ADMS-Urban nested within regional models: an air quality model for all scales

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ADMS-Urban Model Capabilities

- ADMS-Urban is designed to model dispersion from a wide range of urban sources
- Gaussian type model with point, line area, road and grid sources; non-Gaussian vertical profile of concentration in convective conditions
- Concentration calculated at high resolution (<10m)
- Fully integrated street canyon model based on OSPM
- Options for different chemical mechanisms; considers effects of complex terrain
- Integration with Geographical Information Systems (GIS) and an Emissions Inventory Database (EMIT)
- Used in many major cities for air quality management: e.g. London, Dublin, Budapest, Rome, Beijing, Shanghai, Singapore
ADMS-Urban examples

London: Modelled annual average NO2: 2001 & 2010 (DEFRA)

Beijing: AQ Forecasting

Singapore: AQ Assessment (NEA)
Nesting local model (ADMS-Urban) within regional model: motivation

- Why nest a local model within a regional model?
- What are the advantages of a **nested model**?

<table>
<thead>
<tr>
<th>Model feature</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regional (eg grid based)</td>
</tr>
<tr>
<td>Domain extent</td>
<td><strong>Country</strong> (few 1000 km)</td>
</tr>
<tr>
<td>Meteorology</td>
<td><strong>Spatially and temporally varying from meso scale models</strong></td>
</tr>
<tr>
<td>Dispersion in low wind speed conditions</td>
<td><strong>Models stagnated flows correctly</strong></td>
</tr>
<tr>
<td>Deposition and chemical processes</td>
<td><strong>Reactions over large spatial and temporal scales</strong></td>
</tr>
<tr>
<td>Source resolution</td>
<td>Low</td>
</tr>
<tr>
<td>Validity</td>
<td>Background receptors</td>
</tr>
</tbody>
</table>
Regional model/ADMS-Urban nesting system

- **Aim:** to nest local model in regional model without double counting emissions:

\[
\text{Concentration within nested domain} = \text{Regional modelling of emissions (all time)} - \text{Gridded locally modelled emissions (ΔT)} + \text{Explicit locally modelled emissions (ΔT)}
\]

- ΔT is time for pollutants to be well mixed on grid scale
## Regional model/ADMS-Urban nesting implementations

<table>
<thead>
<tr>
<th>Regional model</th>
<th>Name</th>
<th>Met</th>
<th>Domains modelled</th>
<th>Resolution (km x km)</th>
<th>ADMS-Urban nested domain</th>
<th>No. of receptors</th>
<th>AQD pollutants modelled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CMAQ</td>
<td>MM5</td>
<td>SE England</td>
<td>3 x 3</td>
<td>9 x 9 km², centred on central London</td>
<td>17</td>
<td>NOₓ, NO₂, O₃</td>
</tr>
<tr>
<td></td>
<td>EMEP4UK</td>
<td>WRF</td>
<td>Europe</td>
<td>50 x 50</td>
<td>4 (5 x 5) km², centred on central London</td>
<td>19</td>
<td>NOₓ, NO₂, O₃, PM₁₀, PM₂.₅, SO₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UK</td>
<td>5 x 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Scotland</td>
<td>1 x 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CMAQ</td>
<td>WRF</td>
<td>Europe</td>
<td>27 x 27</td>
<td>81 (1 x 1) km², centred on central London</td>
<td>17</td>
<td>NOₓ, NO₂, O₃, PM₁₀, PM₂.₅, SO₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>UK</td>
<td>9 x 9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Southern England</td>
<td>3 x 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>London</td>
<td>1 x 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CMAQ</td>
<td>WRF/MM5</td>
<td>Hong Kong</td>
<td>1 x 1</td>
<td></td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Preliminary modelling Model set up: NO$_2$ emissions

- CMAQ
- ADMS explicit
- 9km

**NO$_2$ t/year/km$^2$**

- $0 - 1$
- $1 - 3$
- $3 - 5$
- $5 - 10$
- $10 - 13$
- $13 - 15$
- $15 - 18$
- $18 - 20$
- $20 - 25$
- $25 - 40$

CERC
CMAQ (Preliminary modelling)
Model results: receptors – NO₂

Roadside and Kerbside

<table>
<thead>
<tr>
<th>Model</th>
<th>Monitored NO₂ (μg/m³)</th>
<th>0</th>
<th>50</th>
<th>100</th>
<th>150</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADMS nested</td>
<td></td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>ADMS only</td>
<td></td>
<td>0</td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>CMAQ</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Background

<table>
<thead>
<tr>
<th>Model</th>
<th>Monitored NO₂ (μg/m³)</th>
<th>0</th>
<th>20</th>
<th>40</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADMS nested</td>
<td></td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
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<tr>
<td>CMAQ</td>
<td></td>
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<td></td>
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</tbody>
</table>

(Summer)
EMEP4UK (Full implementation)
Model results: receptors – $O_3$ and $PM_{10}$

O$_3$

Measured $O_3$ ($\mu g/m^3$)

Modelled $O_3$ ($\mu g/m^3$)

- ADMS nested
- ADMS only
- EMEP4UK

PM$_{10}$

Measured $PM_{10}$ ($\mu g/m^3$)

Modelled $PM_{10}$ ($\mu g/m^3$)

- ADMS nested
- ADMS only
- EMEP4UK

(All sites)
CMAQ (Preliminary modelling)
Model results: NO$_2$ average contours

- **CMAQ outer domain**
- **ADMS-Urban nested domain**
- **Consistency of background concentrations**
- **9km**
- **1km**

**NO$_2$ µg/m$^3$**

- 4-15
- 15-25
- 25-35
- 35-45
- 45-55
- 55-65
- 65-75
- 75-95
- 95-150
HKUST CMAQ/CAMx Modelling for Hong Kong; ADMS-Urban to be nested within this.
London Model Inter-comparison Study: Annual Average NO$_2$

- NO$_2$
Pollution roses at Marylebone Road, London: NO$_x$ and NO$_2$

**Marylebone Road 2008:** road width 22m, canyon height 20m

<table>
<thead>
<tr>
<th>ADMS/OSPM Calculated NO$_x$</th>
<th>Monitored NO$_x$</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
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<tr>
<th>ADMS/OSPM Calculated NO$_2$</th>
<th>Monitored NO$_2$</th>
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<tr>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
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New Canyon Model

- Well mixed recirculating region
- Flow/turbulence within canyon has dependence on height and width; allows for high aspect ratio
- Can consider pavements and road lanes
- One-sided/asymmetric canyons
- Channelling of flow along canyon

Urban profiles of mean flow and turbulence
Discussion

• Nesting a model with explicit source representation and street scale spatial resolution (e.g. ADMS-Urban within a regional model (e.g. CMAQ, CAMx, EMEP) allows the full range of relevant scales to be considered within one modelling system

• This approach allows for modelling of:
  – chemical reactions over large and small temporal and spatial scales
  – spatially varying meteorology
  – low wind conditions
  – local modelling (street canyons, noise barriers, cuttings etc)

• The system allows for model validation at all sites: background, roadside and kerbside

• A revised street canyon model is being developed to allow for asymmetric canyons and those of high aspect ratio; it will take account of current knowledge of flow in urban areas.