

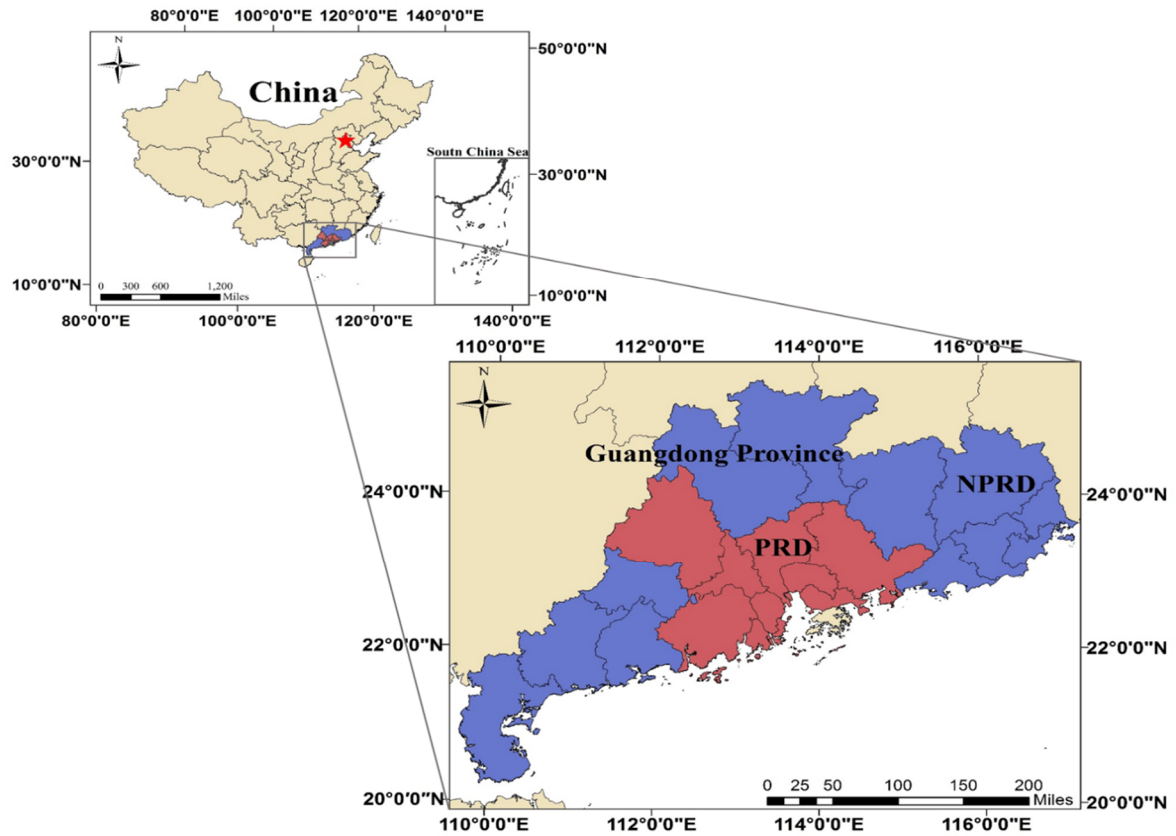
---

*Supplement of*

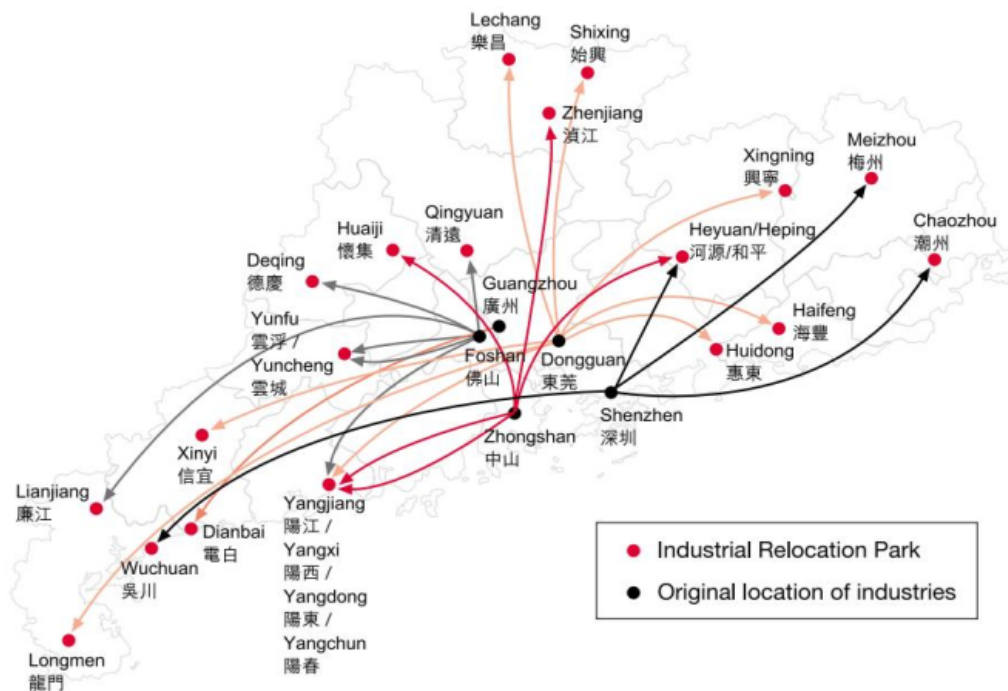
**Evolution of Anthropogenic Air Pollutants Emissions in Guangdong Province, China from  
2006 to 2015**

Yahui Bian, et al.

*Correspondence to:* Zhijiong Huang (bmmj@163.com), Junyu Zheng (zhengjunyu\_work@hotmail.com)

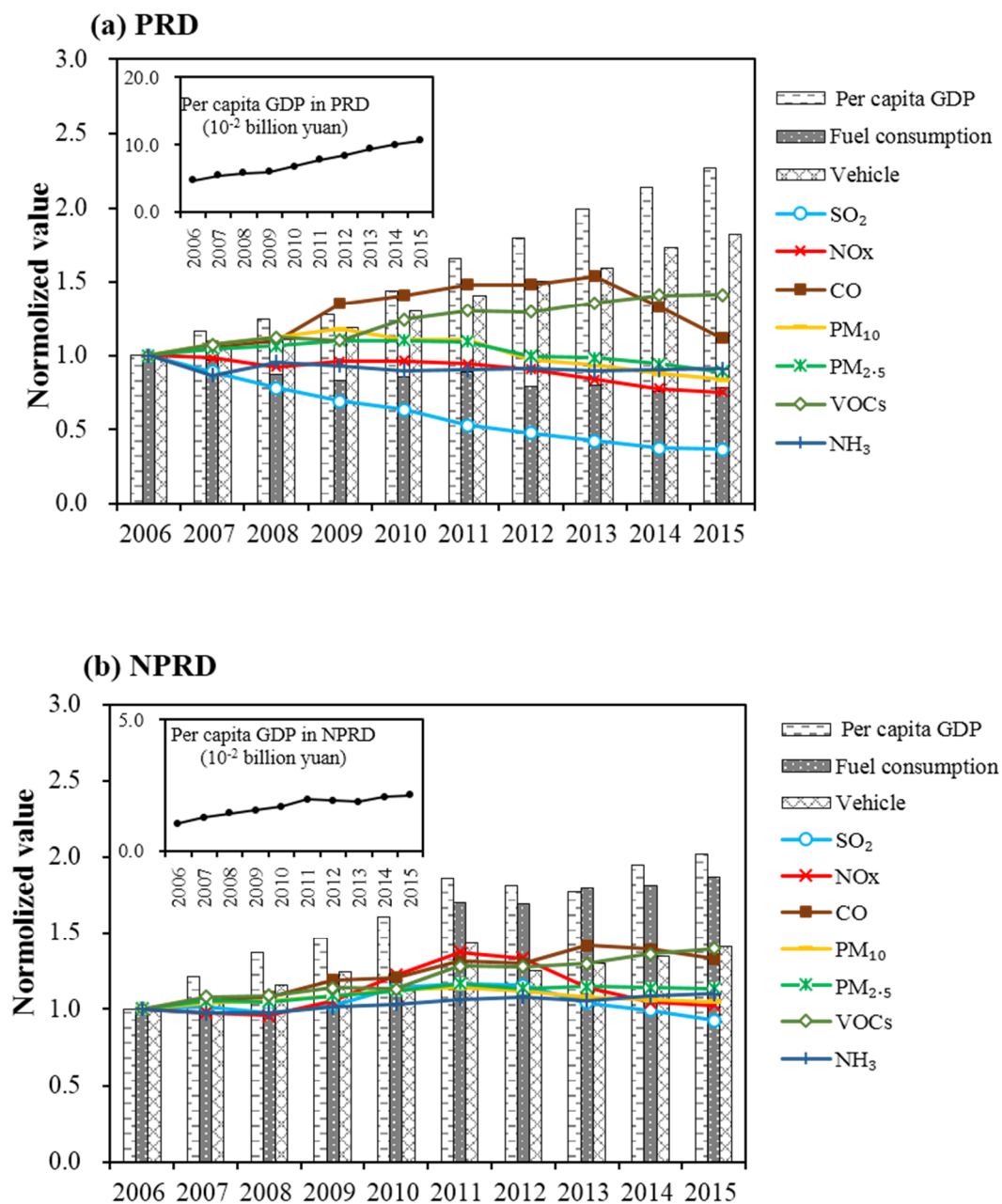


**Figure S1.** The geographical location of Guangdong Province, China

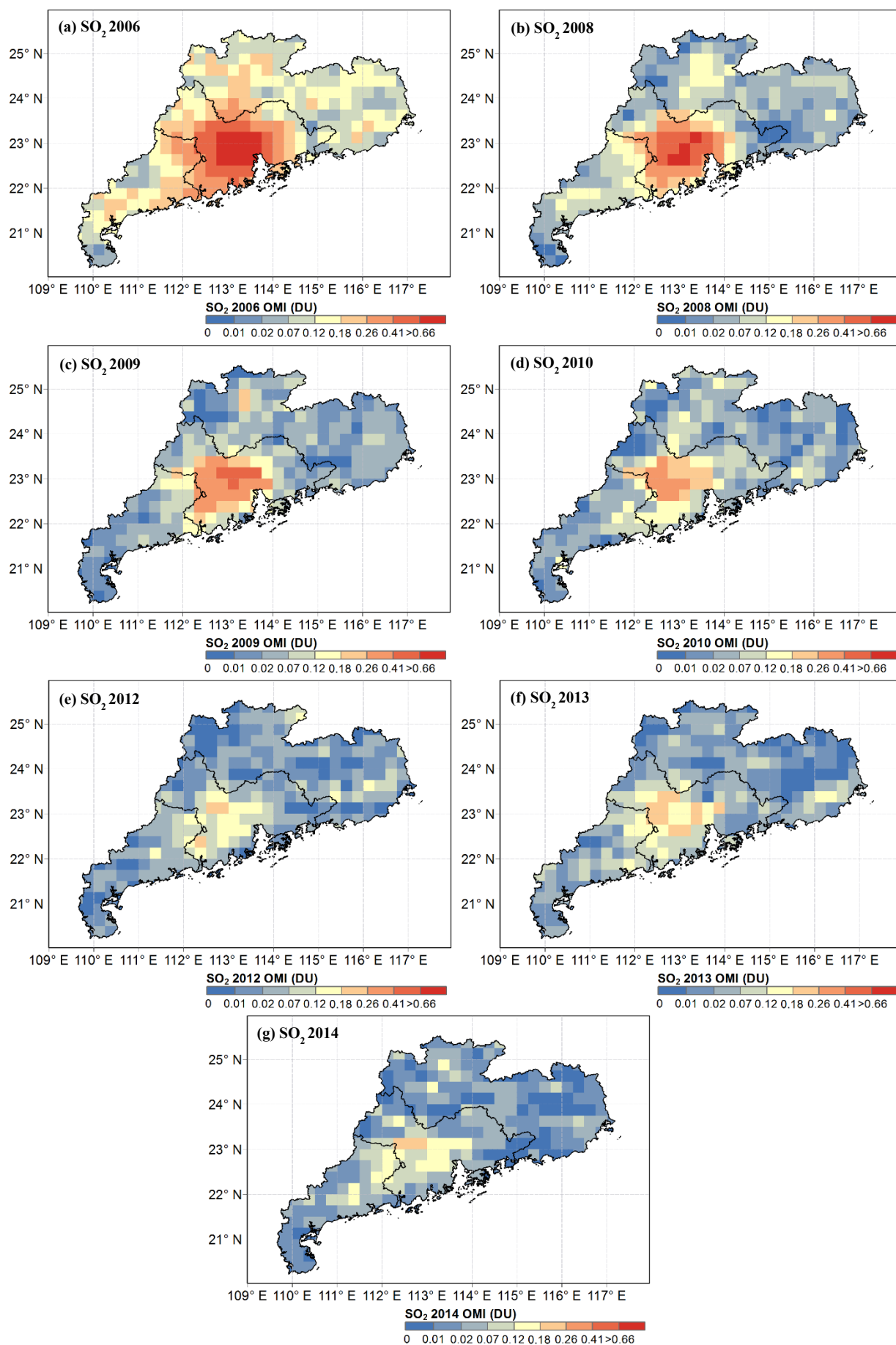


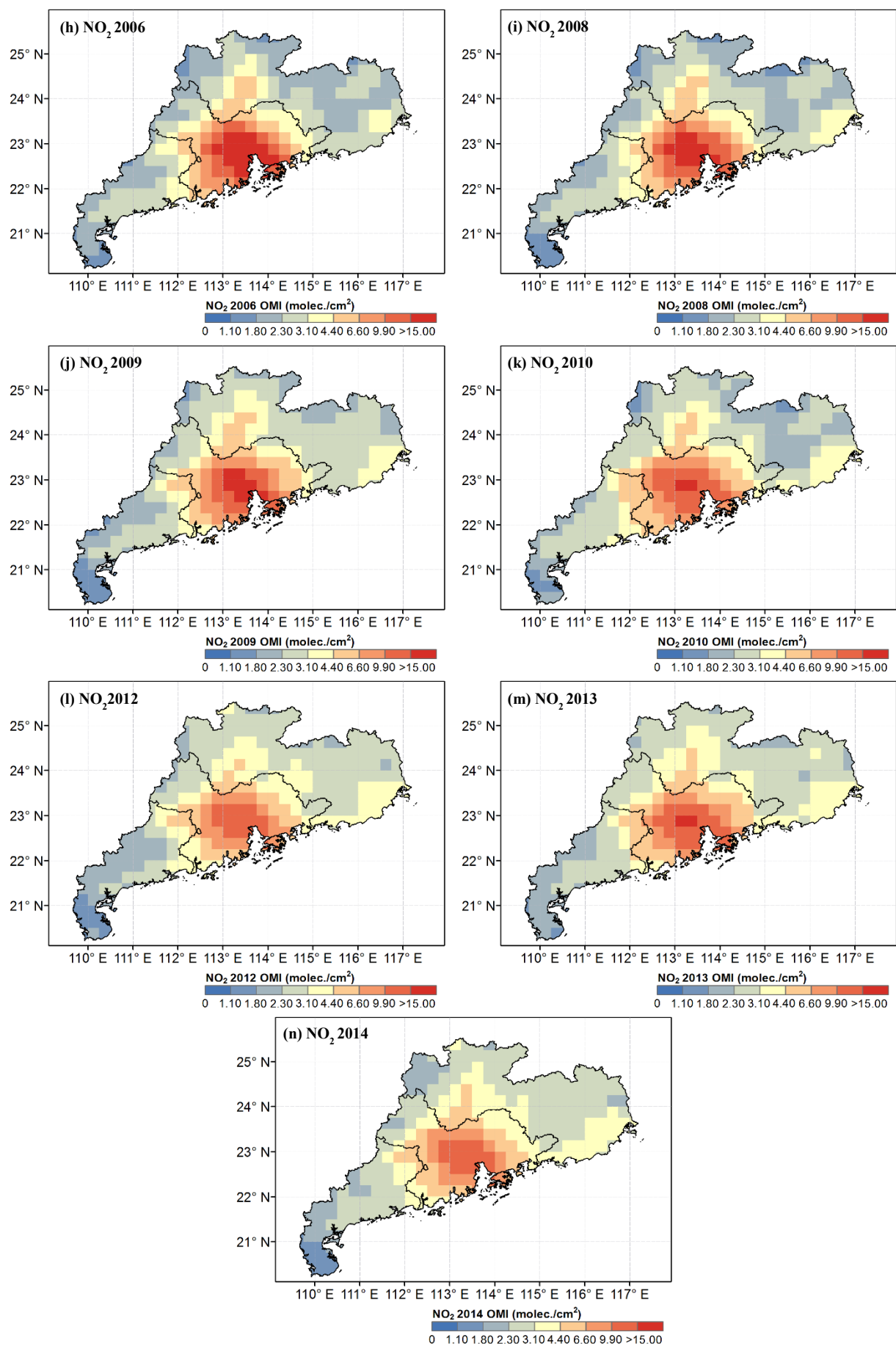
**Figure S2.** Government-designated industrial relocation parks in Guangdong province.

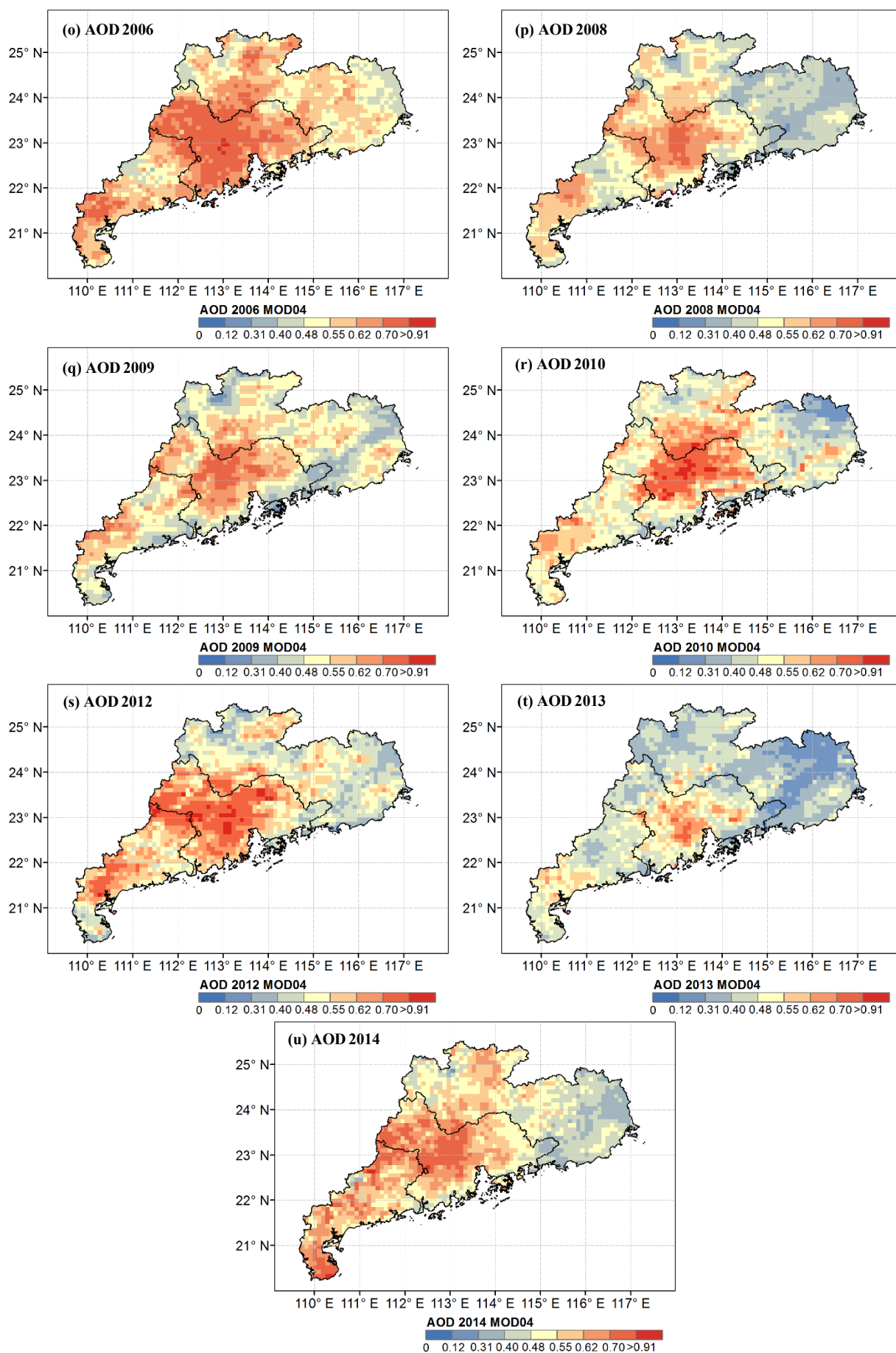
*Source: Li and Fung Centre Research (2008)*



**Figure S3.** Trends in the air pollutant emissions, per capita GDP, fuel consumption and vehicle population in the (a) PRD (b) NPRD (all of data are normalized to the year 2006).

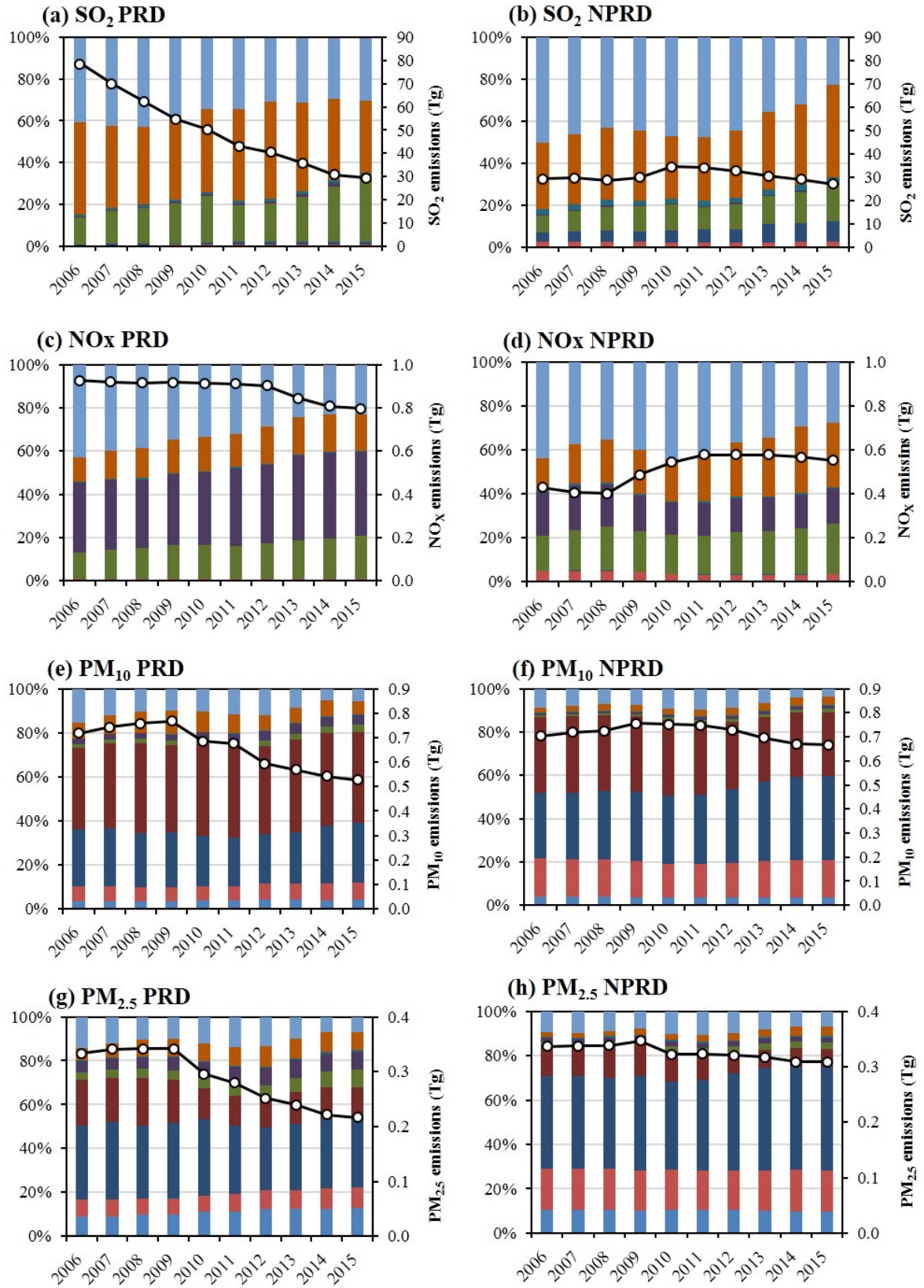


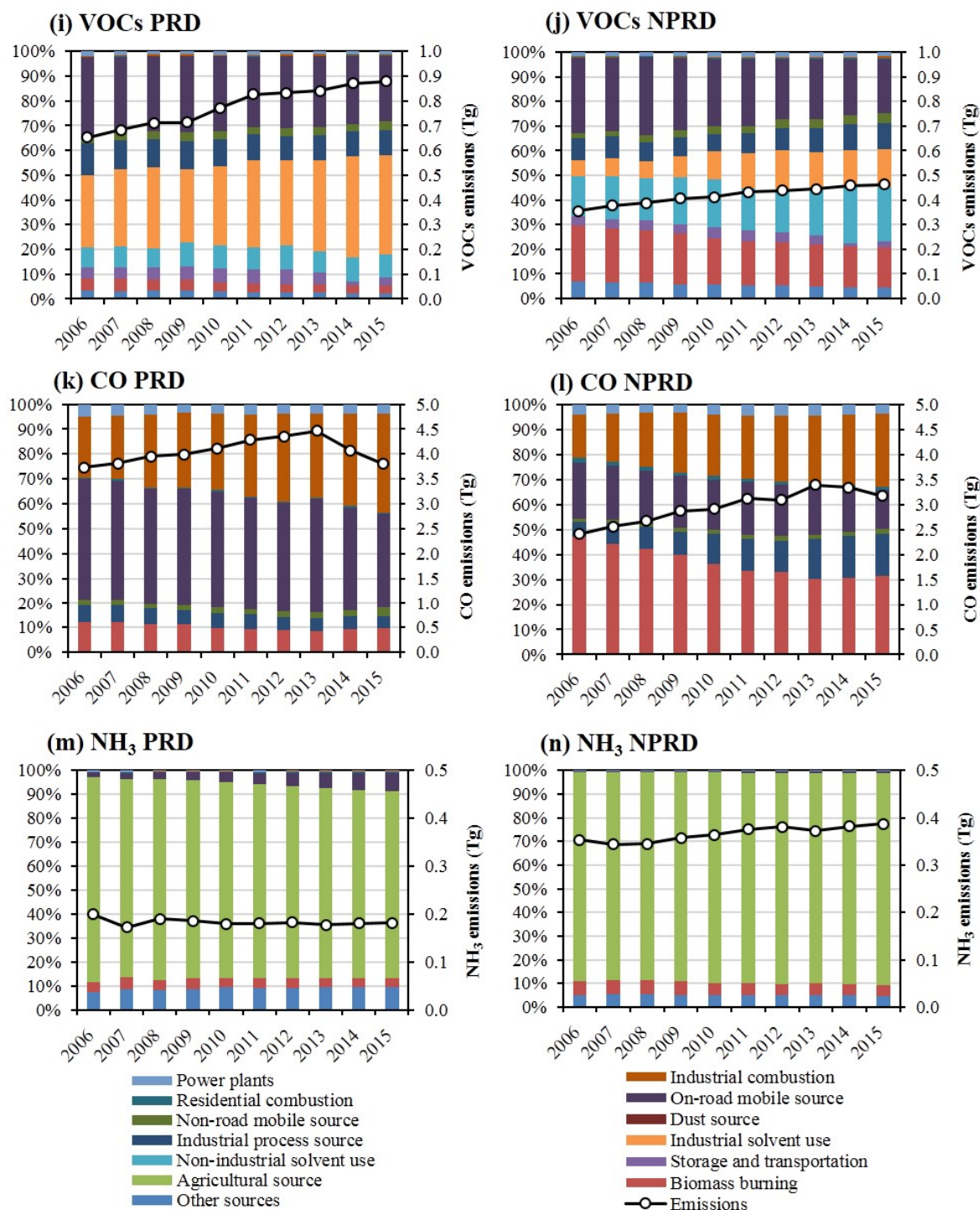






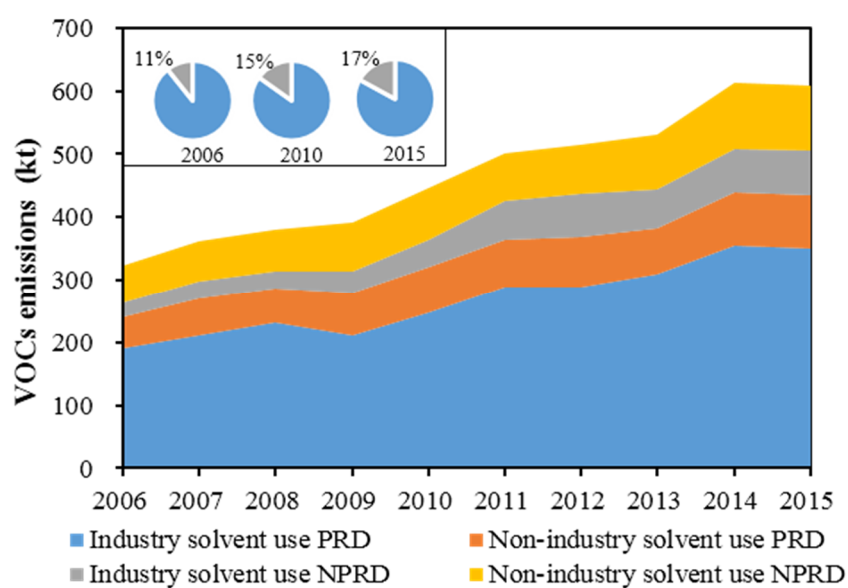
**Figure S4.** The spatial patterns of satellite observations in GD during 2006-2015 (except 2007, 2011 and 2015). **(a)-(g)** SO<sub>2</sub>, **(h)-(n)** NO<sub>2</sub>, **(o)-(u)** AOD.





**Figure S5.** Evolutions of emissions and their source contributions in the PRD and NPRD for (a)-(b) SO<sub>2</sub>, (c)-(d) NO<sub>x</sub>, (e)-(f) PM<sub>10</sub>, (g)-(h) PM<sub>2.5</sub>, (i)-(j) VOCs, (k)-(l) CO and (m)-(n) NH<sub>3</sub> from 2006 to 2015.





**Figure S6.** Trends of VOC emissions from solvent use (both industrial and non-industrial) and the contributions of industrial solvent use in the PRD and NPRD from 2006 to 2015.

**Table S1.** Source classification in Guangdong Province

| Category               | Sub-category                       | Category                  | Sub-category                 |
|------------------------|------------------------------------|---------------------------|------------------------------|
| Power plants           |                                    |                           | Electronics coating          |
| Industrial combustion  |                                    |                           | Appliance coating            |
| Residential combustion |                                    |                           | Furniture surface coating    |
| On-road mobile source  | Heavy duty gasoline vehicle (HDGV) | Industrial process source | Shoemaking                   |
|                        | Heavy duty diesel vehicle (HDDV)   |                           | Printing                     |
|                        | Light duty gasoline vehicle (LDGV) |                           | Textile fabric printing      |
|                        | Light duty diesel vehicle (LDDV)   |                           | Artificial board             |
|                        | Heavy duty gasoline truck (HDGT)   |                           | Office supply                |
|                        | Heavy duty diesel truck (HDDT)     |                           | Vegetable oil process        |
|                        | Light duty gasoline truck (LDGT)   |                           | Alcohol production           |
|                        | Light duty diesel truck (LDDT)     |                           | Food production              |
|                        | Bus                                |                           | Pharmacy                     |
|                        | Taxi                               |                           | Pulp and paper manufacturing |
| Non-road mobile source | Motorcycle                         |                           | Synthetic rubber             |
|                        | Airplane                           |                           | Coating manufacturing        |
|                        | Marine                             |                           | Chemical fiber               |
|                        | Fisher                             |                           | Oil refinery                 |
|                        | Agricultural machinery             |                           | Cement                       |
|                        | Farm transport vehicle             |                           | Bricks                       |

---

|                            |                             |                            |                                |
|----------------------------|-----------------------------|----------------------------|--------------------------------|
|                            | Construction machinery      |                            | Ceram                          |
|                            | Locomotive                  |                            | Glass                          |
|                            | Harbor machinery            |                            | Sulfuric acid                  |
| Dust source                | Road dust                   |                            | Sintering                      |
|                            | Construction dust           |                            | Iron                           |
| Storage and transportation | Oil refinery storage        |                            | Steel                          |
|                            | Oil products transportation |                            | Plastics manufacturing         |
|                            | Gas station                 |                            | Synthetic resin                |
| Biomass burning            | Household straw             |                            | Tire manufacturing             |
|                            | Household fire wood         |                            | Synthesis ammonia              |
|                            | Straw open burning          | Non-industrial solvent use | Personal domestic product      |
|                            | Forest fire                 |                            | Architecture surface coating   |
| Agricultural source        | Livestock                   |                            | Pesticide                      |
|                            | Agriculture fertilizing     |                            | Asphalt paving                 |
| Industrial solvent use     | Vehicle coating             |                            | Decontaminating and degreasing |
|                            | Shipping coating            |                            | Dry-cleaning                   |
|                            | Container coating           | Other sources              | Human body                     |
|                            |                             |                            | Cooking                        |

---

**Table S2.** Data type, data source and estimating methods of emission sources

| Category                      | Sub-category                  | Data type                                                                    | Data source                                            | Method              |
|-------------------------------|-------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------|---------------------|
| <b>Power plants</b>           |                               | Fuel consumption by fuel types                                               | CSPG(2007-2014);<br>GDPSR(2006,2010,2012,2014,2015)    | Zheng et al., 2009  |
|                               | <b>Industrial combustion</b>  | Fuel consumption by fuel types                                               | GDPSR(2006,2010,2012,2014,2015); GDPBS(2007-2016)      | Zheng et al., 2009  |
|                               | <b>Residential combustion</b> | Fuel consumption by fuel types                                               | CEBS(2007-2016); GDPBS(2007-2017)                      | Manual <sup>a</sup> |
| <b>On-road mobile source</b>  |                               | The number of light/heavy passenger car/truck, bus, taxi and motorcycle, VKT | GDPBS(2007-2016); GDPCSY(2007-2017);<br>A field survey | Pan et al., 2015    |
|                               | Airplane                      | The number of landing take-off (LTO)                                         | CAAC (2006-2015)                                       | Zhang et al., 2010  |
|                               | Marine                        | freight volume,<br>transport distance of the main shipping lines             | GDPBS(2007-2017);<br>A field survey                    | Li et al., 2017     |
|                               | Fisher                        | The power of fisher                                                          | GDPABS(2007-2016)                                      | Zhang et al., 2010  |
|                               | Agricultural machinery        | The number of agricultural machinery                                         | GDPABS(2007-2016)                                      | Zhang et al., 2010  |
| <b>Non-road mobile source</b> | Farm transport vehicle        | The number of farm transport vehicle                                         | GDPABS(2007-2016)                                      | Manual <sup>a</sup> |
|                               | Construction machinery        | Construction areas and the fuel consumption of construction of machinery     | GDPBS(2007-2016); CESY(2007-2016)                      | Zhang et al., 2010  |
|                               | Locomotive                    | The fuel consumption of locomotive, passenger and goods volume by railroad   | CTBS(2007-2016); GDPCSY(2007-2016)                     | Manual <sup>a</sup> |
|                               | Harbor machinery              | The throughput of container and bulk cargo                                   | CPBS(2007-2016)                                        | Fan et al., 2017    |
|                               | <b>Dust source</b>            | Road dust                                                                    | GDPCSY(2007-2016);                                     | Peng et al., 2013   |

|                                       |                                |                                                                                                                       |                                         |                     |
|---------------------------------------|--------------------------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------|---------------------|
|                                       |                                | traffic flow                                                                                                          | A field survey                          |                     |
|                                       | Construction dust              | Construction areas,<br>Construction cycles                                                                            | GDPCSY(2007-2016)                       | Yang, 2014          |
| <b>Industrial process<br/>source</b>  | All                            | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Pan et al., 2015    |
|                                       | Vehicle coating                | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Zheng et al., 2009  |
|                                       | Shipping coating               | The usage of print for shipping                                                                                       | BSPRD(2006,2010,2012,2014,2015)         | Zheng et al., 2009  |
|                                       | Container coating              | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Zheng et al., 2009  |
|                                       | Electronics coating            | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Zheng et al., 2009  |
|                                       | Appliance coating              | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Zheng et al., 2009  |
|                                       | Furniture surface coating      | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Manual <sup>a</sup> |
| <b>Industrial solvent use</b>         | Shoemaking                     | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Manual <sup>a</sup> |
|                                       | Printing                       | Output value                                                                                                          | GDPCSY(2007-2016)                       | Zheng et al., 2009  |
|                                       | Textile fabric printing        | Product output by types                                                                                               | GDPCSY(2007-2016)                       | Manual <sup>a</sup> |
|                                       | Artificial board               | Product output by types                                                                                               | GDPABS(2007-2016);<br>GDPCSY(2007-2016) | Manual <sup>a</sup> |
|                                       | Office supply                  | The number of industrial enterprises of<br>manufacture of cultural, educational, sports<br>and entertainment articles | GDPBS(2007-2016)                        | Manual <sup>a</sup> |
|                                       | Personal domestic product      | Population                                                                                                            | GDPBS(2007-2016)                        | Zheng et al., 2009  |
| <b>Non-industrial<br/>solvent use</b> | Architecture surface coating   | Floor space of buildings completed                                                                                    | GDPBS(2007-2016);<br>CEBS(2007-2016)    | Manual <sup>a</sup> |
|                                       | Pesticide                      | The usage of pesticide                                                                                                | GDPABS(2007-2016)                       | Manual <sup>a</sup> |
|                                       | Asphalt paving                 | The areas of new road                                                                                                 | GDPBS(2007-2016)                        | Manual <sup>a</sup> |
|                                       | Decontaminating and degreasing | Population                                                                                                            | GDPBS(2007-2016)                        | Manual <sup>a</sup> |



---

|                                   |                             |                                         |                                      |                     |
|-----------------------------------|-----------------------------|-----------------------------------------|--------------------------------------|---------------------|
| <b>Storage and transportation</b> | Dry-cleaning                | Population                              | GDPBS(2007-2016)                     | Manual <sup>a</sup> |
|                                   | Oil refinery storage        | Production of gasoline and diesel       | CEBS(2007-2016)                      | Manual <sup>a</sup> |
|                                   | Oil products transportation | Throughput of gasoline and diesel       | CEBS(2007-2016)                      | Manual <sup>b</sup> |
|                                   | Gas station                 | Sale volume of gasoline and diesel      | CEBS(2007-2016)                      | Manual <sup>b</sup> |
| <b>Agricultural source</b>        | Livestock                   | Product output by livestock types       | GDPABS(2007-2016)                    | Manual <sup>b</sup> |
|                                   | Agriculture fertilizing     | The usage of agriculture fertilizer     | GDPABS(2007-2016)                    | Manual <sup>b</sup> |
|                                   | Household straw             | Straw consumption                       | CEBS(2007-2016);<br>GDPBS(2007-2016) | He et al., 2011     |
| <b>Biomass burning</b>            | Household fire wood         | Fuelwood consumption                    | CEBS(2007-2016);<br>GDPBS(2007-2016) | He et al., 2011     |
|                                   | Straw open burning          | The output of rice and other crop yield | GDPBS(2007-2016)                     | He et al., 2011     |
|                                   | Forest fire                 | The areas of fires                      | GDPABS(2007-2016)                    | He et al., 2011     |
| <b>Other sources</b>              | Human body                  | Population                              | GDPBS(2007-2016)                     | Shen et al., 2014   |
|                                   | Cooking                     | Population                              | GDPBS(2007-2016)                     | Manual <sup>a</sup> |

---

CSPG is China Southern Power Grid;

GDPSR is Guangdong provincial pollutant statistical reports;

GDPBS is Guangdong Statistical Yearbook;

CEBS is China Energy Statistical Yearbook;

GDPCSY is Guangdong provincial 21 city Statistical Yearbooks;

CAAC is Civil Aviation Administration of China;

GDPABS is Agricultural Statistical Yearbook of Guangdong;

CTBS is China Transport Statistical Yearbook;

CPBS is China Port Statistical Yearbook;

Manual <sup>a</sup> is the Guideline of Air Pollutant Emission Inventory Development for Chinese Cities;

Manual <sup>b</sup> is Emission Inventory Handbook for Guangdong Province and Hong Kong.

**Table S3.** The major regulations for emission controls implemented during 2006-2015

| Control category                   |                                        | Main Measures                                                                                                                                                                                                                                                                                             | Sources    |
|------------------------------------|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Emission controls for power plants | Desulfurization                        | Manage strictly flue gas online monitoring in thermal power plants, making the operating efficiency of thermal power plants desulfurization facilities stably reach 85% or more.                                                                                                                          | 1, 5       |
|                                    |                                        | New coal-fired units must be equipped with desulphurization facilities, and the comprehensive desulfurization rate reach 95% or more.                                                                                                                                                                     | 6          |
|                                    |                                        | By the end of 2015, the comprehensive desulfurization rate of all the coal-fired thermal power units that are more than 125,000 KW has reached 95% or more.                                                                                                                                               | 9          |
|                                    | Control sulfur content of fuels        | The sulfur content of coal in thermal power plant is controlled below 0.7%; The sulfur content of industrial boiler and kiln is controlled below 0.6%, and the sulfur content of oil is controlled below 0.8%.                                                                                            | 1, 9       |
|                                    | Nitrogen reduction and denitrification | Adopt low-nitrogen combustion technology in thermal power plants; Research and promote clean combustion technology and flue gas denitrification technology.                                                                                                                                               | 1, 3, 4, 5 |
|                                    |                                        | The coal-fired units more than 125,000 KW in GD will be all equipped with the nitrogen reduction and denitrification facilities, of which comprehensive denitrification efficiency is more than 70%.                                                                                                      | 6          |
|                                    |                                        | Complete low-nitrogen combustion and flue gas denitrification transformation; The circulating fluidized bed boiler generating units that cannot stably achieve the discharge standard must increase the flue gas denitrification facilities; The comprehensive denitrification efficiency is 85% or more. | 9          |
|                                    | Dust removal                           | Implement special soot emission limit requirements of <i>Air Pollutant Emission Standards of Thermal Power Plants (GB13223-2011)</i> in coal-fired units.                                                                                                                                                 | 1          |
|                                    | Shut down small thermal power          | Shut down small heavy polluted thermal power plants; Develop large capacity, low energy consumption units; Transform low efficiency units. Gradually phase out high energy consumption,                                                                                                                   | 1          |

|                                     |                                                                       |                                                                                                                                                                                                                                                                                                           |         |
|-------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|
|                                     | <b>units</b>                                                          | heavy polluted processes and equipment.                                                                                                                                                                                                                                                                   |         |
|                                     |                                                                       | By the end of 2007, shut down the province's small thermal power units which power is below 50,000 KW.                                                                                                                                                                                                    | 4       |
|                                     |                                                                       | Gradually shut down the conventional coal-fired thermal power units which power is below 100MW.                                                                                                                                                                                                           | 5       |
|                                     | <b>Prohibit new coal-fired power plants or oil-fired power plants</b> | Forbid to plan and station new coal-fired or oil-fired power plants.                                                                                                                                                                                                                                      | 1       |
|                                     | <b>Improve the heating system</b>                                     | Adopt cogeneration enterprises as heating source in new industrial parks; Plan and build a sound central heating system.                                                                                                                                                                                  | 8, 9    |
|                                     | <b>Fuel power plants-oil to gas</b>                                   | Encourage oil-fired power plants to implement "oil to gas" project.                                                                                                                                                                                                                                       | 11      |
|                                     | <b>Ultra-low emission improvement of coal-fired power plants</b>      | Promote ultra-low emissions on >300,000 KW coal-fired generating units, >100,000 KW self-owned coal-fired generating units and other qualified coal-fired generating units, by the end of 2020, the air pollutant concentrations of coal-fired units reaches the emission limit of the gas turbine in GD. | 1, 5, 8 |
| <b>Industrial emission controls</b> | <b>Boiler renovation</b>                                              | By the end of 2012, strive to eliminate coal-fired, heavy oil-fired and wood-fired industrial boilers, which are < 4t/h or >10t/h over 8-year lifetime.                                                                                                                                                   | 11      |
|                                     |                                                                       | By the end of June 2016, basically eliminate <10t/h boilers in the PRD, which use high-polluting fuel but located outside the highly polluting fuel forbidden area.                                                                                                                                       | 8       |
|                                     |                                                                       | Forbid to build, expand and rebuild <20t/h industrial boilers that use highly polluting fuels in key control areas; Prohibit the construction of <10t/h industrial boilers that use highly polluting fuels                                                                                                | 4       |

|  |                                               |                                                                                                                                                                                                                                                                      |      |
|--|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|  |                                               | in other urban districts and the industrial parks.                                                                                                                                                                                                                   |      |
|  | <b>Control sulfur content of fuel</b>         | Control the sulfur content of coal <0.7% and that of oil <0.8% in enterprises without desulphurization facilities, and those fail to meet the requirements must use sulfur fixation or desulfurization agent.                                                        | 8    |
|  |                                               | Prohibit the use of fuel with sulfur content >1.5%. Sulfur content of coal must be controlled <0.6%, ash content be controlled <15%. Sulfur content of oil must be controlled below 0.8%.                                                                            | 6    |
|  | <b>Flue gas desulfurization</b>               | Strengthen the treatment of sulfur dioxide of industrial furnace flue gas, and the existing oil refining equipment, nonferrous metal smelting equipment, building materials kilns and coke oven, etc. should be installed flue gas desulfurization facilities.       | 6, 9 |
|  |                                               | Promote the iron and steel industry sintering machine flue gas desulfurization, and the new sintering machine should be equipped with flue gas desulfurization and denitrification facilities.                                                                       | 7    |
|  | <b>Nitrogen reduction and denitrification</b> | Encourage low nitrogen combustion technology and flue gas denitrification in the cement industry, especially in the new dry cement kiln with >2000 tons of clinker a day.                                                                                            | 8    |
|  |                                               | By the end of 2015, Coal-fired industrial boilers with >20t/h capacity must complete low-nitrogen combustion technology transformation. Additionally, Coal-fired industrial boilers with >65t/h capacity encourage construction of flue gas denitrification project. | 8    |
|  | <b>Desulfurization and dust removal</b>       | All industrial boilers with >10t/h capacity should be converted to use clean energy or equipped with efficient desulfurization and dust removal facilities to ensure pollutants satisfy stably emission standards.                                                   | 1    |
|  | <b>Prohibit new/extended cement plants</b>    | No longer plan to build and expand new cement plants in principle; Eliminate high energy consumption and heavy polluted production processes; Phase out shaft kiln gradually.                                                                                        | 11   |
|  | <b>Ceramic industries-coal to</b>             | Promote the ceramic manufacturing enterprises to use the natural gas and other clean energy; denitrification measures should be taken if nitrogen oxides cannot satisfy stably the emission                                                                          | 5    |

|                                                   |                                                                                         |                                                                                                                                                                                                                                                                      |              |
|---------------------------------------------------|-----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|
|                                                   | <b>gas</b>                                                                              | standards.                                                                                                                                                                                                                                                           |              |
|                                                   | <b>Centralized heating</b>                                                              | Realize basically central heating in industrial park with heating demand in the PRD.                                                                                                                                                                                 | 9            |
|                                                   | <b>Pollution control of non-metallic minerals industries</b>                            | Speed up the elimination of high energy consumption and seriously polluted old-fashioned production processes. By the end of 2012, eliminate completely backward cement production capacity, and "horizontal sheet process" backward flat glass production capacity. | 6            |
|                                                   |                                                                                         | All building materials kilns and sintering equipment without electrostatic precipitators (ESP) should be installed efficient dust removal facilities.                                                                                                                | 7            |
|                                                   |                                                                                         | By the end of 2010, all cement enterprises in the PRD need to install efficient dust removal equipment, dust removal efficiency should not be less than 95%.                                                                                                         | 11           |
|                                                   |                                                                                         | Promote the implementation of dust suppression measures in the raw materials transportation, storage, product packaging, drying, grinding, calcination and other processes for the cement enterprises; Control effectively fugitive dust emissions.                  | 9, 11        |
| <b>Volatile Organic Compounds (VOCs) controls</b> | <b>Implementation of environmental protection coatings/strict end-of--pipe controls</b> | Automobile manufacturing, shipbuilding, container manufacturing and other surface coating industry use low VOCs content paint that meets the environmental requirements; VOCs removal efficiency of the processes with solvent-based paint is up to 90%.             | 9, 11        |
|                                                   |                                                                                         | Printing, shoemaking, furniture manufacturing, electronics manufacturing and other industries to promote the use of low VOCs raw materials, organic waste gas purification rate is up to 80%.                                                                        | 6, 9, 10, 11 |
|                                                   |                                                                                         | Reduce sharply VOCs containing architectural coatings, household solvents and other production, the reduction rate is up to 80%.                                                                                                                                     | 10           |
|                                                   |                                                                                         | The proportion of low VOCs content paint use in new industrial coating project is more than 50%; The proportion of the use of low VOCs content of the total paint coating in new vehicle manufacturing and maintenance coating project is not less than 80%.         | 10, 11       |
|                                                   | <b>Implementation of LDAR</b>                                                           | Promote Comprehensively leak detection and repair (LDAR) technology, by the end of 2015 all oil refining enterprises using LDAR technology in the PRD; By the end of 2017, apply fully LDAR                                                                          | 11           |



|                                        |                                     |                                                                                                                                                                                                                                                                                                                                                           |      |
|----------------------------------------|-------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
|                                        | <b>technology of key industries</b> | technology by all the oil refining enterprises, organic chemicals and pharmaceutical chemicals and other key enterprises in GD.                                                                                                                                                                                                                           |      |
|                                        |                                     | Liquid organic materials should be sealed storage in key cities, low boiling point organic material storage tank should be set to maintain and equipped with the nitrogen seal device, the larger tank should use effectively seal inner (outer) floating roof tank, large storage tank should use efficient floating roof tank and nitrogen seal device. | 6, 9 |
|                                        | <b>Oil and gas recovery</b>         | By the end of 2011, conduct comprehensively oil and gas recovery and management, and complete all the gas stations, tankers and oil depots of oil and gas comprehensive management and acceptance in the PRD; By the end of 2012, complete integrated oil and gas management in the other region.                                                         | 9    |
|                                        |                                     | By the end of 2014, complete the oil and gas storage tank management in gas stations, oil depots, tankers and chemical enterprises and construct online monitoring system in oil and gas recovery.                                                                                                                                                        | 11   |
|                                        |                                     | Strengthen the daily inspection of oil and gas recovery facilities in gas station; Increase recovery efficiency of oil and gas reach up to more than 80%.                                                                                                                                                                                                 | 4    |
| <b>Motor vehicle emission controls</b> | <b>Improve emission standards</b>   | Since January 1, 2007, the national III emission standards have been carried out in advance in the PRD. Since July 1, 2007, the national III emission standards have been adopted in GD.                                                                                                                                                                  | 6, 7 |
|                                        |                                     | Implement the emission standards for vehicles national IV and motorcycles national III, and prohibit the registration and transfer procedures for automobiles and motorcycles that do not meet the corresponding standards.                                                                                                                               | 11   |
|                                        |                                     | Since December 31, 2015, vehicle national V emission standards has be implemented in advance in the PRD, the scope includes light ignition engine vehicles and public transportation, sanitation, postal heavy compression ignition engine vehicles.                                                                                                      | 4    |
|                                        | <b>Improve oil quality</b>          | Improve the quality of oil products, and promote vigorously the national III vehicle fuel standards in GD.                                                                                                                                                                                                                                                | 5, 7 |
|                                        |                                     | Comprehensively promote the use of GD III fuel standards in refined products, and strive for the                                                                                                                                                                                                                                                          | 6, 7 |

|                                        |                                          |                                                                                                                                                                                                                                                                              |             |
|----------------------------------------|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
|                                        |                                          | gradual supply of refined oil products for GD IV fuel standards in the PRD in 2010.                                                                                                                                                                                          |             |
|                                        |                                          | Improve the quality of vehicle fuel, and supply fully GD IV vehicle fuel in the PRD; Supply gradually GD IV vehicle fuel in the other region.                                                                                                                                | 9           |
|                                        |                                          | By the end of 2014, supply fully of GD V automotive gasoline in the PRD.                                                                                                                                                                                                     | 6, 7, 9, 11 |
|                                        | <b>Yellow label car management</b>       | Speed up the elimination of high emission vehicles, eliminate all yellow cars in the Pearl River Delta region by the end of 2015.                                                                                                                                            | 11          |
|                                        |                                          | In 2015, the proportion of the restricted area of yellow-label cars in the PRD was not less than 40% of the urban districts.                                                                                                                                                 | 4, 6, 7, 11 |
|                                        | <b>Implement the I/M system</b>          | Implement comprehensively vehicle emission inspection and maintenance (I/M) system.                                                                                                                                                                                          | 9, 11       |
|                                        | <b>Carry out green traffic</b>           | Implement the bus priority development strategy, optimize the layout of public transport network, strengthen walking, bicycle transportation system construction, improve public transport, walking, biking proportion, and reasonably control the amount of motor vehicles. | 11          |
|                                        |                                          | In 2015, new energy vehicles are up to 20% among the added or updated buses in the PRD; In new or updated vehicles of passenger transport, taxi, sanitation, city logistics and other public services, the proportion of the total new energy vehicles are up to 20%.        | 5           |
| <b>Non-road mobile source controls</b> | <b>Control sulfur content of fuels</b>   | Promote the use of low sulphur diesel, and speed up the elimination of highly polluting ship and machinery.                                                                                                                                                                  | 7           |
|                                        |                                          | Establish ship emission control area in the PRD, and gradually implement the use of fuel that sulfur content is less than 0.5% <sub>m/m</sub> during the ship moored.                                                                                                        | 11          |
|                                        | <b>Connect Ship to shore electricity</b> | By 2017, 30% of container, passenger ship and cruise specialized wharfs have the capability to supply ships with shore power.                                                                                                                                                | 11          |
|                                        |                                          | New coastal cruise berths and container berths of more than 100 thousand tons need to be equipped with shore power facilities; By the end of 2017, working vessels and harbor management vessels have basically realized the use of shore power.                             | 11          |

|                                           |                                             |                                                                                                                                                                                                                                                                                                                                                                                                                    |           |
|-------------------------------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
|                                           |                                             | By 2020, 90% of ships, official ships using shore power to berth and land in the main ports of the PRD water area, and 50% of container, passenger ship and cruise specialized wharfs have the capability to supply ships with shore power.                                                                                                                                                                        | 11        |
|                                           | <b>Port machinery-oil to electricity</b>    | By the end of 2017, basically complete the "oil to electricity" transformation in coastal and inland port rubber-tyred container gantry crane; Encourage to develop "oil to electricity" transformation in other port handling machinery and equipment.                                                                                                                                                            | 11        |
| <b>Emission controls for dust sources</b> | <b>Building dust control and management</b> | Strictly implement the construction site enclosed and removal of refuse and clay residue, spray dust and other measures, and strive to achieve the "six 100%" (namely 100% block of construction site, 100% sand cover, 100% road hardening, 100% sprinkling of demolition, 100% rinse wheel and body when transport vehicles go outside with sealed and no leakage, 100% green of temporary not developed sites). | 9         |
|                                           |                                             | Promote the control technology in construction dust; Establish dust source dynamic information database and particulate matter online monitoring system.                                                                                                                                                                                                                                                           | 9, 11     |
|                                           |                                             | Construction site muck and powdery materials are fully enclosed transport and equipped with global positioning system (GPS) in transport vehicles.                                                                                                                                                                                                                                                                 | 9, 11     |
|                                           |                                             | The total construction area of 100 thousand square meters or more shall be regulated by the installation of dust video surveillance equipment.                                                                                                                                                                                                                                                                     | 9, 11     |
|                                           | <b>Road dust control</b>                    | Control pollution of road dust, and increase the frequency of road cleaning; The rate of roads cleaning in urban districts reaches more than 85%.                                                                                                                                                                                                                                                                  | 7         |
| <b>Management for living area source</b>  | <b>Dining fumes</b>                         | Strengthen the division of catering service and their pollution prevention and control work                                                                                                                                                                                                                                                                                                                        | 9         |
|                                           |                                             | Promote the use of efficient purification type household smoke exhauster; Forbid open-air barbecue or open-air cooking with lampblack in the main urban districts.                                                                                                                                                                                                                                                 | 9, 10, 11 |
|                                           |                                             | Strengthen the control of lampblack emission in catering industry and achieve the standard discharge, and the normal utilization rate of facilities shall be no less than 95%.                                                                                                                                                                                                                                     | 7, 9      |
| <b>Adjustment of</b>                      | <b>Total control of</b>                     | By the end of 2015, the total consumption of coal was less than 1.6 tons in the PRD.                                                                                                                                                                                                                                                                                                                               | 7         |

|                         |                                               |                                                                                                                                                                  |   |
|-------------------------|-----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| <b>energy structure</b> | <b>coal consumption</b>                       | By 2017, the proportion of coal to total energy consumption in GD has dropped to less than 36%, and the total coal consumption has achieved downward in the PRD. | 9 |
|                         | <b>Expand the supply range of natural gas</b> | Natural gas pipelines are accessible to industrial parks in the PRD which are in need of gas.                                                                    | 9 |

\*The number “1-11” represent the main documents as follows:

| <b>NO.</b> | <b>Release Year</b> | <b>Main documents</b>                                                                                                 |
|------------|---------------------|-----------------------------------------------------------------------------------------------------------------------|
| 1          | 2004                | Outline plan for environmental protection in the Pearl River Delta (2004-2020 )                                       |
| 2          | 2006                | Rectification content and requirements of the provincial control of key pollution sources online monitoring system    |
| 3          | 2006                | Outline plan of environmental protection of Guangdong province (2006-2020)                                            |
| 4          | 2006                | Planning for environmental protection and ecological construction in Guangdong Province in 11 <sup>th</sup> Five-Year |
| 5          | 2010                | Integrated planning for environmental protection in the Pearl River Delta (2009-2020)                                 |
| 6          | 2010                | Clean air action plan for the Pearl River Delta in Guangdong province                                                 |
| 7          | 2011                | Planning for Guangdong province environmental protection and ecological construction in 12 <sup>th</sup> Five-Year    |
| 8          | 2012                | Guangdong industrial boiler pollution remediation program (2012-2015)                                                 |
| 9          | 2014                | Action plan for air pollution prevention and control in Guangdong province (2014-2017)                                |
| 10         | 2014                | About volatile organic compounds in key industries (2014-2017)                                                        |
| 11         | 2015                | Guangdong provincial environmental protection planning in 13 <sup>th</sup> Five-Year (2015-2020)                      |

**Table S4.** NO<sub>x</sub> emission factors for power plants, industrial combustion and on-road mobile source

| Category              | Subcategory | Type                | EFs    | Unit             | References         |
|-----------------------|-------------|---------------------|--------|------------------|--------------------|
| Power plants          | Coal        | <300MW, without LNB | 6.68   | g/kg             | Zhao et al., 2010  |
|                       |             | <300MW, with LNB    | 4.3    | g/kg             |                    |
|                       |             | ≥300MW,with LNB     | 5.58   | g/kg             |                    |
|                       | Fuel oil    |                     | 10.06  | g/kg             | Tian, 2003         |
|                       | Natural gas |                     | 1.76   | g/m <sup>3</sup> | Zhao and Ma, 2008  |
| industrial combustion | Coal        |                     | 4.29   | g/kg             | Zhang et al., 2007 |
|                       | Fuel oil    |                     | 5.84   | g/kg             | Tian, 2003         |
|                       | Natural gas |                     | 1.76   | g/m <sup>3</sup> | Zhao and Ma, 2008  |
|                       | Coke        |                     | 4.8    | g/kg             | Zhao and Ma, 2008  |
|                       | HDGV        |                     | 7.759  | g/VKT            | 2007-based IVE     |
| On-road mobile source | HDDV        |                     | 13.515 | g/VKT            | 2007-based IVE     |
|                       | LDGV        |                     | 0.814  | g/VKT            | 2007-based IVE     |
|                       | LDDV        |                     | 0.976  | g/VKT            | 2007-based IVE     |
|                       | HDGT        |                     | 6.906  | g/VKT            | 2007-based IVE     |
|                       | HDDT        |                     | 13.524 | g/VKT            | 2007-based IVE     |
|                       | LDGT        |                     | 1.689  | g/VKT            | 2007-based IVE     |
|                       | LDDT        |                     | 1.135  | g/VKT            | 2007-based IVE     |
|                       | Bus         |                     | 14.191 | g/VKT            | 2007-based IVE     |
|                       | Taxi        |                     | 0.855  | g/VKT            | 2007-based IVE     |
|                       | Motorcycle  |                     | 0.05   | g/VKT            | 2007-based IVE     |



**Table S5.** PM emission factors for power plants, industrial combustion and dust source

| Category              | Subcategory       | Type                                           | EFs       | Unit                | References        |
|-----------------------|-------------------|------------------------------------------------|-----------|---------------------|-------------------|
| Power plants          | Coal              | Pulverized coal furnace, without control       | 1.5       | g/kg                | Zhao et al., 2010 |
|                       |                   | Pulverized coal furnace, with ESP <sup>a</sup> | 0.065     | g/kg                |                   |
|                       |                   | Pulverized coal furnace, with wet scrubber     | 0.291     | g/kg                |                   |
|                       |                   | Pulverized coal furnace, with FF <sup>b</sup>  | 0.0034    | g/kg                |                   |
|                       |                   | Grate-fired furnace, without control           | 0.26      | g/kg                |                   |
|                       |                   | Grate-fired furnace, with ESP <sup>a</sup>     | 0.02012   | g/kg                |                   |
|                       |                   | Grate-fired furnace, with wet scrubber         | 0.054     | g/kg                |                   |
|                       | Fuel oil          |                                                | 0.85      | g/kg                | Zhang, 2005       |
|                       | Natural gas       |                                                | 0.24      | g/m <sup>3</sup>    | Zhao and Ma, 2008 |
|                       | Coal              | Pulverized coal furnace/grate-fired furnace    | 28.08/5.4 | g/kg                | Zhang, 2005       |
| industrial combustion | Fuel oil          |                                                | 1.03      | g/kg                | Zhang, 2005       |
|                       | Natural gas       |                                                | 0.24      | g/m <sup>3</sup>    | Zhao and Ma, 2008 |
|                       | Coke              |                                                | 0.288     | g/kg                | Zhao and Ma, 2008 |
|                       | Road dust         |                                                | 1.60      | g/VKT               | Peng et al., 2013 |
| Dust source           | Construction dust | Earthwork excavation                           | 0.41      | g/m <sup>2</sup> ·h | Yang, 2014        |
|                       |                   | Foundations                                    | 0.14      | g/m <sup>2</sup> ·h |                   |
|                       |                   | Earthwork backfill                             | 0.2012    | g/m <sup>2</sup> ·h |                   |
|                       |                   | General construction                           | 0.11      | g/m <sup>2</sup> ·h |                   |
|                       |                   |                                                |           |                     |                   |

<sup>a</sup> is electrostatic precipitators; <sup>b</sup> is Fabric filter

**Table S6.** PM<sub>2.5</sub> emission factors for power plants and industrial process source

| Category                     | Subcategory | Type                                           | EFs       | Unit             | References        |
|------------------------------|-------------|------------------------------------------------|-----------|------------------|-------------------|
| <b>Power plants</b>          | Coal        | Pulverized coal furnace, without control       | 0.4       | g/kg             | Zhao et al., 2010 |
|                              |             | Pulverized coal furnace, with ESP <sup>a</sup> | 0.032     | g/kg             |                   |
|                              |             | Pulverized coal furnace, with wet scrubber     | 0.135     | g/kg             |                   |
|                              |             | Pulverized coal furnace, with FF <sup>b</sup>  | 0.0019    | g/kg             |                   |
|                              |             | Grate-fired furnace, without control           | 0.1       | g/kg             |                   |
|                              |             | Grate-fired furnace, with ESP <sup>a</sup>     | 0.008     | g/kg             |                   |
|                              |             | Grate-fired furnace, with wet scrubber         | 0.032     | g/kg             |                   |
| <b>industrial combustion</b> | Fuel oil    |                                                | 0.62      | g/kg             | Zhang, 2005       |
|                              | Natural gas |                                                | 0.17      | g/m <sup>3</sup> | Zhao and Ma, 2008 |
|                              | Coal        | Pulverized coal furnace/grate-fired furnace    | 5.4 /1.89 | g/kg             | Zhang, 2005       |
|                              | Fuel oil    |                                                | 0.67      | g/kg             | Zhang, 2005       |
|                              | Natural gas |                                                | 0.17      | g/m <sup>3</sup> | Zhao and Ma, 2008 |
|                              | Coke        |                                                | 0.144     | g/kg             | Zhao and Ma, 2008 |
|                              |             |                                                |           |                  |                   |

<sup>a</sup> is electrostatic precipitators; <sup>b</sup> is Fabric filter

**Table S7.** VOCs emission factors for solvent use and on-road mobile source

| Category                   | Subcategory                  | Type                     | EFs     | Unit                  | References          |
|----------------------------|------------------------------|--------------------------|---------|-----------------------|---------------------|
| Industrial solvent use     | Appliance coating            | Appliance                | 0.2     | kg/piece              | Manual <sup>a</sup> |
|                            | Furniture surface coating    | Metal furniture          | 0.4     | kg/piece              | Manual <sup>a</sup> |
|                            | Printing                     | Output value of printing | 20.68   | kg/(10000 yuan· year) | Report              |
| Non-industrial solvent use | Architecture surface coating | Water-based paints       | 120     | g/kg                  | Manual <sup>a</sup> |
|                            |                              | Solvent-based paints     | 450     | g/kg                  | Manual <sup>a</sup> |
| On-road mobile source      | HDGV                         |                          | 7.924   | g/VKT                 | 2007-based IVE      |
|                            | HDDV                         |                          | 1.535   | g/VKT                 | 2007-based IVE      |
|                            | LDGV                         |                          | 1.422   | g/VKT                 | 2007-based IVE      |
|                            | LDDV                         |                          | 0.395   | g/VKT                 | 2007-based IVE      |
|                            | HDGT                         |                          | 8.197   | g/VKT                 | 2007-based IVE      |
|                            | HDDT                         |                          | 1.596   | g/VKT                 | 2007-based IVE      |
|                            | LDGT                         |                          | 1.978   | g/VKT                 | 2007-based IVE      |
|                            | LDDT                         |                          | 0.749   | g/VKT                 | 2007-based IVE      |
|                            | Bus                          |                          | 1.62012 | g/VKT                 | 2007-based IVE      |
|                            | Taxi                         |                          | 1.493   | g/VKT                 | 2007-based IVE      |
|                            | Motorcycle                   |                          | 3.69    | g/VKT                 | 2007-based IVE      |

Noted: In the sub-category of solvent use, EFs we listed here were the major contributors of solvent use

Manual <sup>a</sup> is the Manual of Air Pollutant Inventory Emission for Chinese Cities;

Report is *Study on air pollutant emission factors and the second phase of the emission investigation in Foshan*, edited by Guangdong Polytechnic of Environmental Protection Engineering South China University of Technology, and published in Environmental Protection Agency (EPA) of Foshan.

**Table S8.** NH<sub>3</sub> emission factors for agricultural source

| Category            | Subcategory             | Type                                                           | EFs                   | Unit    | References   |
|---------------------|-------------------------|----------------------------------------------------------------|-----------------------|---------|--------------|
| Agricultural source | Livestock               | Pork                                                           | 3.061                 | kg/head | Shen et al., |
|                     |                         | Dorking                                                        | 0.052                 | kg/head | 2014         |
|                     | Agriculture fertilizing | AC <sup>a</sup> /urea/AN <sup>b</sup> /AS <sup>c</sup> /others | 24.29/24.29/7.83/2.61 | %       | Shen, 2014   |

<sup>a</sup> is Ammonium carbonate; <sup>b</sup> is Ammonium nitrate; <sup>c</sup> is Ammonium sulfate

**Table S9.** CO emission factors for biomass burning and on-road mobile source

| Category                     | Subcategory         | Type                                | EFs    | Unit  | References           |
|------------------------------|---------------------|-------------------------------------|--------|-------|----------------------|
| <b>Biomass burning</b>       | Household straw     | Straw consumption                   | 82.18  | g/kg  | He et al., 2011      |
|                              | Household fire wood | Fuelwood consumption                | 63.63  | g/kg  |                      |
|                              | Straw open burning  | The output of rice/other crop yield | 78.45  | g/kg  | Zhang et al., 2013   |
|                              |                     | Wheat straw/maize stover            | 60/53  | g/kg  | Li et al., 2007      |
|                              | Forest fire         | The areas of fires                  | 113    | g/kg  | Chang and Song, 2010 |
|                              | HDGV                |                                     | 82.903 | g/VKT | 2007-based IVE       |
| <b>On-road mobile source</b> | HDDV                |                                     | 6.765  | g/VKT | 2007-based IVE       |
|                              | LDGV                |                                     | 9.010  | g/VKT | 2007-based IVE       |
|                              | LDDV                |                                     | 1.132  | g/VKT | 2007-based IVE       |
|                              | HDGT                |                                     | 38.433 | g/VKT | 2007-based IVE       |
|                              | HDDT                |                                     | 7.287  | g/VKT | 2007-based IVE       |
|                              | LDGT                |                                     | 8.665  | g/VKT | 2007-based IVE       |
|                              | LDDT                |                                     | 1.673  | g/VKT | 2007-based IVE       |
|                              | Bus                 |                                     | 7.103  | g/VKT | 2007-based IVE       |
|                              | Taxi                |                                     | 12.614 | g/VKT | 2007-based IVE       |
|                              | Motorcycle          |                                     | 6.780  | g/VKT | 2007-based IVE       |



---

## References

- Chang, D., and Song, Y.: Estimates of biomass burning emissions in tropical Asia based on satellite-derived data, *Atmo. Chem. Phys.*, 10, 2335-2351, 2010.
- Fan, X. L., Xia, Z. Q., Li, C., Huang, Z. J., Wang, Y. L., and Zheng, J. Y.: An improved method for building an emission inventory for cargo handling equipment and its application, *Research of Environmental Sciences*, 628-635, 2017.
- He, M., Zheng, J. Y., Yin, S. S., and Zhang, Y. Y.: Trends, temporal and spatial characteristics, and uncertainties in biomass burning emissions in the Pearl River Delta, China, *Atmospheric Environment*, 45, 4051-4059, 2011.
- Li, C., Jens, B., Zheng, J. Y., Yuan, Z. B., Ou, J. M., Li, Y., Wang, Y. L., and Xu, Y. Q.: Decadal evolution of ship emissions in China from 2004 to 2013 by using an integrated AIS-based approach and projection to 2040, *Atmo. Chem. Phys.*, 18, 6075-6093, doi: 10.5194/acp-18-6075-2018, 2018.
- Li and Fung Centre Research.: China's industry relocation and upgrading Trends: implications for sourcing business, *China Distribution & Trading*, 56, 2008..
- Li, X. H., Wang, S. X., Lei, D., Hao, J. M., Chao, L., Chen, Y. S., and Liu, Y.: Particulate and trace gas emissions from open burning of wheat straw and corn stover in China, *Environ Sci Technol.*, 41, 6052, 2007.
- Pan, Y. Y., Li, N., Zheng, J. Y., Yin, S. S., Li, C., Yang, J., Zhong, L. J., Chen, D. H., Deng, S. X., and Wang, S. S.: Emission inventory and characteristics of anthropogenic air pollutant sources in Guangdong Province, *Acta Scientiae Circumstantiae*, 59, 133-135, 2015.
- Peng, K., Yang, Y., Zheng, J. Y., Yin, S. S., Gao, Z., and Huang, X.: Emission factor and inventory of paved road fugitive dust sources in the Pearl River Delta region, *Acta Scientiae Circumstantiae*, 33, 2657-2663, 2013.
- Shen, X. L., Yin, S. S., Zheng, J. Y., Lu, Q., and Zhong, L. J.: Anthropogenic ammonia emission inventory and its mitigation potential in Guangdong Province, *Acta Scientiae Circumstantiae*, 34, 43-53, 2014.
- Shen, X. L.: A highly resolved anthropogenic ammonia emission inventory in Guangdong Province and assessment of control strategies, South China University of Technology, Guangzhou, China, 2014. (A thesis for the degree of master).
- Tian, H. Z.: Studies on Present and Future Emissions of Nitrogen Oxides and Its Comprehensive Control Policies in China, Tsinghua University, Beijing, China, 2003. (A thesis for the degree of master).
- Yang, Y.: Character, Level and Regulatory Measures Study of Fugitive Dust Emissions from Building Construction Sites in PRD, South China University of Technology, Guangzhou, China, 2014. (A thesis for the degree of. Thesis).
- Zhang, L. J., Zheng, J. Y., Yin, S. S., Peng, K., and Zhong, L. J.: Development of non-road mobile source emission inventory for the Pearl River Delta region, *Acta Scientiae Circumstantiae*, 31, 886, 2010.
- Zhang, Q.: 2005. Study on Regional Fine PM Emissions and Modeling in China, Tsinghua University, Beijing, China, 2015. (A thesis for the degree of doctor).
- Zhang, Q., Streets, D. G., He, K. B., Wang, Y. X., Richter, A., Burrows, J. P., Uno, I., Jang, C.

- 
- J., Chen, D., Yao, Z. L., and Lei, Y.: NO<sub>x</sub> emission trends for China, 1995-2004: The view from the ground and the view from space, *Journal of Geophysical Research Atmospheres*, 112, D22306, 2007.
- Zhang, Y., Shao, M., Lin, Y., Luan, S., Mao, N., Chen, W., and Wang, M.: Emission inventory of carbonaceous pollutants from biomass burning in the Pearl River Delta Region, China, *Atmospheric Environment*, 76, 189-199, 2013..
- Zhao, B., and Ma, J. Z.: Development of an air pollutant emission inventory for Tianjin, *Acta Scientiae Circumstantiae*, 2008.
- Zhao, Y., Wang, S. X., Nielsen, C. P., Li, X. H., and Hao, J. M.: Establishment of a database of emission factors for atmospheric pollutants from Chinese coal-fired power plants, *Atmospheric Environment*, 44, 1515-1523, 2010.
- Zheng, J. Y., Zhang, L. J., Che, W. W., Zheng, Z. Y., and Yin, S. S.: A highly resolved temporal and spatial air pollutant emission inventory for the Pearl River Delta region, China and its uncertainty assessment, *Atmospheric Environment*, 43, 5112-5122, 2009.