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# A Simulation Study of Global Distribution of Temporal and Spatial Variation of PM2.5 Concentration

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# Outline

1. Significance
2. Observational fact
3. Experiment Design
4. Results and Discussion
5. Summary

# Significance

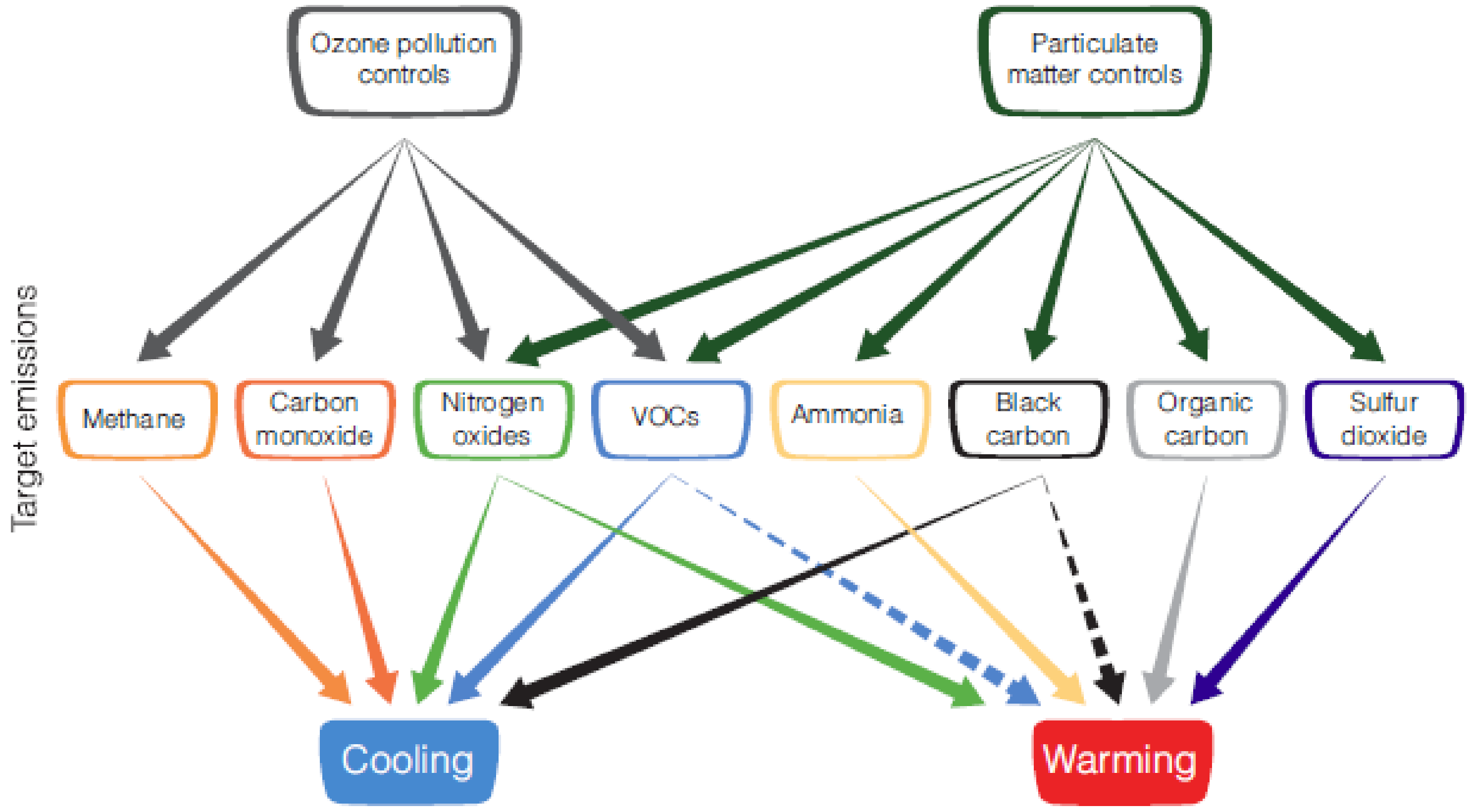
1

- **PM2.5——Environment and Health**
- Reduce visibility, affect the quality of air;
- Increase mortality rates of severe and chronic disease and damage respiratory system; increase the cancer rates.

2

- **PM2.5——Climate**
- Influence cloud, precipitation, etc.
- Influence the radiation balance of atmosphere.

# Air pollution and Climate

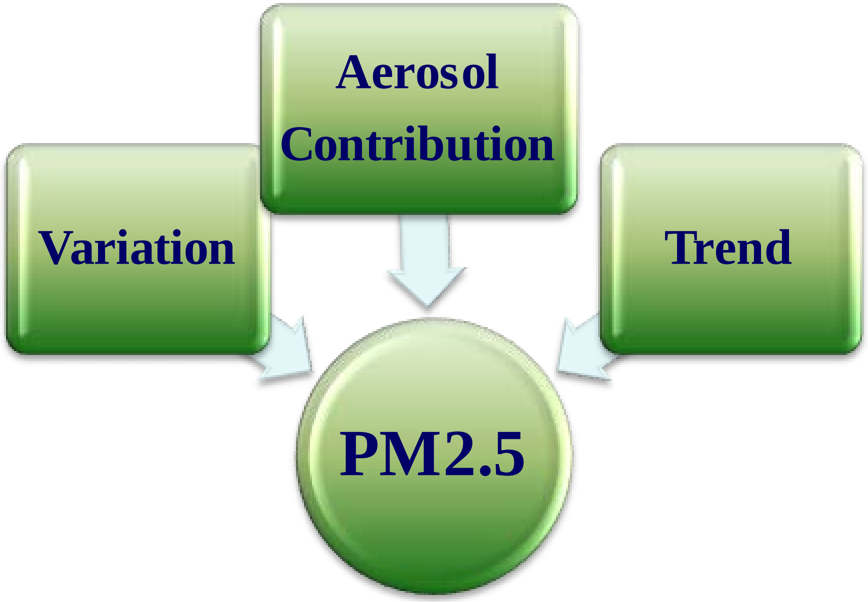



**FAQ 8.2, Figure 1:** Schematic diagram of the impact of pollution controls on specific emissions and climate impact. Solid black line indicates known impact, dashed line indicates uncertain impact.

**From IPCC AR5**

# Purpose

From the past to the future： 1850-2010-2050-2100：




**(1)The variation of PM2.5/anthropogenic/natural aerosol concentration.**

**(2)The contribution of each aerosol to PM2.5 and its variation over China.**

**(3)The trend of PM2.5 concentration at typical regions of the world.**

# Observational PM2.5 in 2013 air pollution event In China

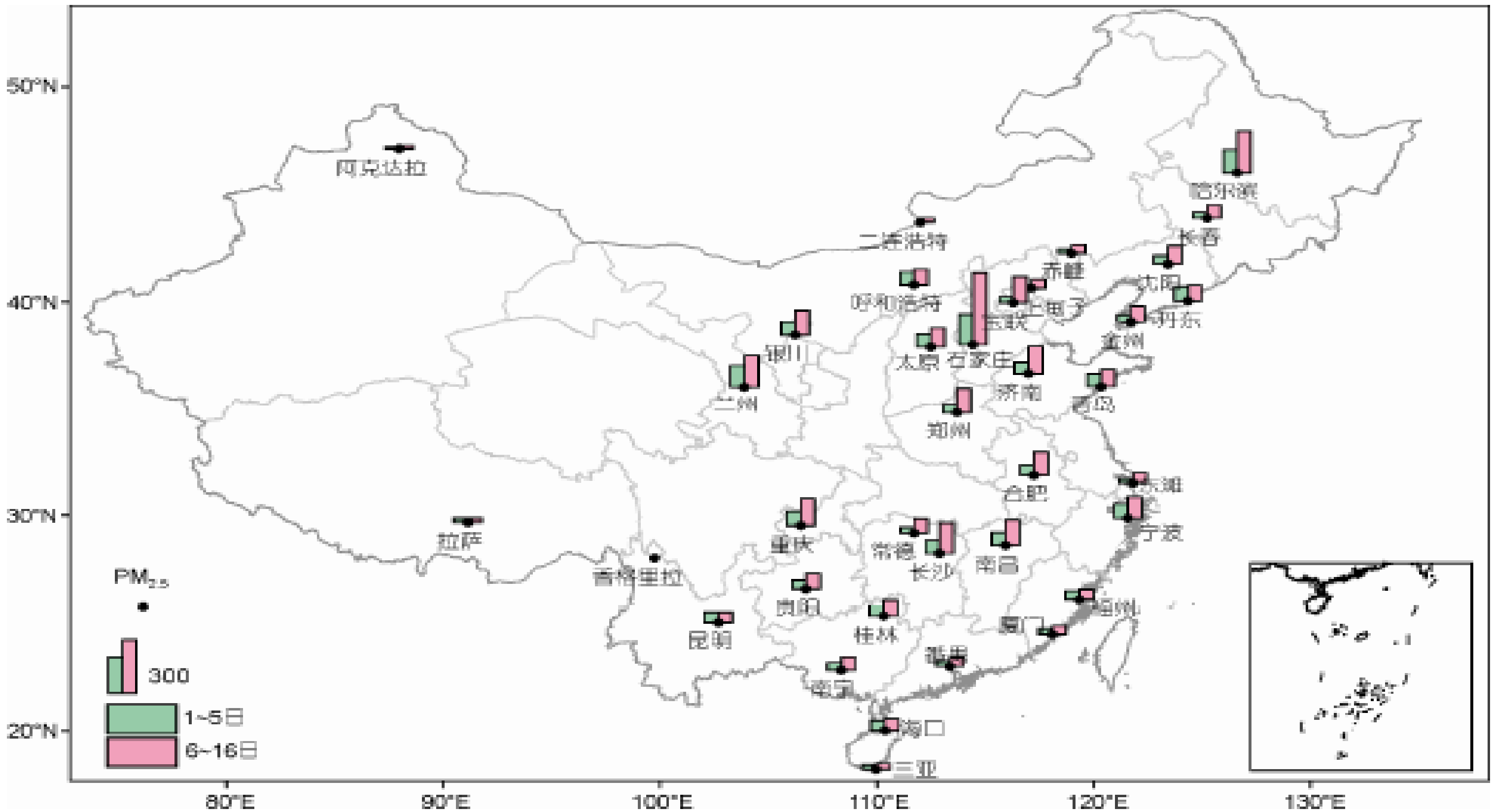



图 4 2013 年 1 月 1-5 日和 6-16 日中国气象局大气成分观测网-CAWNET 获得的 $PM_{2.5}$ 质量浓度($\mu g\ m^{-3}$)平均值对比

From ZHANG Xiao Ye, et al., Factors contributing to haze in China, Chin Sci Bull (Chin Ver), 2013, 58:1178-1187

# The contribution of components to PM 10 in China

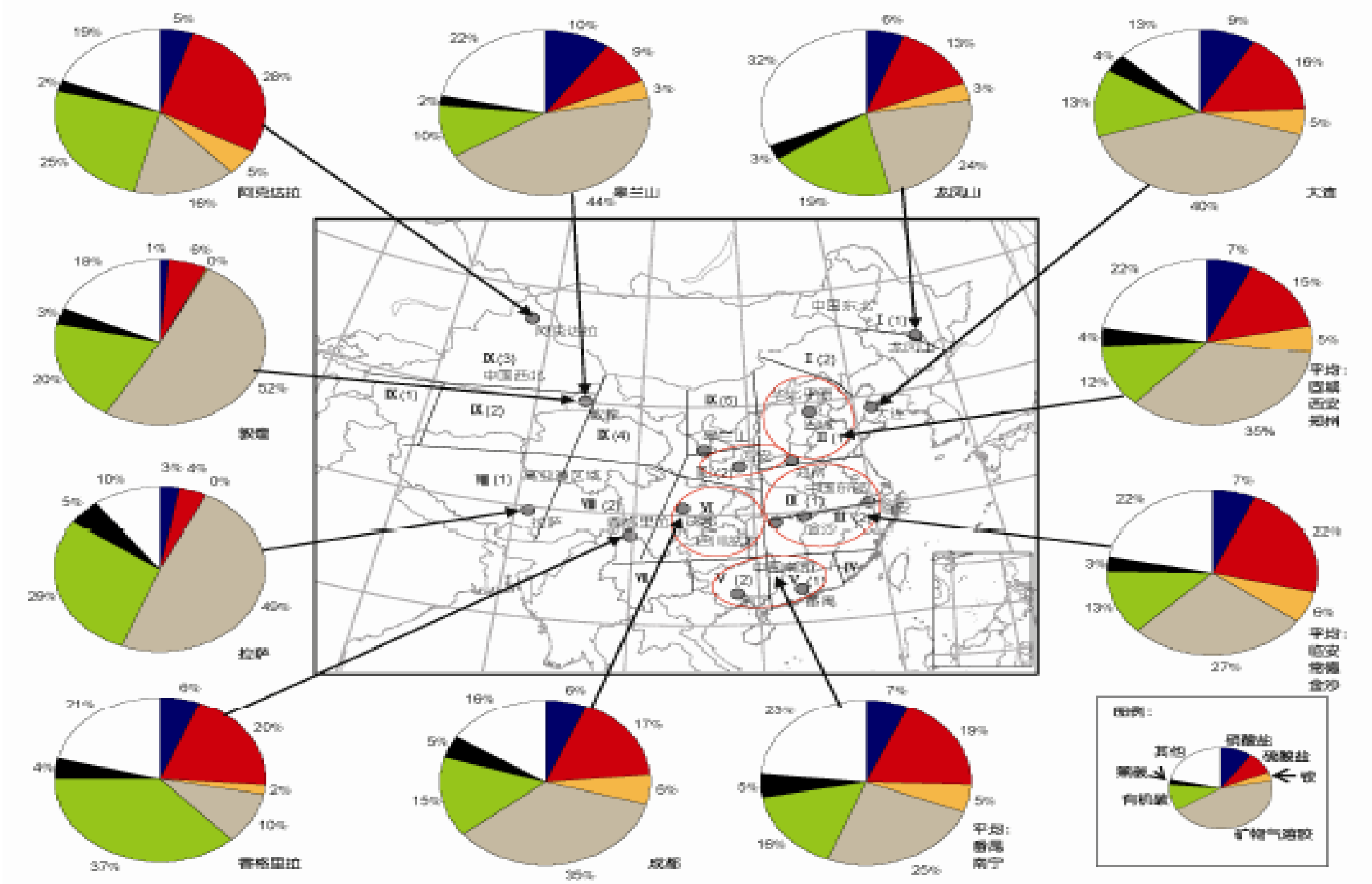


图 5　中国气象局大气成分观测网-CAWNET 在我国不同区域的站点 $PM_{10}$ 中各化学组成所占比例
中间是观测站点分布图及 9 个我国霾的分布区域，其中红圈划出的是我国 4 个最严重的霾分布区[2]

From ZHANG Xiao Ye, et al., Factors contributing to haze in China, Chin Sci Bull (Chin Ver), 2013, 58:1178-1187

# Experiment Design

## ——Model Introduction

**BCC_AGCM2.0.1**

- **Dynamical formulation：Eulerian dynamical core**
- **Horizontal resolution：T42（approximately 2.8º ×2.8º）**
- **Vertical direction：terrain-following hybird coordinate，26 levels，with a top located at about 2.9 hPa.**
- **Radiation scheme：BCC_RAD**
- **Cloud overlap scheme：McICA-BCC_RAD**
- **Two-moment microphysical cloud scheme**

- Aerosol model **CUACE/Aero** was developed by the Chinese Academy of Meteorological Sciences of the China Meteorological Administration (**CAMS/CMA**)

- The processes for the **emission, transport, chemical transformation, cloud interaction, and deposition** of five aerosol species (**sulfate, BC, OC, soil dust, and sea salt**) were taken into account.
- The aerosol size bin was divided into 12 bins: (in radius: μm)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.005~0.01 | 0.01~0.02 | 0.02~0.04 | 0.04~0.08 | 0.08~0.16 | 0.16~0.32 | 0.32~0.64 | 0.64~1.28 | 1.28~2.56 | 2.56~5.12 | 5.12~10.24 | 10.24~20.48 |

PM2.5

- Emissions of BC, OC, $SO_2$ and sulfate, and dimethyl sulfide (DMS) are from **AeroCom**, Sea salt and dust aerosols are **emitted online**: the sea salt module was developed by Gong et al. (2002), and **the soil dust scheme was from Marticorena and Bergametti (1995).**

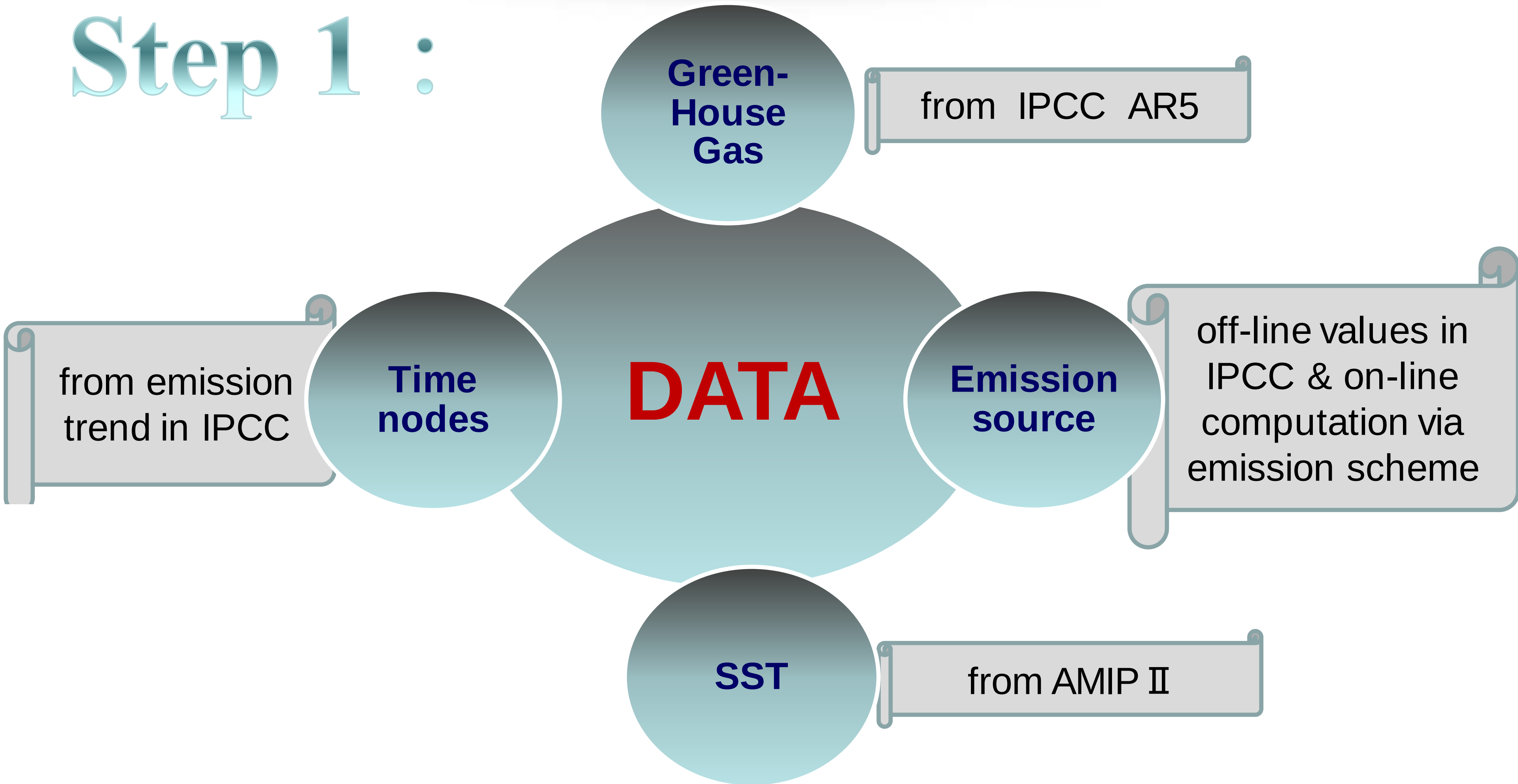
**BCC_AGCM2.0.1_CUACE/Aero online coupled model system:**

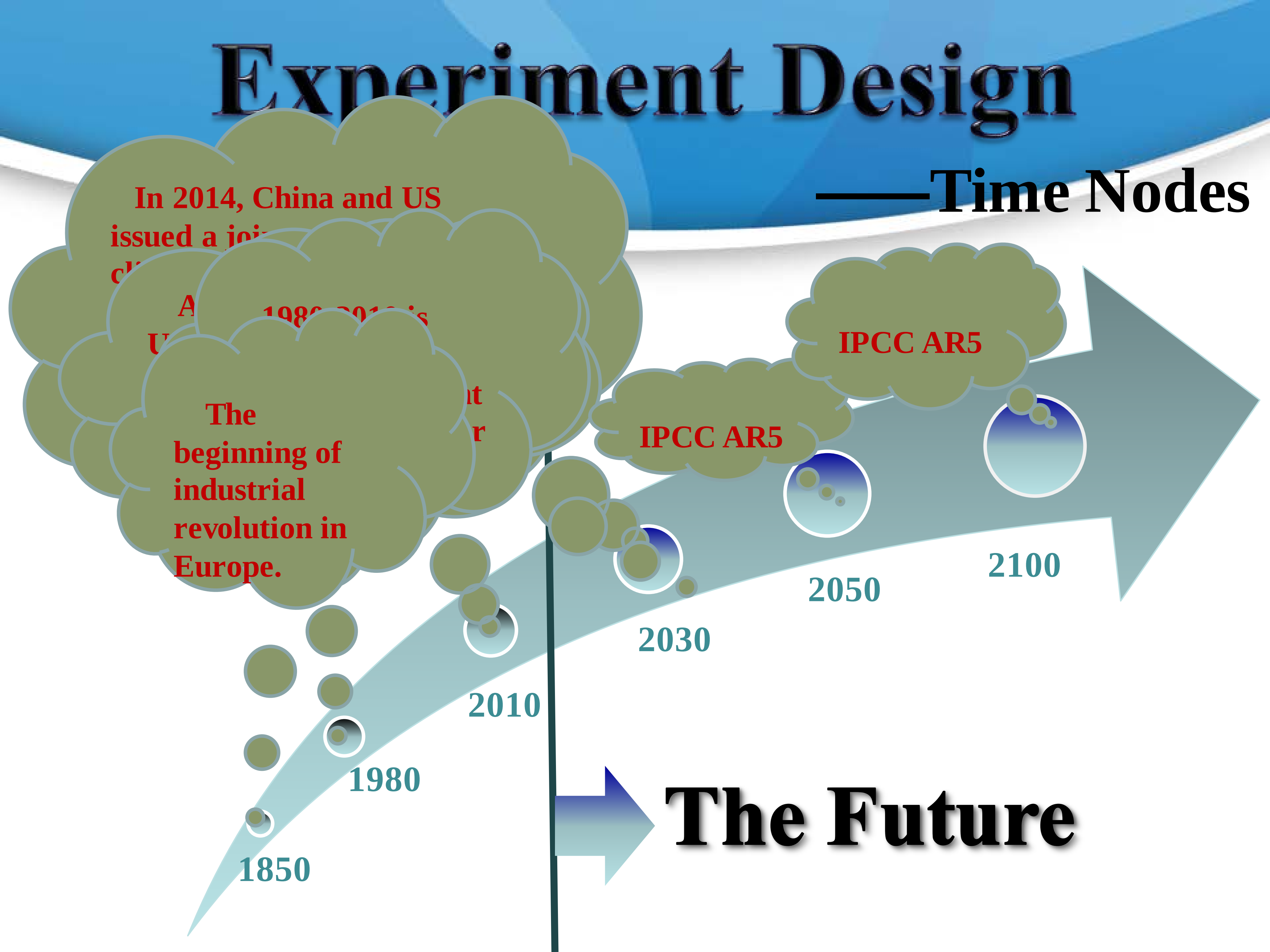
Every development of **BCC_AGCM2.0.1_CUACE/Aero** was tested and assessed to keep the simulation of both the climatic state and aerosols reasonable, e.g. Wu et al. (2008, 2010), Zhang et al. (2012, 2014), Jing & Zhang（2012）; Wang et al. (2014)；Zhao et al.（2014）

# Experiment Design

## ——Data Introduction

## Step 1：



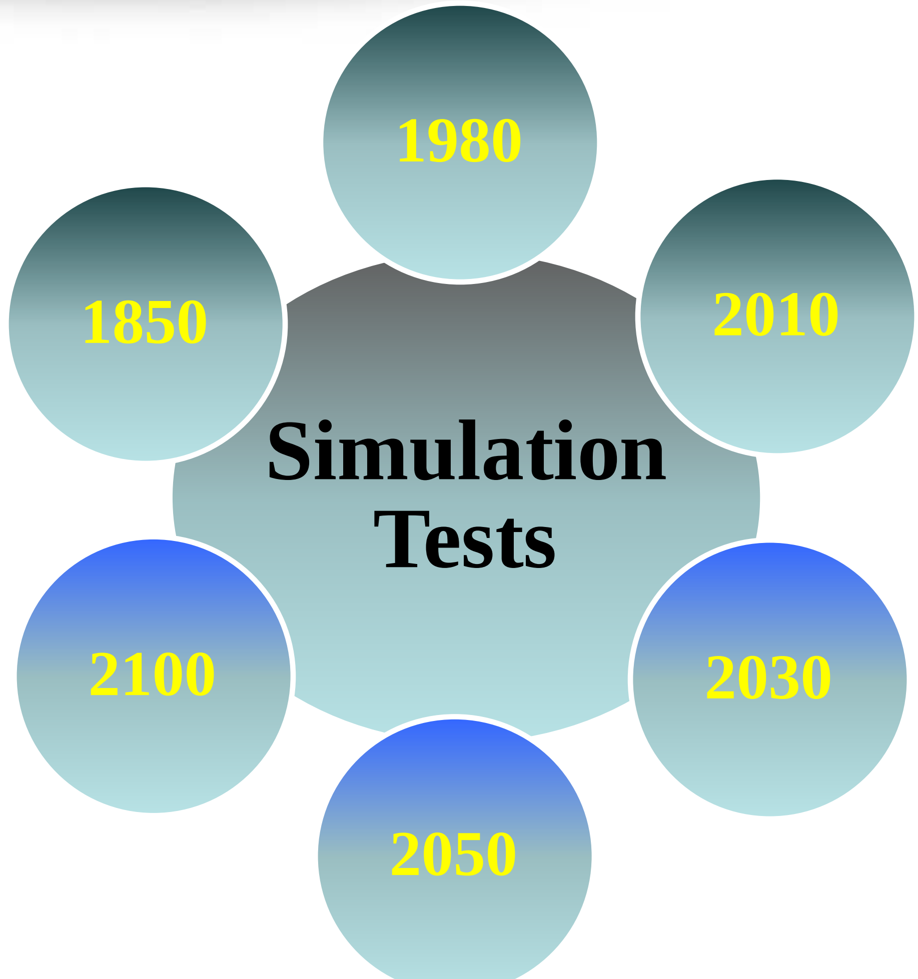


Experiment Design
——Time Nodes
In 2014, China and US
The beginning of industrial revolution in Europe.
IPCC AR5
IPCC AR5
1850
1980
2010
2030
2050
2100
The Future

# Experiment Design

## Step 2：

We have run the model for 23 years on each time node and taken the annual mean of the last 20 years as the climate state.



# Results & Discussion

## (1)1850-1980 /The Past

**The variation of PM2.5 concentration over the globe （annual & seasonal ）**

## (2)2010-2050 /The Future

**The variation of PM2.5 concentration over the globe （annual & seasonal ）**

## (3) The Contribution

**Contribution of anthropogenic and natural aerosols to variation of PM2.5 concentration(etc.China)**

## (4)Trend of Variation

**Northern / Southern America**

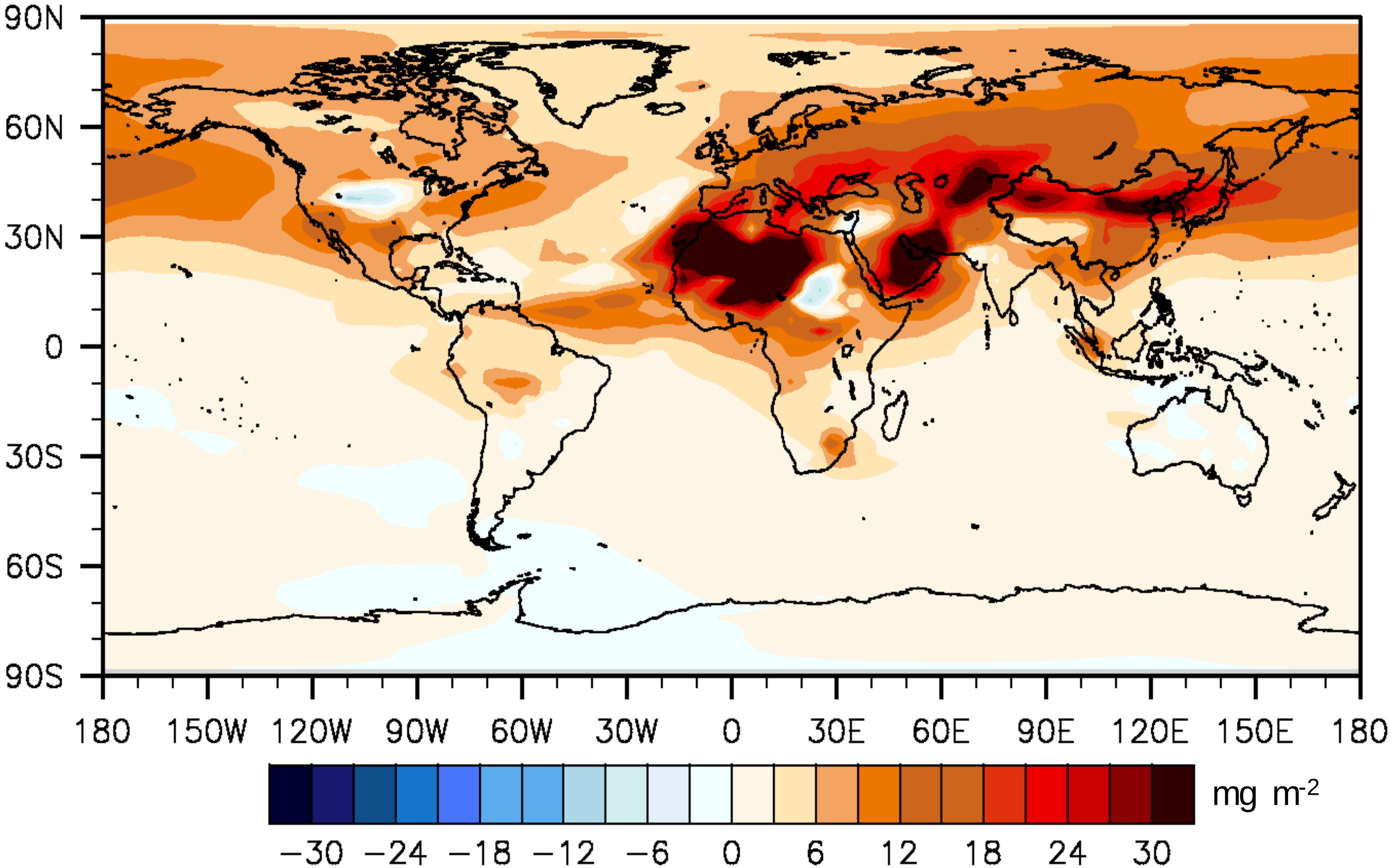
**Northern / Central Africa**

**Western Europe**

**East Asia**

# Annual Mean Variation of PM2.5 Concentration over the Globe (1850-1980)

**(unit:mg $m^{-2}$)**




90N
60N
30N
0
30S
60S
90S

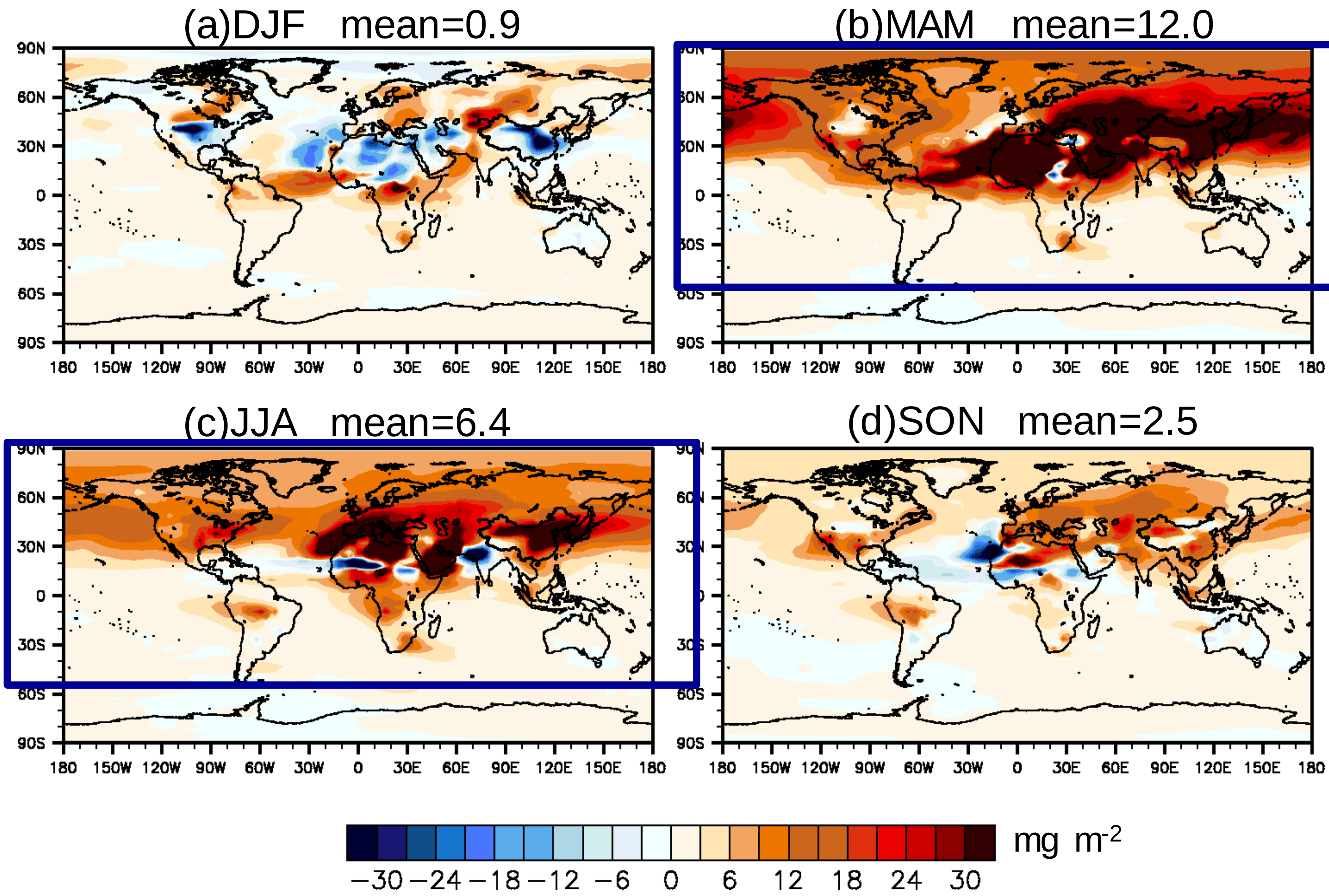
**PM**

**An**

**Na**

# Seasonal Mean Variation of Column Concentration of PM2.5 over the Globe(unit:mg $m^{-2}$)

**Fig 2**



# Results & Discussion

**(1)1850-1980 /The Past**

The variation of PM2.5 concentration over the globe （annual & seasonal ）

**(2)2010-2050 /The Future**

The variation of PM2.5 concentration over the globe （annual & seasonal ）

**(3) The Contribution**

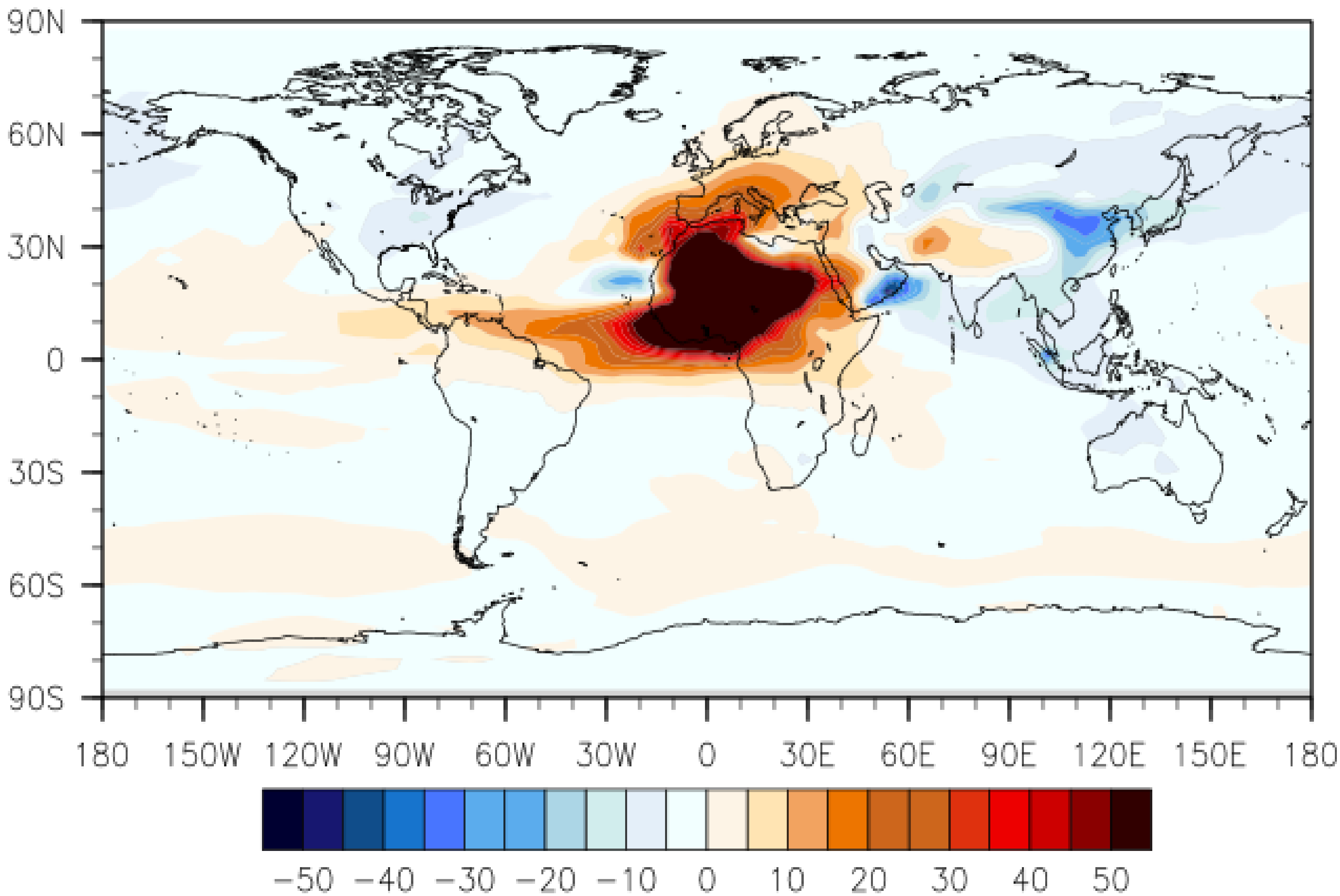
Contribution of anthropogenic and natural aerosols to variation of PM2.5 concentration(etc.China)

**(4)Trend of Variation**

Northern / Southern America
Northern / Central Africa
Western Europe
East Asia

# Annual Mean Variation of PM2.5 Concentration over the Globe (2010-2050)

(unit:mg $m^{-2}$)



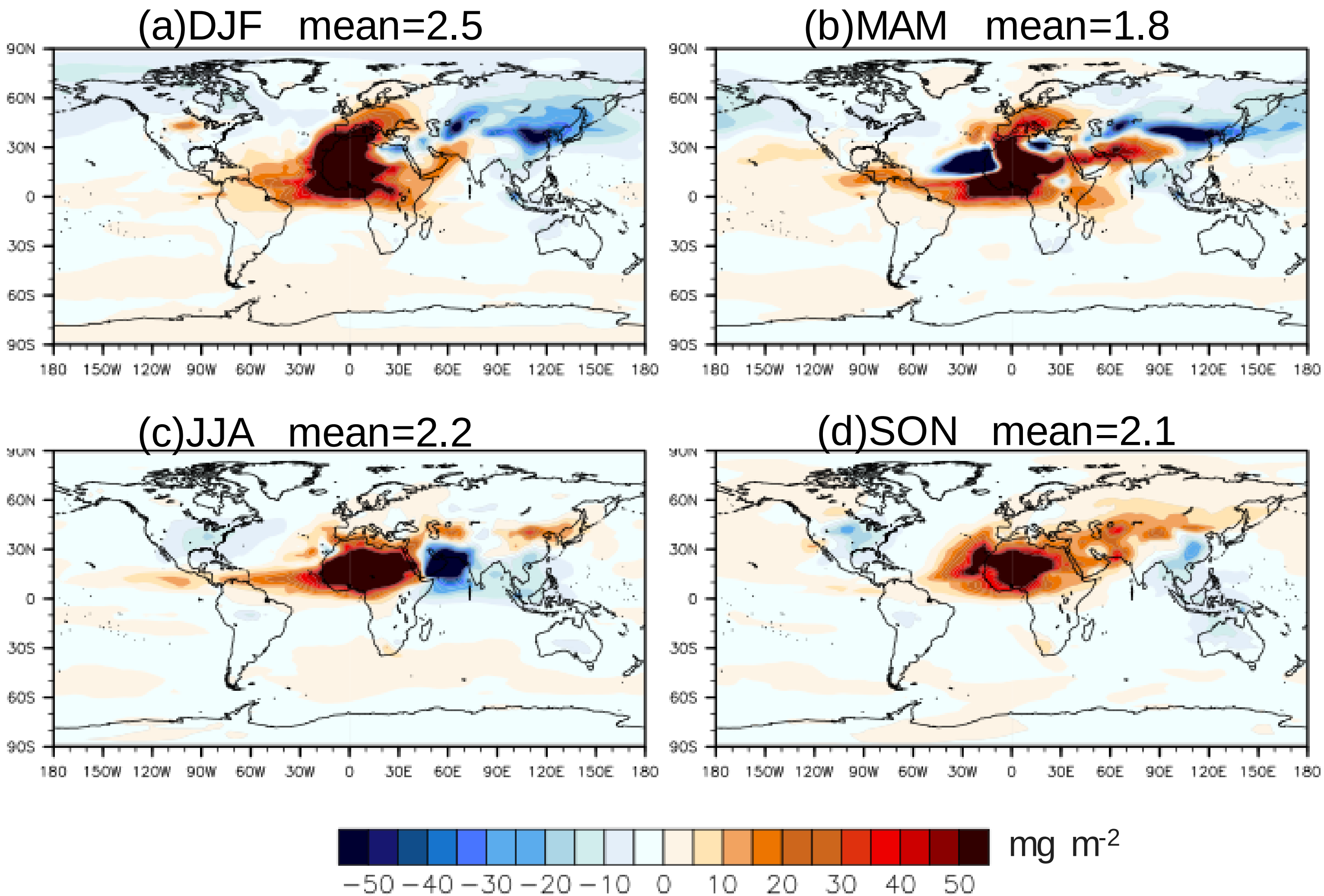

P

A

N

# Seasonal Mean Variation of Column Concentration of PM2.5 over the Globe (unit:mg $m^{-2}$) (2010-2050)

**Fig 4**



# Results & Discussion

**(1)1850-1980 /The Past**
The variation of PM2.5 concentration over the globe （annual & seasonal ）

**(2)2010-2050 /The Future**
The variation of PM2.5 concentration over the globe （annual & seasonal ）

**(3) The Contribution**
Contribution of anthropogenic and natural aerosols to variation of PM2.5 concentration(eg. China)

**(4)Trend of Variation**
Northern / Southern America
Northern / Central Africa
Western Europe
East Asia

# 1850-1980

# Seasonal distribution of PM2.5 Variation over China

(unit:mg $m^{-2}$)

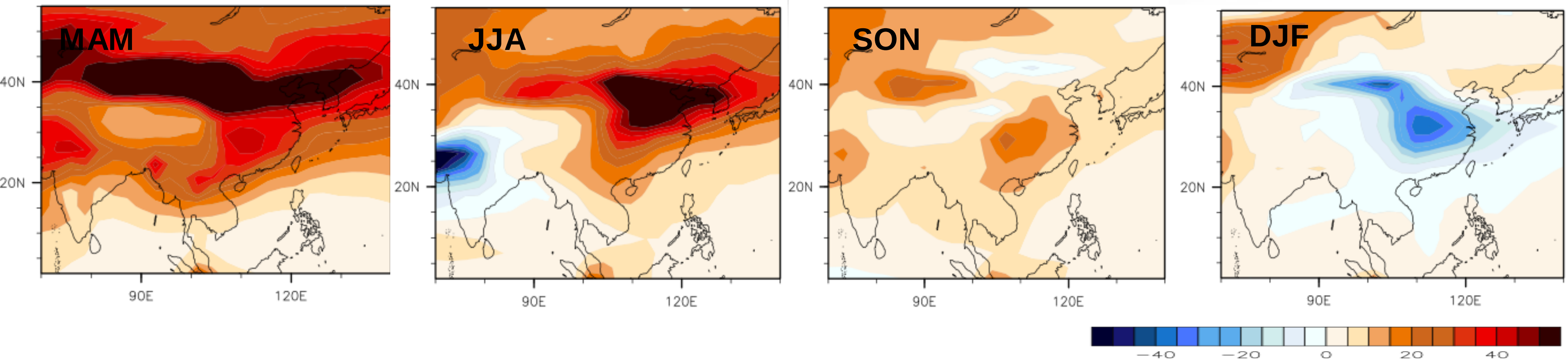



**Table 1 Contribution of Each Aerosol to PM2.5 Concentration variation over China**

| 1850-1980 | MAM | JJA | SON | DJF | ANN |
|---|---|---|---|---|---|
| Sulfate (SF) | 7.1(26%) | 6.4(48%) | 5. 7(74%) | 3.9 (41%) | 5.8(48%) |
| Black Carbon(BC) | 0.3( 1%) | 0.3( 2%) | 0.3( 3%) | 0.2 ( 2%) | 0.3 ( 2%) |
| Organic Carbon(OC) | 1.0( 4%) | 0.5 ( 4%) | 0.8(10%) | 0.9( 9%) | 0.8 ( 6%) |
| Sea Salt (SS) | 0.2( 1%) | 0.0 ( 0%) | 0.1( 1%) | 0.0 ( 0%) | 0.1 ( 1%) |
| Soil Dust(SD) | 18.5(68%) | 6.3(46%) | 0.9 (12%) | -4.7(48%) | 5.2 (43%) |
| Anthro PM2.5 | 8.4 (31%) | 7.2 (54%) | 6.7(87%) | 5.1(52%) | 6.8 (56%) |
| Natural PM2.5 | 18.7(69%) | 6.2 (46%) | 1.0 (13%) | -4.8(48%) | 5.3 (44%) |

# 2010-2050 (RCP4.5)

# Seasonal distribution of PM2.5 Variation over China

(unit:mg m$^{-2}$)

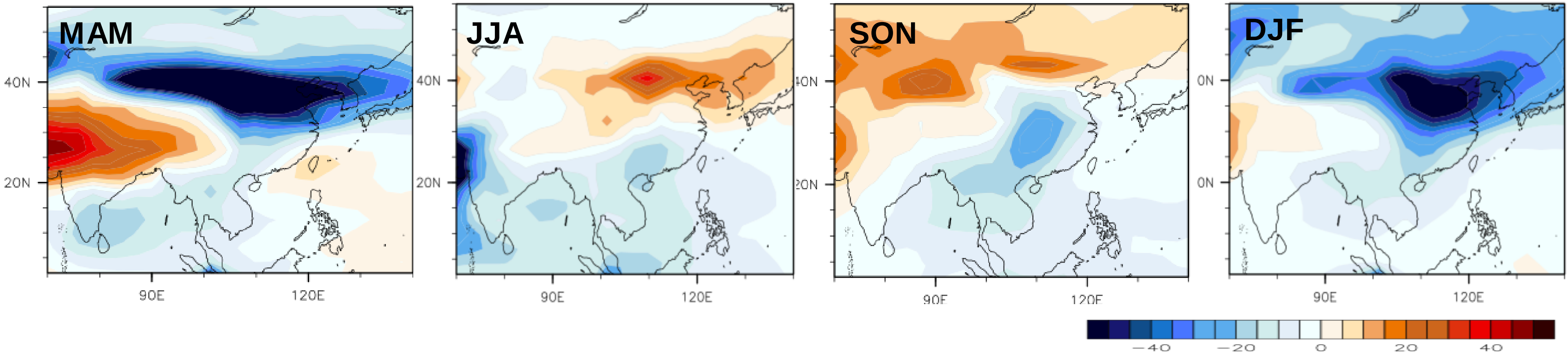



Table 2 Contribution of Each Aerosol to PM2.5 Concentration variation over China

| 2010-2050(RCP4.5) | MAM | JJA | SON | DJF | ANN |
|---|---|---|---|---|---|
| Sulfate (SF) | -4.7 (44%) | -4.8 (65%) | -4.3 (42%) | -2.9 (21%) | -4.2 (57%) |
| Black Carbon(BC) | -0.2 ( 2%) | -0.2 ( 3%) | -0.2 ( 2%) | -0.2 ( 1%) | -0.2 ( 3%) |
| Organic Carbon(OC) | -1.3 (12%) | -0.7 ( 9%) | -0.8 ( 8%) | -0.8 ( 6%) | -0.9 ( 12%) |
| Sea Salt (SS) | -0.1 ( 1%) | -1.3 (18%) | -0.5 ( 5%) | -0.1 ( 1%) | -0.5 ( 7%) |
| Soil Dust(SD) | -4.4 (41%) | 2.9 (39%) | 5.5 (53%) | -10.2 (72%) | -1.6 (22%) |
| Anthro_PM2.5 | -6.3 (58%) | -5.7 (77%) | -5.3 (51%) | -3.8 (27%) | -5.2 (70%) |
| Natural _PM2.5 | -4.5 (42%) | 1.7 (23%) | 5.0 (49%) | -10.3 (73%) | -2.2 (30%) |

# The Contributions of 5 Aerosol Species over China in 2010 to surface PM2.5 concentration

**(unit : μg $m^{-3}$;contribution percentage of each components to PM2.5 IN brackets)**

| AEROSOL | MAM | JJA | SON | DJF | ANN |
|---|---|---|---|---|---|
| Sulfate (SF) | 2.74 (29%) | 2.80 (45%) | 2.22 (40%) | 1.96 （35%） | 2.43 （36%） |
| Black Carbon (BC) | 0.4[illegible] （5%[illegible] | [illegible] | [illegible] | [illegible] | 0.42 （6%） |
| Organic Carbon (OC) | 0.2[illegible] （3%） | [illegible] (4%) | [illegible] (4%) | [illegible] （3%） | 0.23 （3%） |
| Soil Dust (SD) | 5.82 （60%） | 2.40 (39%) | 2.57 (45%) | 2.93 （52%） | 3.43 （52%） |
| Sea Salt (SS) | 0.14 (2%) | 0.29 (5%) | 0.22 (4%) | 0.14 (3%) | 0.20 (3%) |

Anthropogenic Aerosols: 45%

Natural Aerosols: 55%

# Results & Discussion

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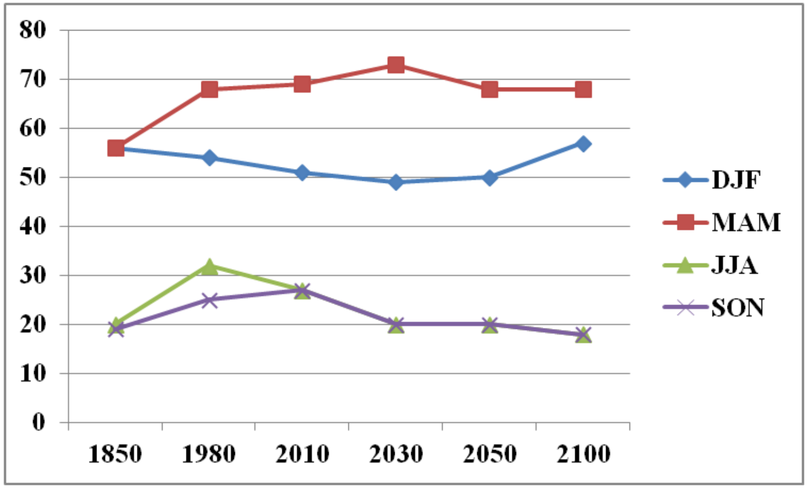
Contribution of anthropogenic and natural aerosols to variation of PM2.5 concentration(eg. China)

**(4)Trend of Variation**

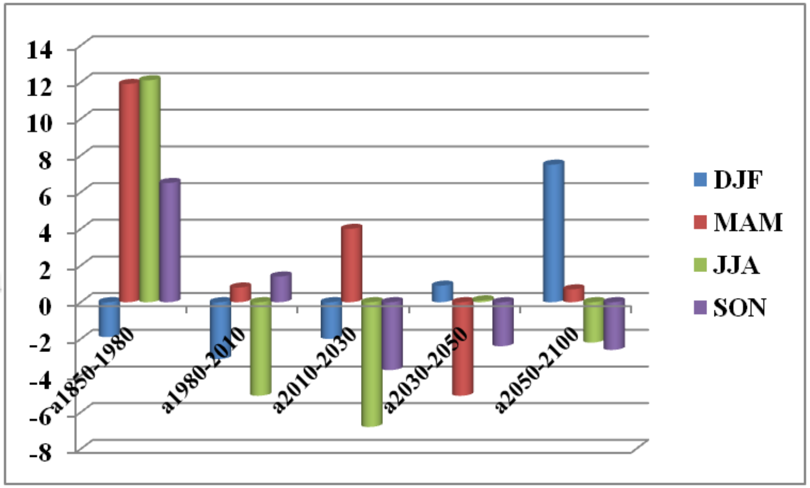
North / South America
Northern / Central Africa
Western Europe
China

# Trend of Variation (unit: mg $m^{-2}$)

## Trend of Concentration

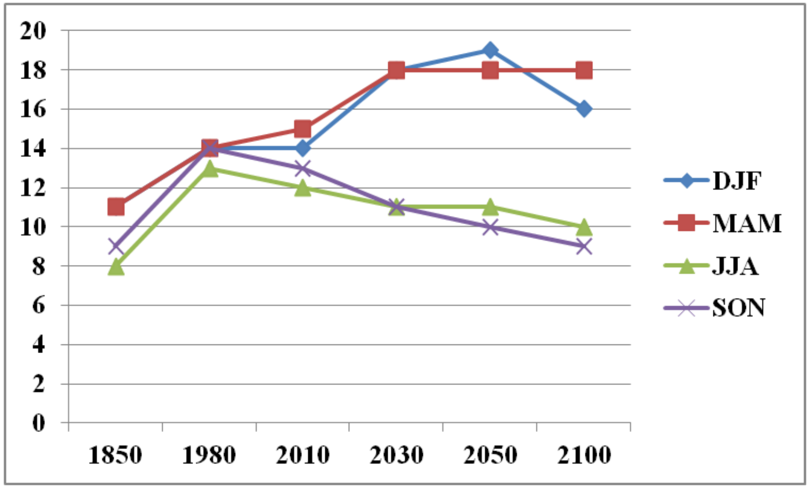



## Concentration Variation

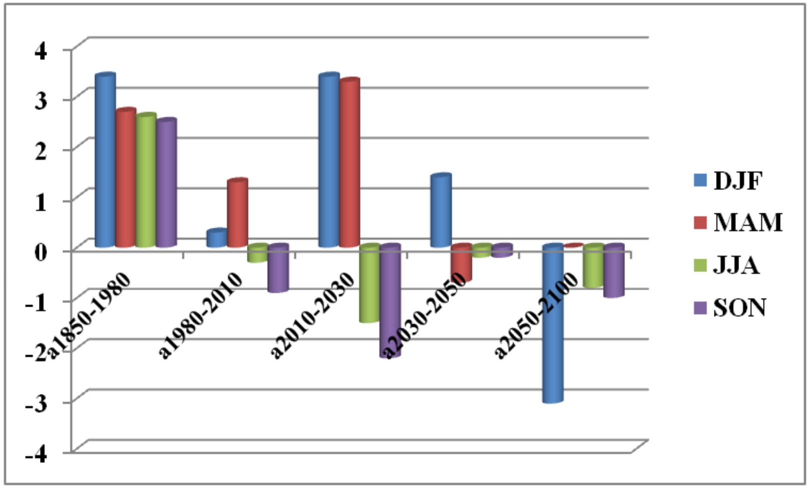



**North America**

## Trend of Concentration



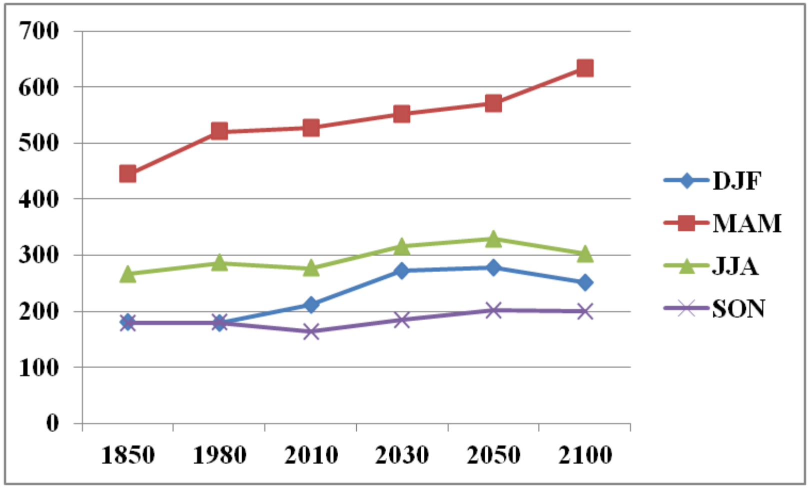

## Concentration Variation



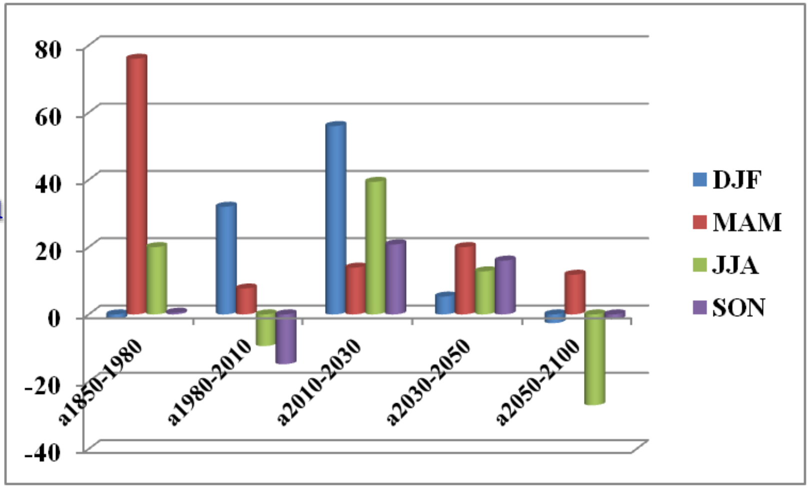

**South America**

# Trend of Variation (unit:mg $m^{-2}$)

## Trend of Concentration

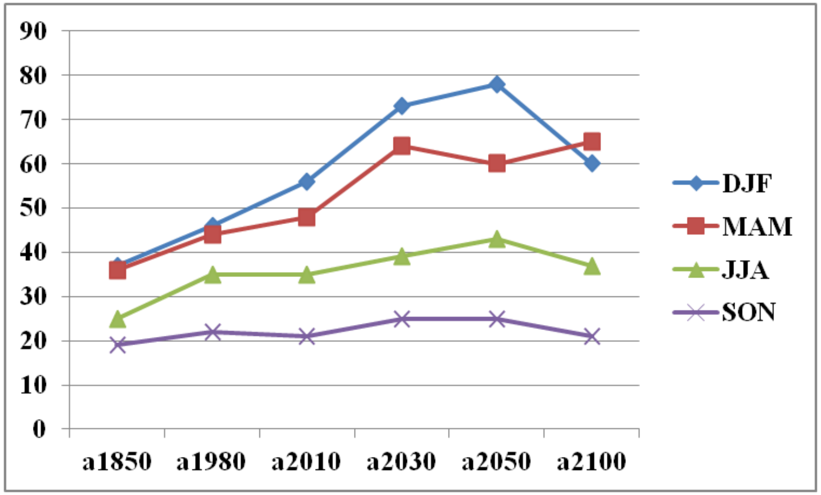



## Concentration Variation

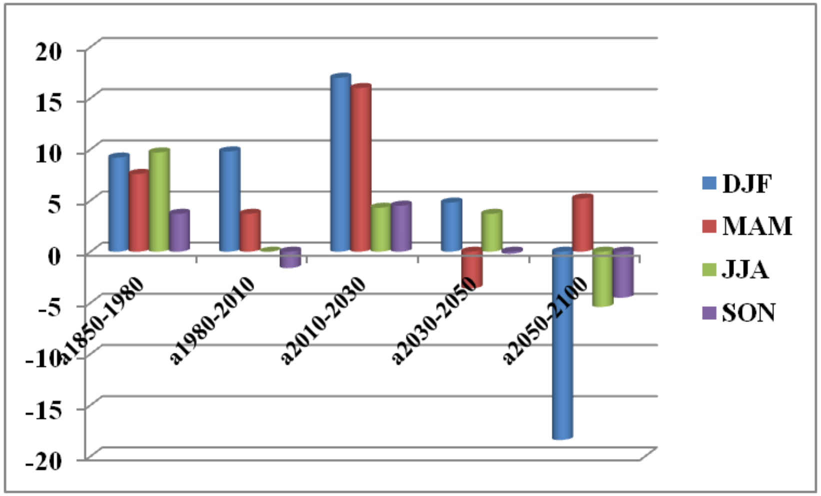



**Northern Africa**

## Trend of Concentration



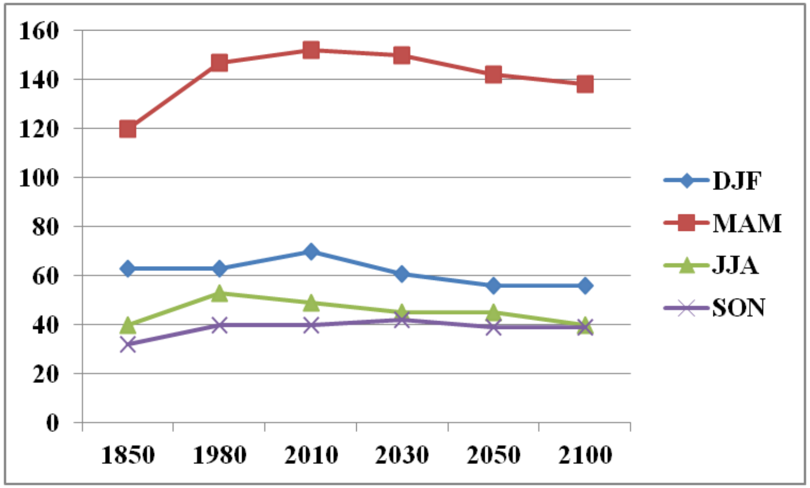

## Concentration Variation



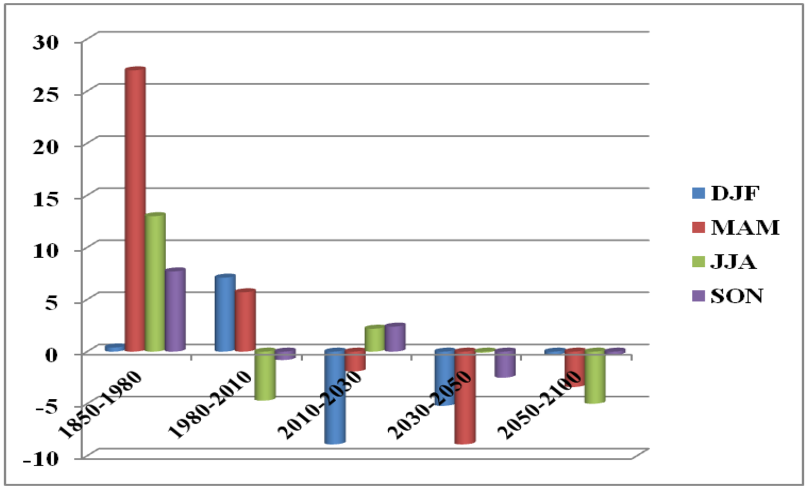

**Central Africa**

# Trend of Variation (unit:mg $m^{-2}$)

## Trend of Concentration

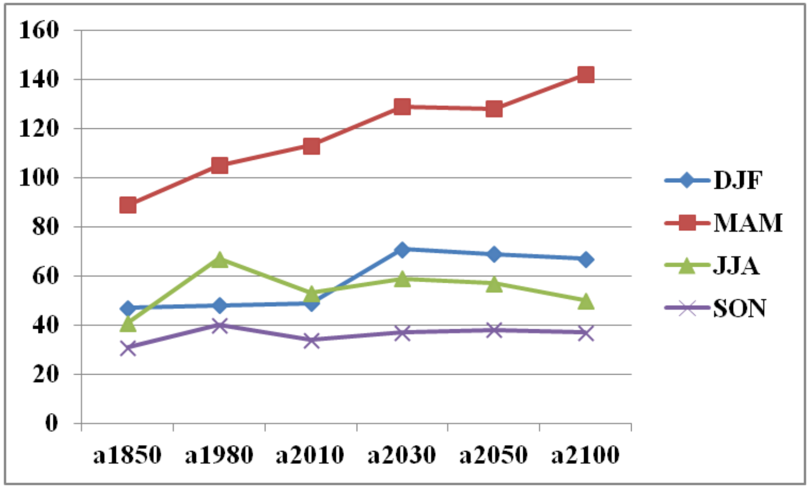



## Concentration Variation

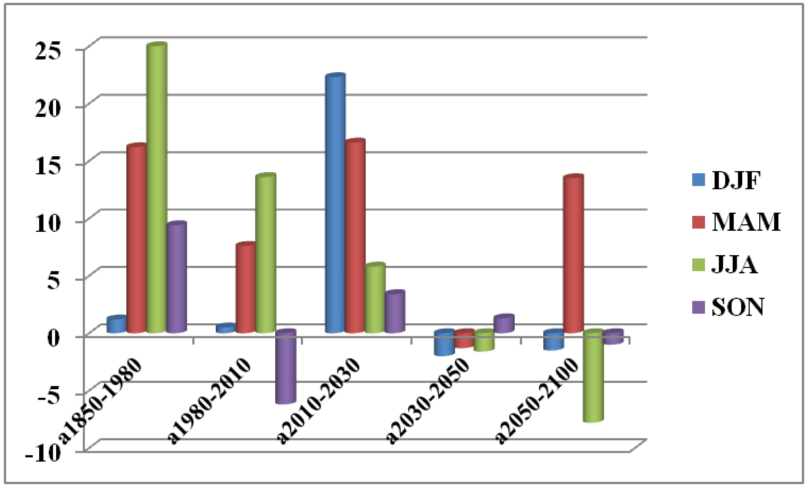



**China**

## Trend of Concentration




## Concentration Variation




**Western Europe**

# Summary

**PM2.5:**

- **1850-1980 the concentration of PM2.5 was increased obviously almost all over the world, especially in Arabian Peninsula, north of China and the Sahara Desert .**
- **2010-2050 the concentration of PM2.5 will be increased over the Sahara Desert, while be decreased in Asia, America and Europe.**

**Contribution to the difference of PM2.5 (over China) :**

- **1850-1980, the contribution of anthropogenic aerosols ( 56% ) to PM2.5 variation is a little bit more than natural aerosols( 44% ).**
- **2010-2050, anthropogenic aerosols ( 70% ) are much more than natural aerosols( 30% ) in the variation of PM2.5.**
- **Natural aerosols occupy more than half (55%) than anthropogenic aerosols (45%) in PM2.5 surface concentration for annual mean over China (under nitrate aerosol is not considered in this work).**

# The End
# Thanks For Your Attention !

23½°N
0°
23½°S
北美沙漠
土耳其斯坦
沙漠
塔克拉瑪干沙漠
戈壁
伊朗沙漠
印度沙漠
撒哈拉沙漠
阿拉伯
沙漠
卡拉哈里沙漠
納米布沙漠
阿塔卡瑪
沙漠
巴塔戈尼亞
沙漠
澳大利亞沙漠