Global Burden of Disease – Major Air Pollution Sources (GBD – MAPS)

Estimates of emissions and PM$_{2.5}$ levels from Major Sources in China

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Background: All causes attributable to ambient PM pollution in 2013, DALYs per 100,000
Major Sources of air pollution in China

- Air pollutant emission has a close relation with coal combustion (left)
- Coal combustion is a dominant source of ambient PM$_{2.5}$ (right)
Technology Roadmap

1. Activity data → Emission factors → Control measures → Base year emission
2. Projection of driving forces → Projection of energy demand → Assumption of energy technology mix → Assumption of control measures → Emission for future scenarios
3. Gridded inventory for base year → Standard simulation for base year → Model validation
4. Emission inventory for base year without coal burning → Sensitivity simulation → Analysis of the contribution for base year
5. Gridded future inventory → Future emission inventories without coal burning → Sensitivity simulation → Analysis of the difference and contribution for future scenarios
6. Standard simulation for future scenarios
Emissions in base year

Specious:
- SO₂
- NOₓ
- PM
- VOCs

Sectors:
- Powerplant combustion
- Industry combustion
- Industry process
- Domestic fossil fuel
- Domestic biofuel
- Traffic
- Open burning
- Solvent use

Future emissions from different sources

In the year of 2013, coal is responsible for 75% of the SO₂ emissions, 54% of the NOₓ emissions, 40% of the primary PM₁₀ emissions, and 35% of the primary PM₂.₅ emissions.
## Future scenarios

<table>
<thead>
<tr>
<th>Energy scenario</th>
<th>Description</th>
<th>Emission scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business as usual (BAU)</td>
<td>Current legislation &amp; implementation status (to end of 2013)</td>
<td>BAU[1]</td>
<td>BAU energy policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End-of-pipe control strategy:</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Based on “12th Five-Year Plan for Environmental Protection”; New emission</td>
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<td></td>
<td></td>
<td></td>
<td>standards released during 2011-2013; progressively strengthened control</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>policies afterwards.</td>
</tr>
<tr>
<td>Business as usual (BAU)</td>
<td></td>
<td>BAU[2]</td>
<td>BAU energy policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End-of-pipe control strategy:</td>
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<td></td>
<td></td>
<td></td>
<td>full implementation of technically feasible control technologies by 2030,</td>
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<tr>
<td></td>
<td></td>
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<td>regardless of cost</td>
</tr>
<tr>
<td>Alternative policy (PC)</td>
<td>New stringently enforced energy-policies including life style changes,</td>
<td>PC[1]</td>
<td>PC energy policy</td>
</tr>
<tr>
<td></td>
<td>structural adjustment &amp; efficiency improvements.</td>
<td></td>
<td>Same end-of-pipe control strategy as BAU[1]</td>
</tr>
<tr>
<td>Alternative policy (PC)</td>
<td></td>
<td>PC[2]</td>
<td>PC energy policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Same end-of-pipe control strategy as BAU[2]</td>
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<tr>
<td></td>
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<td>Maximum feasible reductions of emissions</td>
</tr>
</tbody>
</table>
### Future emissions

<table>
<thead>
<tr>
<th></th>
<th>2013</th>
<th>BAU1</th>
<th>BAU2</th>
<th>PC1</th>
<th>PC2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
<td>23.0</td>
<td>29.7</td>
<td>18.1</td>
<td>19.0</td>
<td>11.5</td>
</tr>
<tr>
<td>NO$_X$</td>
<td>25.6</td>
<td>26.1</td>
<td>17.3</td>
<td>18.7</td>
<td>12.4</td>
</tr>
<tr>
<td>PM</td>
<td>26.0</td>
<td>24.9</td>
<td>16.4</td>
<td>18.3</td>
<td>11.5</td>
</tr>
<tr>
<td>VOCs</td>
<td>24.0</td>
<td>29.0</td>
<td>19.6</td>
<td>24.1</td>
<td>16.1</td>
</tr>
</tbody>
</table>

- Emissions in BAU1 increased compared to those in 2013 except for SO$_2$;
- Emissions in PC2 decreased by around 50%;
- Emissions in BAU2 and PC1 are comparable.
**GEOS-Chem model**

**Region:**
Nested domain for Asia (70°-150°E, -10°-55°N)

**Resolution:**
Horizontal resolution: 0.5 latitude by 0.667 longitude
47 vertical layers up to 0.01 hPa

**Met fields:**
GEOS-5 assimilated meteorological fields from the
Goddard Earth Observing System of the NASA
Global Modeling Assimilation Office

**Boundary fields:**
Tracer concentrations at the lateral boundaries are provided by a global GEOS-Chem simulation at 4 latitude by 5 longitude horizontal resolution and updated in the nested-grid model every 3 h.
Simulated percentage contributions in the base year (2013) from coal burning

**Total coal**
- Sichuan Basin: 50.19%;
- Inner mongolia: more than 50%
- More coal in middle west, backward technology…

**Power plant coal**
- North China Plain: 12.04%, larger number of power plants
- Xinjiang: few other sources

**Industrial coal**
- Sichuan Basin: 25.91%;
- North China Plain and Middle Yangtze River: 16.77% and 20.47%

**Domestic coal**
- Inner mongolia: 25%, large amount of raw coal burning
- Guizhou: 15%, high sulfur content

### Contributions from coal burning in

<table>
<thead>
<tr>
<th></th>
<th>Mean PM$_{2.5}$</th>
<th>Total coal burning</th>
<th>Power plant</th>
<th>Industry</th>
<th>Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Average*</td>
<td>56.7</td>
<td>22.5 (39.6%)</td>
<td>5.6 (9.8%)</td>
<td>9.6 (17.0%)</td>
<td>2.2 (4.0%)</td>
</tr>
</tbody>
</table>
Seasonal variation of coal burning contribution

<table>
<thead>
<tr>
<th></th>
<th>Mean PM$_{2.5}$</th>
<th>Total coal burning contributions</th>
<th>Contributions from coal burning in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Power plant</td>
</tr>
<tr>
<td>Winter</td>
<td>79.6</td>
<td>28.2</td>
<td>6.3</td>
</tr>
<tr>
<td>Summer</td>
<td>38.4</td>
<td>17.8</td>
<td>5.2</td>
</tr>
</tbody>
</table>
Coal burning contribution in future scenarios

Absolute contributions in 2030

Percentage contributions in 2030
Conclusions

• Coal combustion contributes 40% of ambient PM$_{2.5}$ concentration; Industrial coal: 17%, Powerplants: 10%, residential: 4%. Coal burning (especially industrial coal burning) should be prioritized in policies

• While absolute contributions of sources including coal burning in power plants and industry remain at a relatively constant level throughout the year, the percentage contribution almost doubles from winter to summer, due to a larger reduction of emissions from non-coal sources including transportation and biomass burning.

• PM$_{2.5}$ levels and absolute contributions from major sources decrease in all future scenarios, as energy policies and emission control strategies is applied.

• Although absolute contribution decreases in the future, coal (especially industrial coal burning) remains as the single largest contributor and the proportion increases despite the effort toward emission reduction. Urgent need for even more aggressive strategies to reduce emissions from coal combustion (and other sectors).
GBD-MAPS general methodology

- Estimate coal combustion/major source contribution to ambient PM$_{2.5}$
- Calculate fraction ambient PM$_{2.5}$ attributable to each source

- $f_{\text{coal}} \times \text{ambient PM}_{2.5} \rightarrow \text{ambient PM}_{2.5}$ attributable to each source

- Use integrated exposure response functions and cause-specific mortality estimates in combination with PM$_{2.5}$ coal $\rightarrow$ source contribution to disease burden
GBD-MAPS general methodology

- Estimate coal combustion/major source contribution to ambient PM$_{2.5}$
- Calculate fraction ambient PM$_{2.5}$ attributable to each source

\[ f_{\text{coal}} \cdot \text{PM}_\text{coal} \to \text{ambient PM}_\text{coal} \to \text{ambient PM}_\text{coal} \text{ attributable to each source} \]

- Use integrated exposure response functions and cause-specific mortality estimates in combination with PM$_{2.5}$ coal \to source contribution to disease burden
2. Estimating ambient PM$_{2.5}$ attributable to coal combustion

- Final estimates based on average of (1.4 million) grid cell values (SAT, TM5) and calibrated (regression model) with measurements
  - 0.1° x 0.1° resolution
  - extrapolated to 2013 using 2010-2011 trend in SAT
- Incorporate variance between two estimates and measurements in uncertainty assessment
- Unique contributions from each approach

Brauer et al., 2015
GBD-MAPS general methodology

- Estimate coal combustion/major source contribution to ambient PM$_{2.5}$
- Calculate fraction ambient PM$_{2.5}$ attributable to each source

\[ f_{\text{coal}} \]

\[ \text{PM}_{2.5} \text{ coal} \]

- \[ f_{\text{coal}} \times \text{ambient PM}_{2.5} \rightarrow \text{ambient PM}_{2.5} \text{ attributable to each source} \]

\[ \text{Disease Burden} \]

- Use integrated exposure response functions and cause-specific mortality estimates in combination with \( \text{PM}_{2.5} \text{ coal} \rightarrow \text{source contribution to disease burden} \)
3. Integrated Exposure-Response Functions

Forouzanfar et al. 2015; Burnett et al. 2014
GBD-MAPS general methodology

- Estimate coal combustion/major source contribution to ambient $\text{PM}_{2.5}$
- Calculate fraction ambient $\text{PM}_{2.5}$ attributable to each source

\[ f_{\text{coal}} \]

$\text{PM}_{2.5} \text{coal}$

- $f_{\text{coal}} \times \text{ambient } \text{PM}_{2.5} \rightarrow \text{ambient } \text{PM}_{2.5} \text{ attributable to each source}$

Disease Burden

- Use integrated exposure response functions and cause-specific mortality estimates in combination with $\text{PM}_{2.5} \text{coal} \rightarrow \text{source contribution to disease burden}$
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