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Modeling study on the impacts of agricultural emissions on $PM_{2.5}$ in YRD

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Outline

- Background
- Objectives
- Current research
- WRF-CMAQ
- On-going work

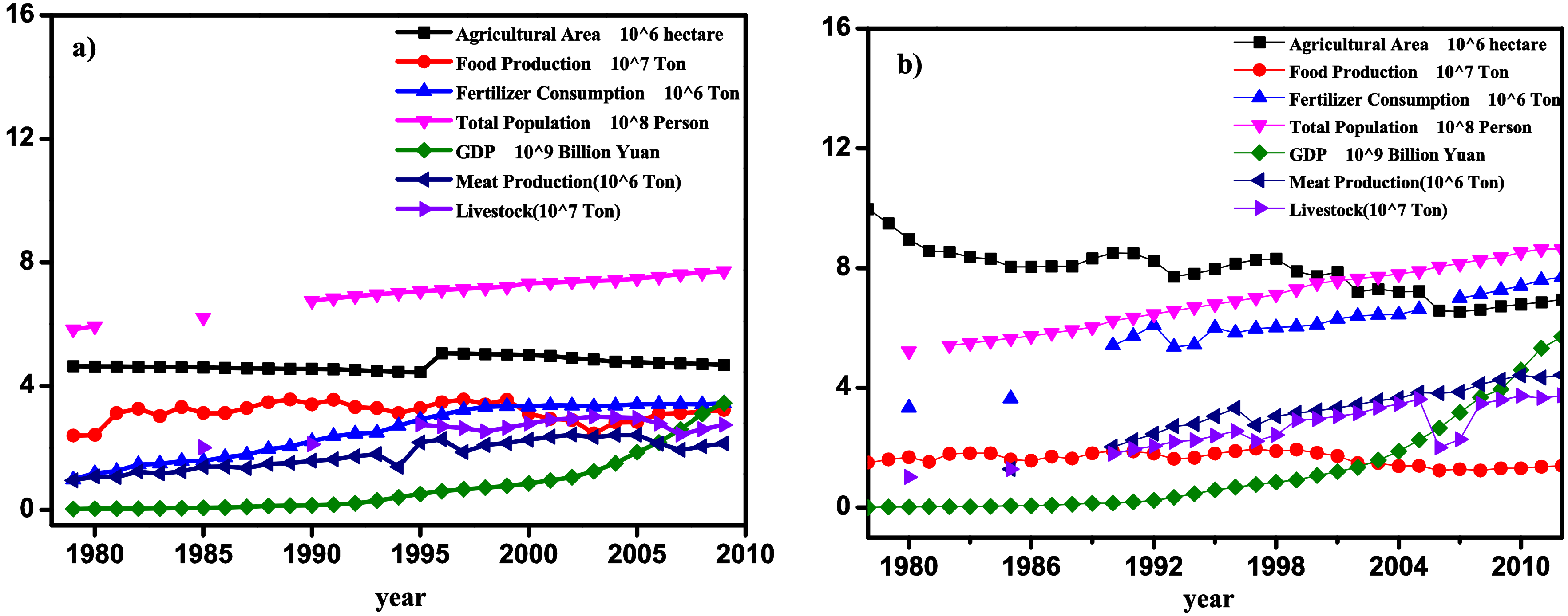
Background

- Along with unprecedented high-speed economic growth, many cities in China, suffer from more serious and more frequent air pollution events, especially extremely high levels of $PM_{2.5}$(particulate matter with diameter less than 2.5 μm).

- Agricultural emissions are important sources of air pollution, mainly NH_3. It is essential to investigate the impacts of agricultural emissions including fertilizer application, livestock and biomass burning on atmospheric $PM_{2.5}$.

- China has experienced a great progress in the air quality modeling system development and applications over the past two decades. However, none of these modeling systems have included agricultural emissions.

Background(ct.)



The total amount of fertilizer consumption was increased in the Yangtze River Delta over the past three decades. On the other hand, emissions of sulfate oxides (SO_x) and NO_x are reduced in the future after the implementation of various strict emission control measures. This indicates that NH_3 will play an increasingly prominent role in $PM_{2.5}$ formation in the future. Thus, it is important to quantify the impact of agricultural emissions on air quality in China.

Figure 1 The annual changes in Gross Domestic Product (GDP), total population, and five agricultural indices from 1978 to 2012 in a) Jiangsu Province and b) Guangdong Province

Scientific Questions

1. How do we reduce the uncertainties associated with estimating emissions from crop residue burning, livestock and fertilizer application?

2. What are the relative contributions of major agricultural emissions to $PM_{2.5}$ and how will the change in agricultural emissions impact the future air quality?

Current Research

- Davison and Cape (2003)found that 90% of the atmospheric NH_3 emission comes from animal production and slurries and manures in the US (Pinder et al., 2008) and many European countries (Van Der Hoek, 1998; Hutchings et al., 2001; Sotiropoulou et al., 2004).

- In China, Zhang et al. (2010) estimated that mineral fertilizer application contributed 54% of total NH_3 emissions, and livestock emissions accounted for the remaining part over the North China Plain. Meanwhile, Zhang et al. (2012) also found that livestock is the most important NH_3 emission source by contributing about 62% of the total NH_3 emissions over the Pearl River Delta region, followed by nitrogen fertilizer application (~23.7%) and non-agricultural sources (~14.6%).

Current Research(ct.)

- The most widely used AQMs include the US EPA Community Multiscale Air Quality modeling system (CMAQ), the Comprehensive Air Quality Model with extensions (CAMx) ,and the online-coupled Weather Research and Forecasting model with Chemistry (WRF/Chem)

- However, none of these modeling systems have included agricultural emissions. Therefore, it is very important to develop an agricultural air quality forecasting stem and to assess the impact of agricultural emissions on $PM_{2.5}$ formation in China.

Overview of the Science in the WRF/CMAQ Modeling System

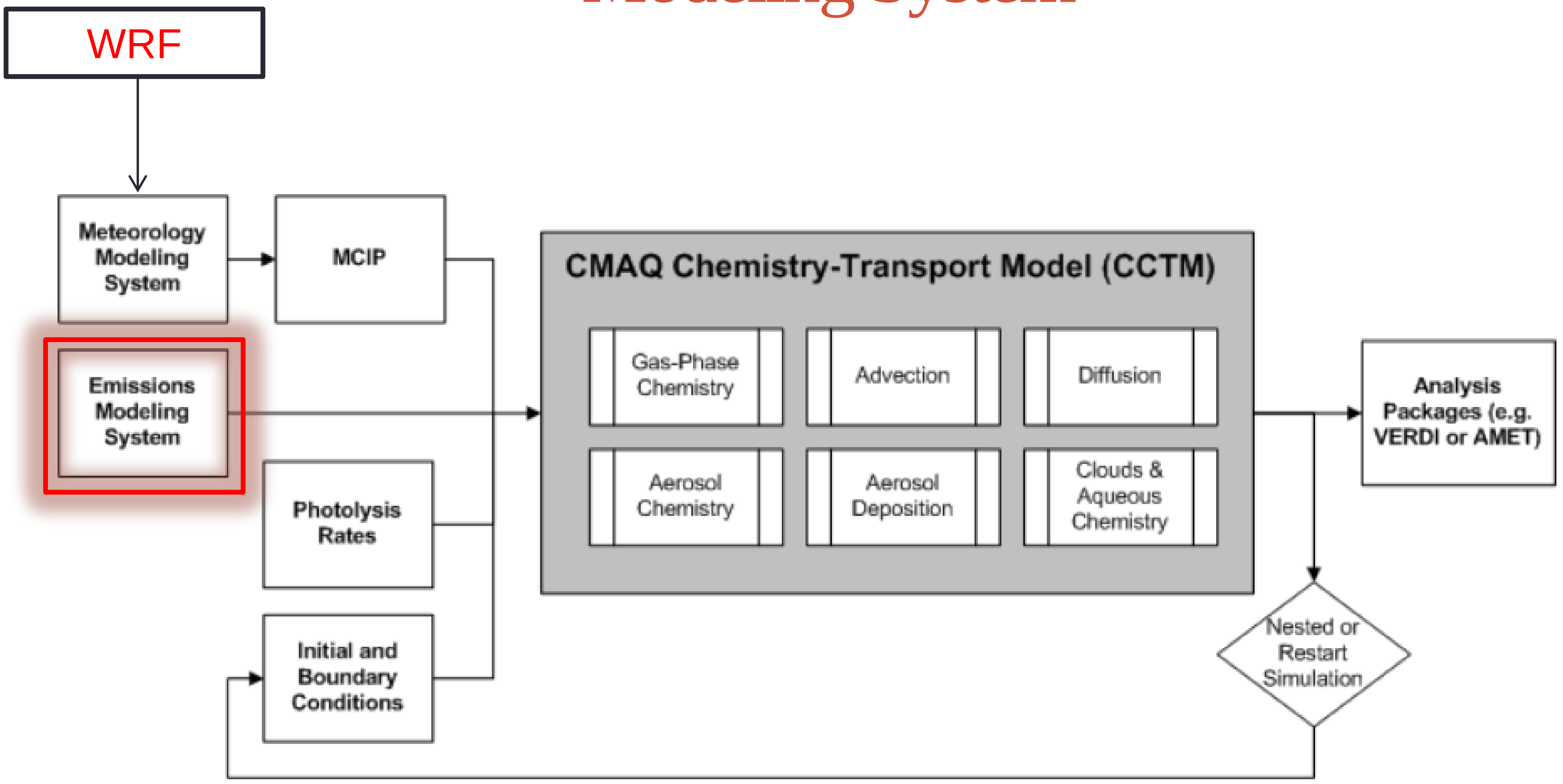


Figure 2. CMAQ Chemistry-Transport Model (CCTM) and input processors

Development of CMAQ

The Community Multiscale Air Quality Model (CMAQ) is developed to process great and diverse information from :

- Complicated emissions **mixtures** and complex distributions of **sources**,
- Modeling the complexities of atmospheric processes that **transport** and **transform** these mixtures in a dynamic environment,
- Operates on a large range of time scales covering minutes to days and weeks, and so on
- Corresponding spatial scales are commensurately large, ranging from local to continental scales.
- Meeting NAAQS requirements and other goals for a cleaner environment varying over a range of time scales, from peak **hourly to annual averages.**

On going work

- To develop an updated and detailed agricultural emission inventory over the Yangtze River Delta regions in China;

➢ Install the WRF/CMAQ

➢ Build up an agricultural emission inventory

➢ Develop agricultural air quality model (AAQM);

- To optimize the parameterization schemes of NH_3 dry and wet depositions in air quality models for improving air quality and atmospheric composition predictions;

Working field

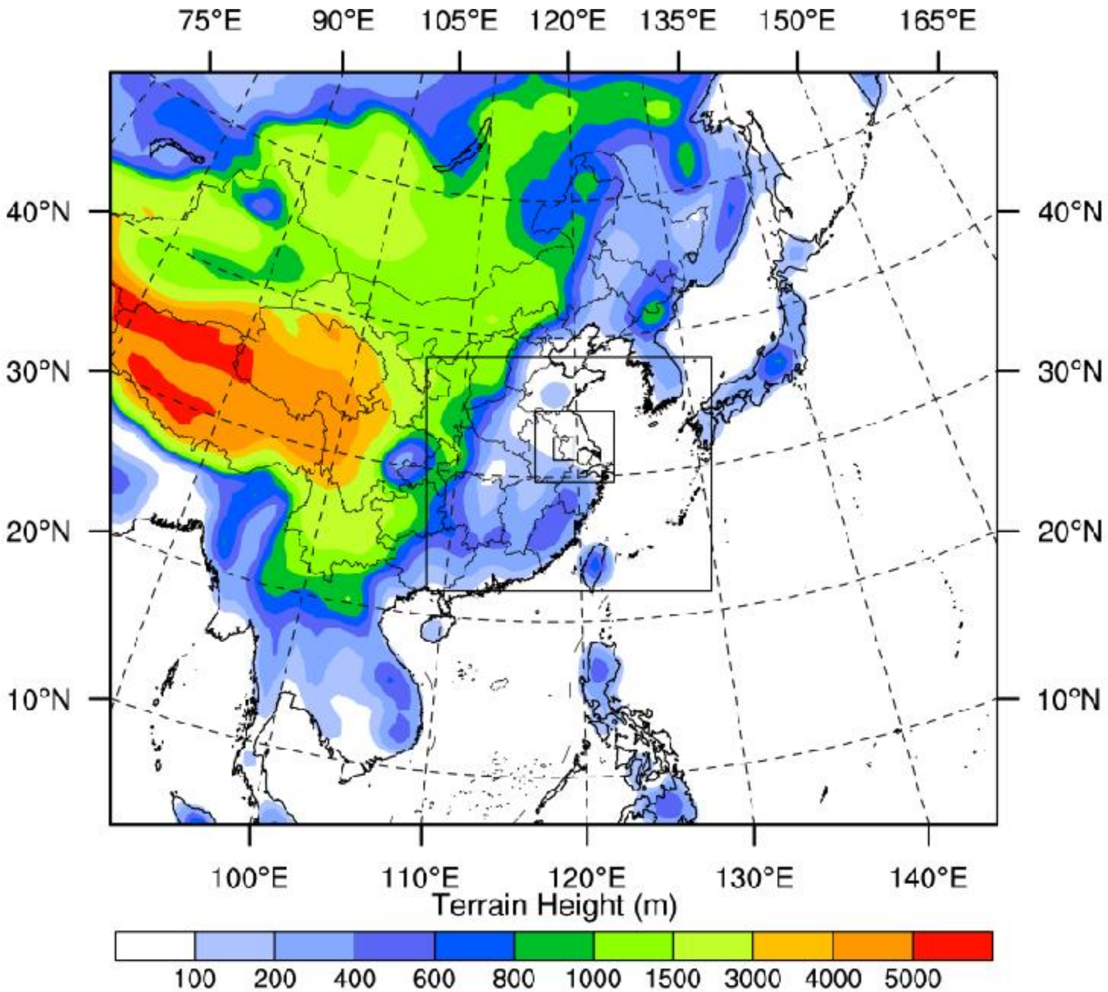


Figure 3. Working field of the model

Nest:81Km,27Km,9Km,3Km；

Vertical:24 levels

Top:100hpa

Lon :120.63 南京
Lat:31.37

Emission source classification

- Anthropogenic emissions:

➢INTEX B 2006 (David Streeet)

➢Multi-resolution Emission Inventory for China (MEIC) (Tsinghua University)

  - agricultural
  - industry
  - power
  - residential
  - transportation

- Biogenic emissions :

➢MEGAN

➢BEIS

David Street `s Emission inventory

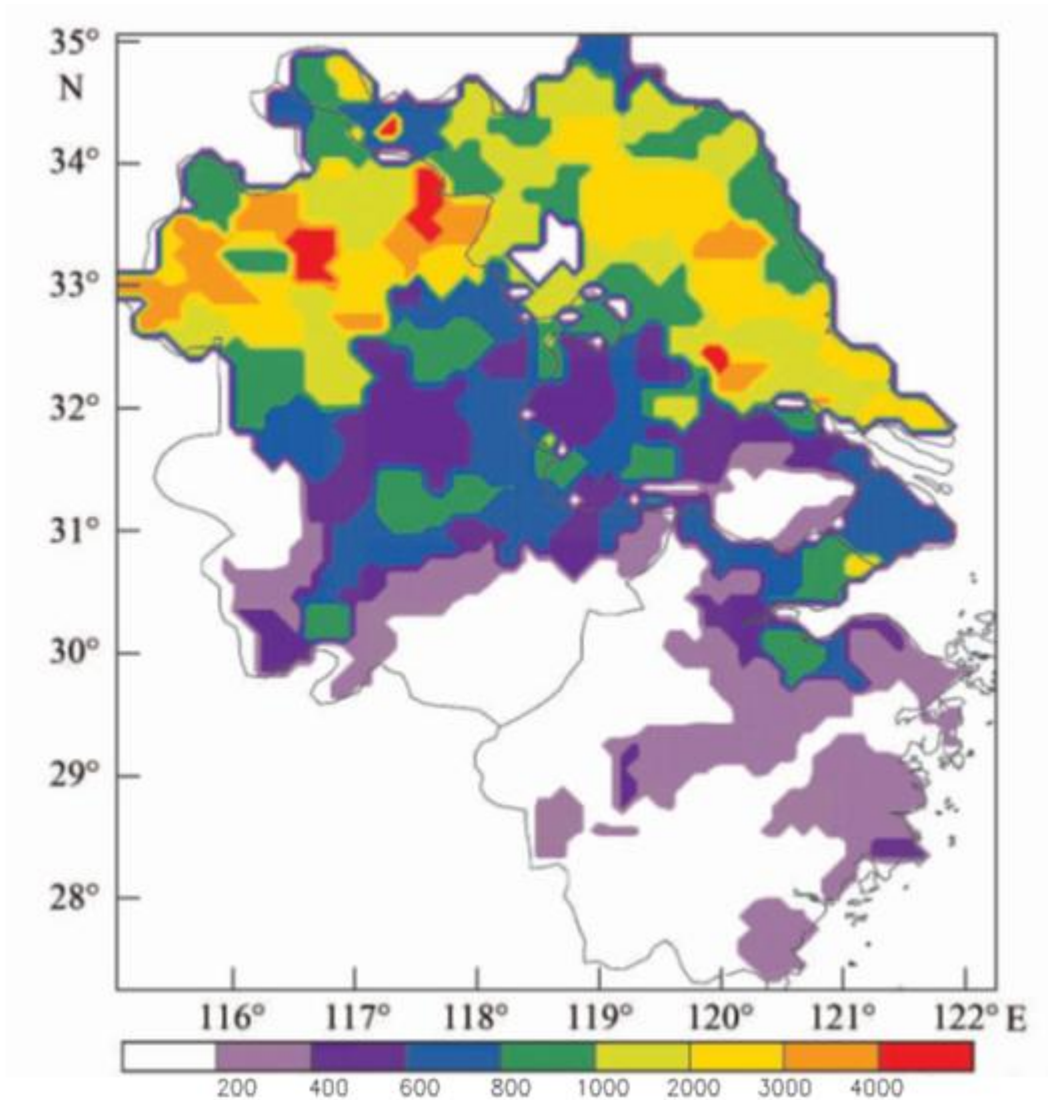


Fig.4 Spatial distribution of PM $_{2.5}$ emission of YRD（ton/year）

MEIC Emission inventory

- Compound types：
  – CO, NOx, SO_2, VOC, $PM_{2.5}$, PMcoarse, BC, OC, CO_2, NH_3
- Year：
  – 2008, 2010
- Nest：
  – 1.0°，0.5°，0.25°
- Temporal resolution：
  – month
- VOC chemical mechanism：
  – CBIV，CB05，SAPRC99，SAPRC07，RADM2

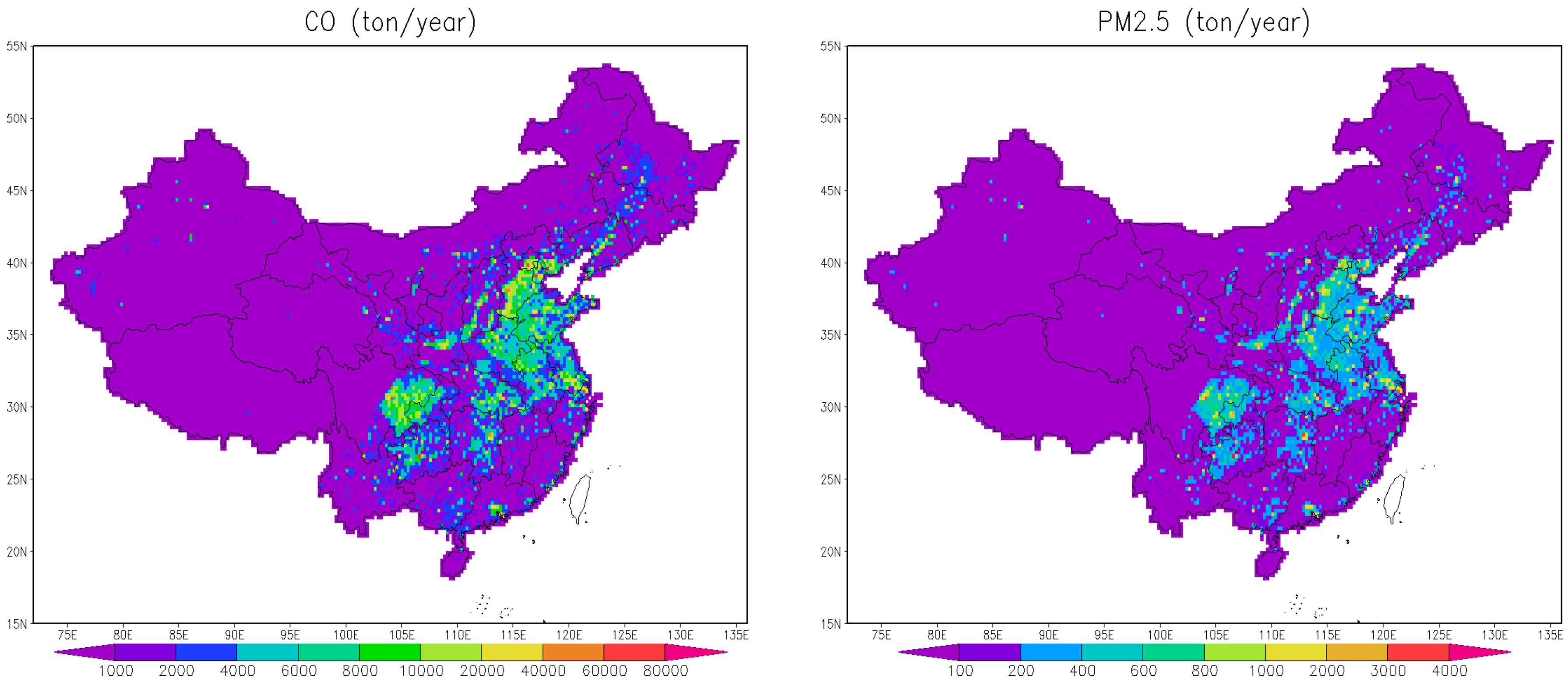


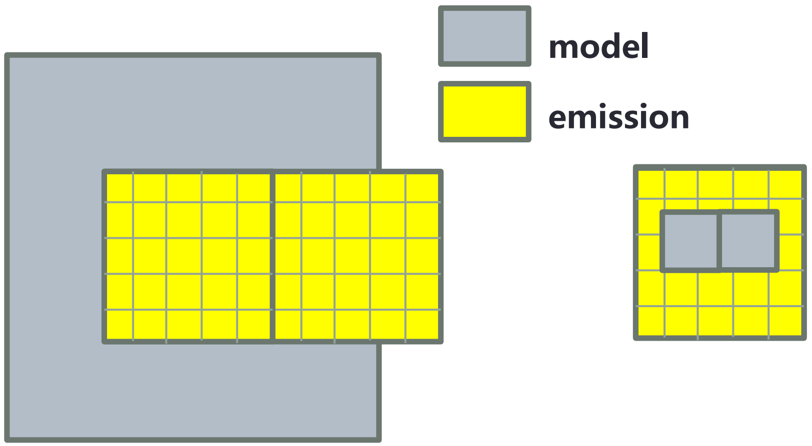
Fig.5 Spatial distribution of PM $_{2.5}$ Emission inventory of MEIC （2010） a)CO ; b)$PM_{2.5}$

The Essence of Emissions refinement

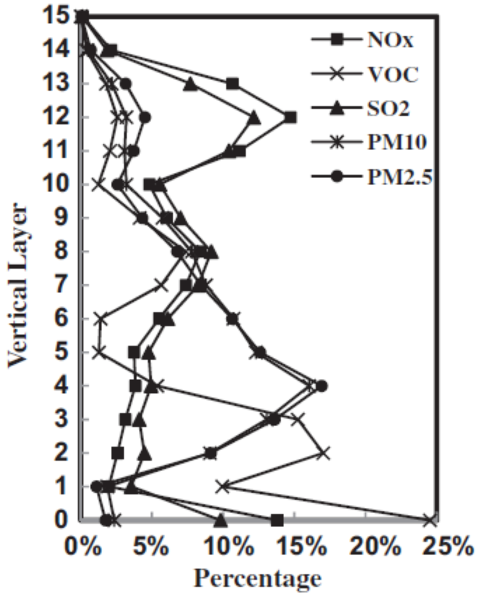
spatial resolution:

✓MEIC： 0.25

✓Horizontal: match to the model nest

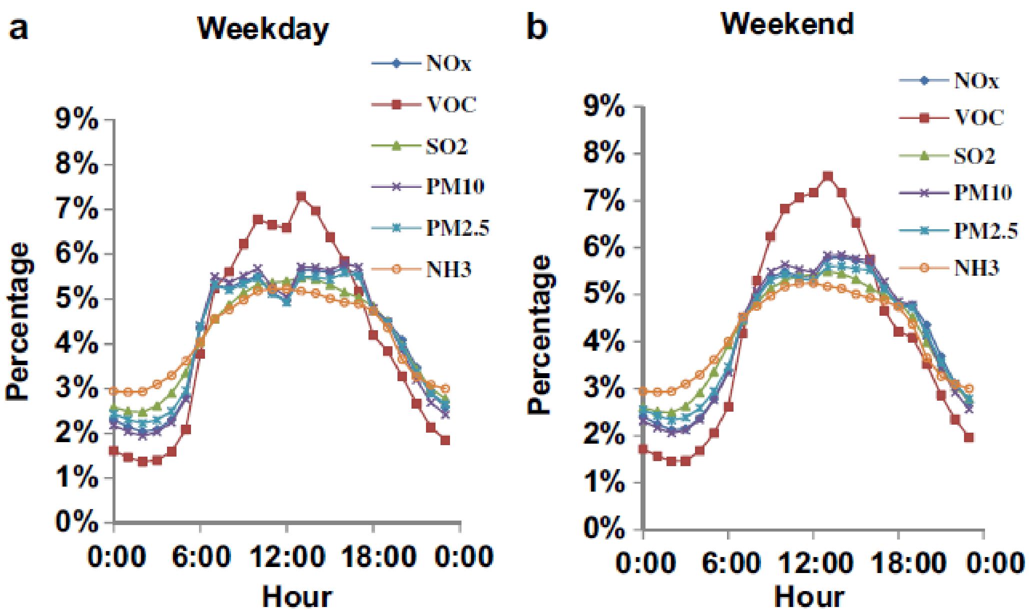


✓Vertical:



Source :Wang et al, 2011, AE

- temporal resolution:
  - ✓Year （2008，2010 vs. 2014)
  - ✓MEIC：month
  - ✓Daily



Diurnal variations in major pollutions on weekdays and weekend (Source :Wang et al, 2011)

Compounds classification

- VOC

  CBIV, CB05, SAPRC99, SAPRC07, RADM2

- NOX

  NO (90%), NO_2(10%)

- $PM_{2.5}$

  PM_{FINE}, P_{SO4}, P_{NO3}, P_{EC}, P_{OC}

Agricultural emission inventory

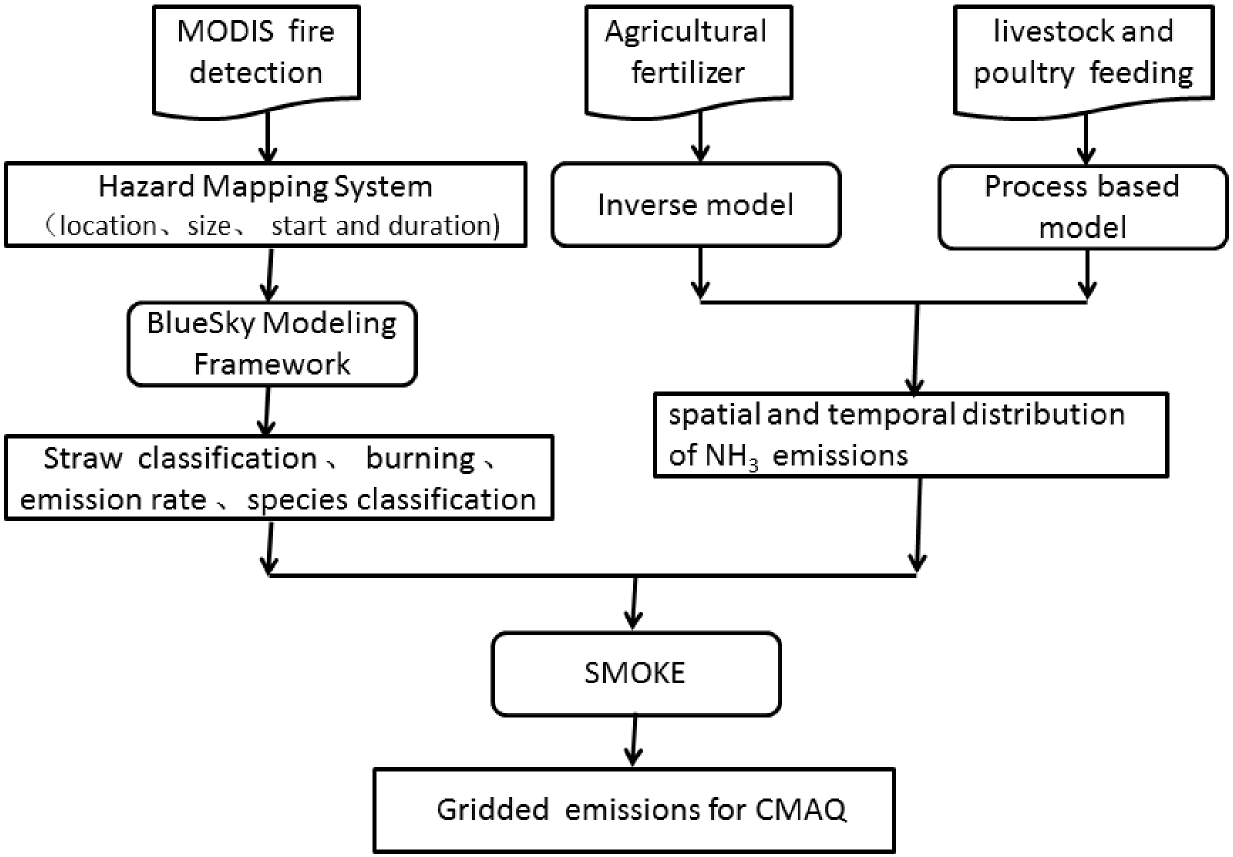


Figure 6 Flowchart of agricultural emission processing

Crop residue burning emissions:

- Dates: MODIS fire retrieval product (MOD14 or MYD14)；
- Tools: BlueSky modeling framework is used to calculate emission rates of different species ($PM_{2.5}$, NO_x, CO, CO_2, VOC）.Finally, converted to the format required by the emission processing system, SMOKE (Sparse Matrix Operator Kernel).

Fertilizer application emissions:

- MEIC as priori estimate;
- Improve the NH_4^{4+} aerosol by performing inverse analysis based on AAQM simulation and assign the emissions to the air quality model simulation domains.

Livestock feeding operation emissions

- obtain spatial and temporal distribution of livestock operation information (e.g., pigs, cows, and chicken) over YRD regions;

- parameterize the livestock feeding processes (grazing, housing, storage, and application)

- utilize process-based mechanism model (e.g., Farm Emission Model, FEM) for estimating NH_3 emission rates and their temporal changes.


Thank you !