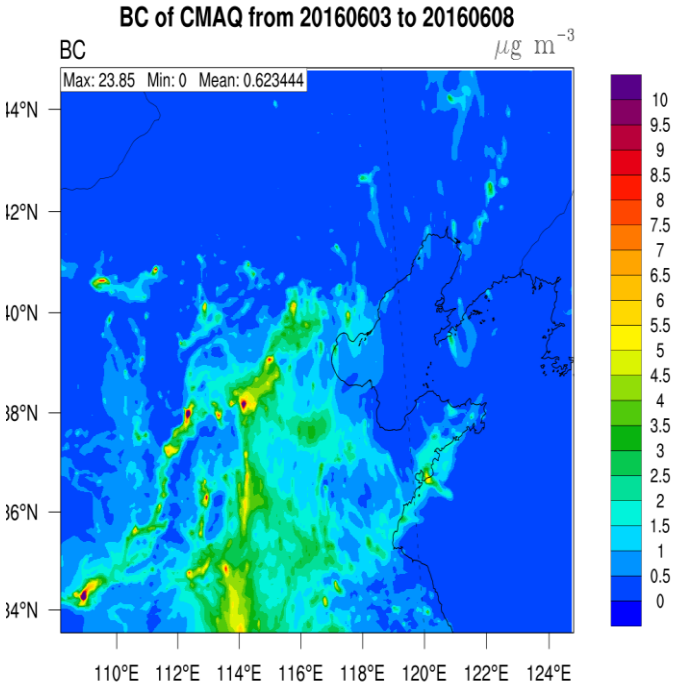


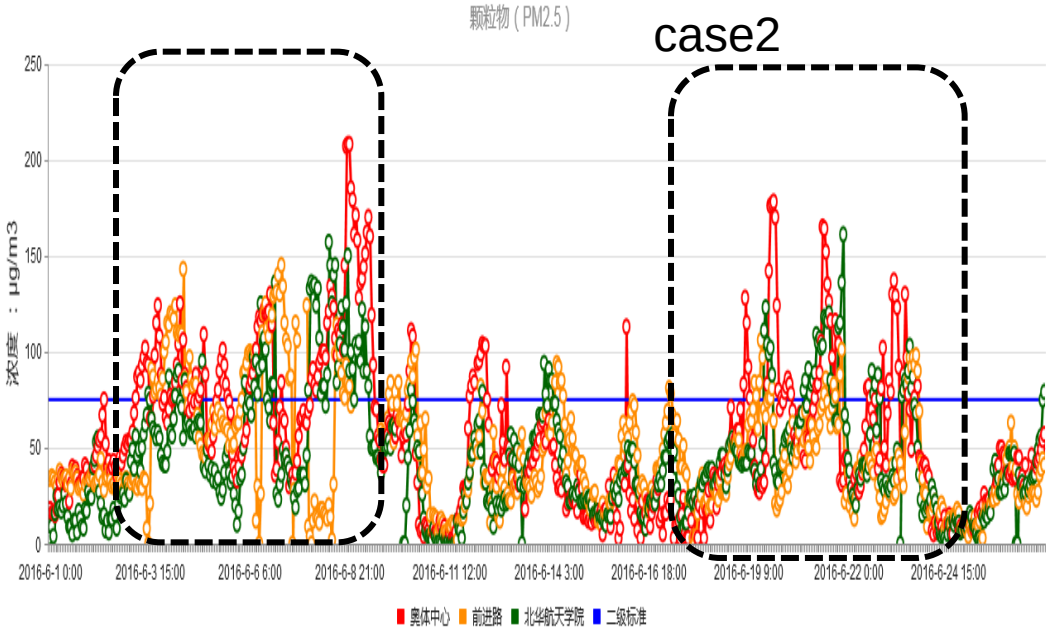


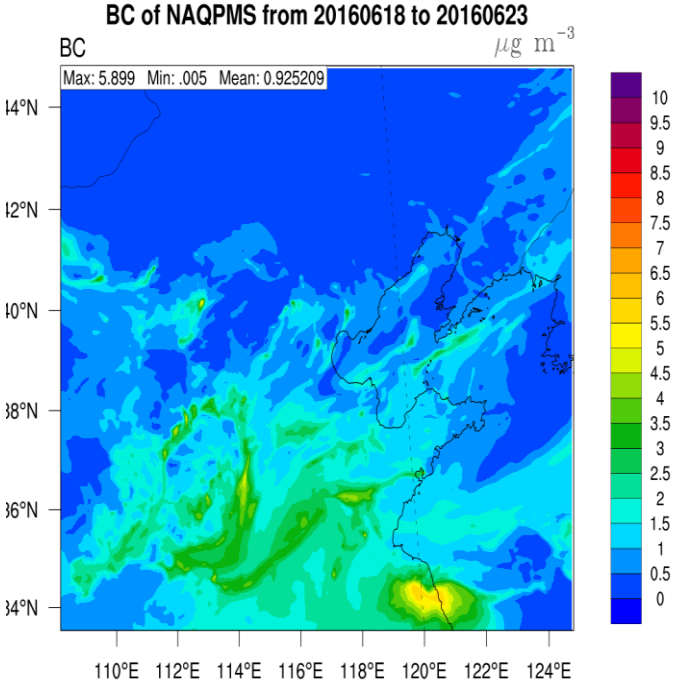

颗粒物 (PM2.5)
case1
浓度 : μg/m3
250
200
150
100
50
0
2016-6-1 0:00
2016-6-3 15:00
2016-6-6 6:00
2016-6-8 21:00
2016-6-11 12:00
2016-6-14 3:00
2016-6-16 18:00
2016-6-19 9:00
2016-6-22 0:00
2016-6-24 15:00
窦体中心
前进路
北华航天学院
二级标准

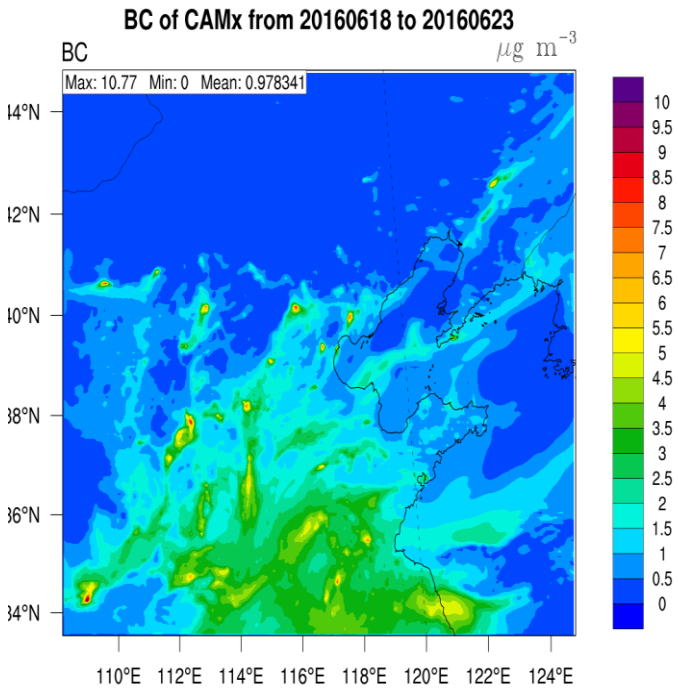

BC of NAQPMS from 20160603 to 20160608
BC
μg m⁻³
Max: 8.283 Min: .01 Mean: 1.19034
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

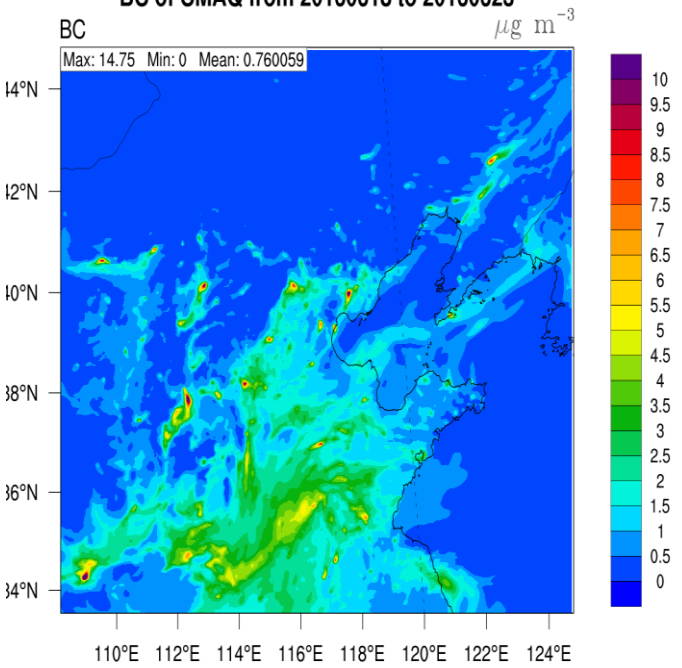

BC of CAMx from 20160603 to 20160608
BC
μg m⁻³
Max: 15.66 Min: 0 Mean: 0.878322
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


BC of CMAQ from 20160603 to 20160608
BC
μg m⁻³
Max: 23.85 Min: 0 Mean: 0.623444
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


颗粒物 (PM2.5)
case2
浓度 ：μg/m3
250
200
150
100
50
0
2016-6-1 0:00
2016-6-3 15:00
2016-6-6 6:00
2016-6-8 21:00
2016-6-11 12:00
2016-6-14 3:00
2016-6-16 18:00
2016-6-19 9:00
2016-6-22 0:00
2016-6-24 15:00
奥体中心
前进路
北华航天学院
二级标准


BC of NAQPMS from 20160618 to 20160623
BC
μg m⁻³
Max: 5.899 Min: .005 Mean: 0.925209
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


BC of CAMx from 20160618 to 20160623
BC
μg m⁻³
Max: 10.77 Min: 0 Mean: 0.978341
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0


BC of CMAQ from 20160618 to 20160623
BC
μg m⁻³
Max: 14.75 Min: 0 Mean: 0.760059
14°N
12°N
10°N
8°N
6°N
4°N
110°E
112°E
114°E
116°E
118°E
120°E
122°E
124°E
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

Thanks for your attention.