Modelling PM$_{2.5}$ Concentrations for the UK and Projections to 2020

John Stedman, Susannah Grice, Sally Cooke & Andrew Kent
Outline

- Introduction
- Overall method
- Recent years results
- Source apportionment results
- Projections and calculation method
- Other results
Introduction

• Pollution Climate Mapping (PCM) Model
• UK model developed within a Geographical Information System (GIS)
• PCM model used to provide maps of PM$_{2.5}$ concentration for 2005, 2006 and 2007
• Used to supply data for assessments required by EU ambient air quality directives
• Maps of future projections up to 2020 (with 2005 as a base year) used to underpin the development of UK air quality policy
Method

- Components of PM$_{2.5}$
  - Secondary inorganic aerosol
  - Secondary organic aerosol
  - Large point sources of primary particles
  - Small point sources of primary particles
  - Area sources of primary particles
  - Regional primary particles
  - Iron & calcium rich dusts
  - Sea salt
Method

• Secondary aerosol
  ➢ Secondary inorganic aerosol
    • Interpolation & scaling of rural sulphate, nitrate & ammonium measurements
    • Scaling factors used to take into account bound water & counter ions & to apportion PM fractions
  ➢ Secondary organic aerosol
    • Semi-volatile organic compounds
    • Estimated from results from the HARM/ELMO model
Method

- **Primary particulate matter**
  - Emissions estimates from the UK NAEI
  - Large point sources
    - Emissions > 500 tonnes per year
    - Modelled explicitly using ADMS
  - Small point sources
    - Emissions < 500 tonnes per year
    - Estimated using a generic model derived using ADMS
  - Area sources
    - 1km x 1km grid squares
    - Local area source contribution estimated using a dispersion kernel based model derived using ADMS
      - calibrated using monitoring data
    - Regional background estimated using TRACK
      - Emissions estimates from NAEI & EMEP
Method

• **Iron and calcium rich dusts**
  - Estimated from measurements made in Birmingham
  - Using surrogate variables for spatial distribution of emissions
    • Vehicle movements & population
  - Additional urban increment

• **Sea salt**
  - Derived by interpolation of chloride measurements at 28 rural sites
    • Scaled to take account of sodium counter ion
Method

- Calculation of fine fraction of PM

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage of total that is fine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary organic aerosol</td>
<td>75%</td>
</tr>
<tr>
<td>Secondary inorganic aerosol</td>
<td></td>
</tr>
<tr>
<td>Ammonium</td>
<td>95%</td>
</tr>
<tr>
<td>Sulphate</td>
<td>95%</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>55%</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>25%</td>
</tr>
<tr>
<td>Calcium rich dusts</td>
<td>25%</td>
</tr>
<tr>
<td>Iron rich dusts</td>
<td>25%</td>
</tr>
<tr>
<td>Sea salt</td>
<td>25%</td>
</tr>
</tbody>
</table>

Primary PM$_{2.5}$ is calculated separately by NAEI
Method

• Maps calculated on a 1 km x 1 km grid for the whole of the UK land area

• Monitoring data
  ➢ From UK national monitoring networks
    • Few PM\(_{2.5}\) sites up to 2008
    • 64 sites from 2009 onwards as required for compliance with CAFÉ Directive

• Model calibration and verification
  ➢ Using ambient monitoring data
  ➢ Measurements of PM\(_{10}\) and PM\(_{2.5}\) from Partisol 2025 gravimetric instruments (Range of measurement methods for PM\(_{10}\) verification)
  ➢ Corrected for field blanks
Results - Maps for 2005, 2006 and 2007

- Mapped annual mean background PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)
- Mapped annual mean background PM$_{2.5}$ concentrations in 2006 (µg m$^{-3}$)
- Mapped annual mean background PM$_{2.5}$ concentrations in 2007 (µg m$^{-3}$)
Results – Source Apportionment

- UK Population-weighted annual mean PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary PM</td>
<td>2.72</td>
</tr>
<tr>
<td>Secondary PM</td>
<td>7.10</td>
</tr>
<tr>
<td>Iron &amp; calcium rich dusts</td>
<td>0.87</td>
</tr>
<tr>
<td>Sea salt</td>
<td>0.50</td>
</tr>
<tr>
<td>Total</td>
<td>11.19</td>
</tr>
</tbody>
</table>
Results – Source Apportionment

- Primary PM contributions to mapped annual mean background PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)
- Secondary PM contributions to mapped annual mean background PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)
Results – Source Apportionment

- Iron & calcium rich dust contribution to mapped annual mean background PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)
- Sea salt contribution to mapped annual mean background PM$_{2.5}$ concentrations in 2005 (µg m$^{-3}$)
Method - Projections

- Projections of concentration to 2020
  - Maps of PM$_{2.5}$ concentration in 2010, 2015 & 2020 have been calculated for the baseline scenario
  - Primary PM from NAEI
  - Secondary inorganic aerosol, precursor emissions from EMEP
  - Secondary organic aerosol, iron & calcium rich dusts and sea salt assumed to remain unchanged from 2005

- Future impacts of potential measures
  - Can be modelled using PCM
  - No alternative scenarios presented here
Method - Calculations

- Concentrations
  - Number of exceeding zones

- Exposure Concentration Obligations
  - Based on modelled results at urban background & urban centre sites measuring PM$_{10}$ in 2005

- Exposure Reduction Targets
  - For agglomerations > 100,000 population
  - Population-weighted means

\[
\sum (1\, \text{km} \times 1\, \text{km} \text{ background maps}) \times (1\, \text{km} \times 1\, \text{km} \text{ population stats}) \\
\text{Total population}
\]

- Population data from 2001 census
Results – Projections to 2020

- Mapped annual mean background PM$_{2.5}$ concentrations in 2005 ($\mu g \cdot m^{-3}$)
- Mapped annual mean background PM$_{2.5}$ concentrations in 2010 ($\mu g \cdot m^{-3}$)
- Mapped annual mean background PM$_{2.5}$ concentrations in 2020 ($\mu g \cdot m^{-3}$)
**Results**

- **Number of exceeding zones (out of total of 43 for UK)**

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>&gt;20 ug m(^{-3})</strong> <em>(indicative L.V. 2020)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roadside</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>&gt;25 ug m(^{-3})</strong> <em>(T.V. 2010, L.V. 2015)</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Background</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Roadside</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Results

- Exposure Concentration Obligation (ug m\(^{-3}\))

<table>
<thead>
<tr>
<th>Annual Exposure Indicator</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12.3</td>
<td>11.2</td>
<td>10.7</td>
<td>10.4</td>
</tr>
</tbody>
</table>
Results

- Exposure Reduction Target

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (ug m⁻³)</td>
<td>12.33</td>
<td>11.32</td>
<td>10.84</td>
<td>10.60</td>
</tr>
<tr>
<td>2010-2020 ER (Target = -10%)</td>
<td></td>
<td></td>
<td></td>
<td>-6.35%</td>
</tr>
</tbody>
</table>
Acknowledgements

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  - UK Department for Environment, Food & Rural Affairs
  - Welsh Assembly Government
  - The Scottish Executive
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