Using Air Quality Modelling to Improve Air Emission Inventories

A. Monteiro, C. Borrego, A. I. Miranda
CESAM, Departamento de Ambiente, Universidade de Aveiro

V. Gois, P. Torres, A.T. Perez
Portuguese Agency for the Environment, Lisbon, Portugal
Objective

to evaluate the available emission inventories for Portugal through air quality modelling application/validation
to identify weakness and strengthens and the key sources of uncertainty that can be targeted for reduction via additional data collection and research.
air quality modelling applications with **MM5-CHIMERE** model system using three emissions inventories for Portugal **INERPA, EMEP, LOTOS**

And also testing the…

different **values and resolution of the three inventories**

further **spatial disaggregation**

different **temporal profiles** used for time disaggregation.
Use of Air Emission Inventories

- Verify compliance of national and international obligations.
  - CLRTAP
  - UNFCCC and its subsidiary Kyoto Protocol;
  - Stockholm Convention on Persistent Organic Pollutants (POP);
  - UE’s Directive of National Ceilings

- Modelling of pollutant dispersal and deposition;

- Establishment of baseline scenarios for the identification and definition of policies and measures.
Spatial Emission Inventories in Portugal

- **INERPA**
  - APA – Portuguese Agency for the Environment
  - National Official Inventory (CLRTAP, UNFCCC)
  - Gridded data for EMEP (50x50 km)
  - Municipality + LPS disaggregation for National (e.g. EIA)

- **EMEP/EXPERT data**
  - National submission with some corrections
  - EXPERT DB (Internet), June 2006. (MSC-W)
  - Cover Europe (0.5° x 0.5° long-lat)

- **LOTOS**
  - TNO emission DB and baseline for 2000
  - resolution: 0.25° x 0.125° long-lat (about 15 x 15 km2)
  - EF PM from CEPMEIP
the modelling system

meteorological model
MM5

boundary conditions
climatological model
GOCART

emissions
anthropogenic
biogenic

CHIMERE

gaseous chemistry
44 species, 116 reactions

transport
horizontal (PPM)
vertical diffusion

aerosols module

gas deposition/aerosols
dry
wet

pollutants concentration
gases/aerosols

pollutants deposition
gases/aerosols
## Motivation

<table>
<thead>
<tr>
<th>Model input category</th>
<th>Input variable</th>
<th>Uncertainty range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial conditions</td>
<td>$O_3$ concentration</td>
<td>Factor of 3</td>
</tr>
<tr>
<td></td>
<td>NOx or VOC concentration</td>
<td>Factor of 5</td>
</tr>
<tr>
<td>Boundary conditions</td>
<td>$O_3$ concentration aloft or at side</td>
<td>Factor of 1.5</td>
</tr>
<tr>
<td></td>
<td>NOx or VOC concentration aloft or at side</td>
<td>Factor of 3</td>
</tr>
<tr>
<td>Meteorology</td>
<td>Wind speed</td>
<td>Factor of 1.5</td>
</tr>
<tr>
<td></td>
<td>Wind direction</td>
<td>+/- 40 degrees</td>
</tr>
<tr>
<td></td>
<td>Air temperature</td>
<td>+/- 3 K</td>
</tr>
<tr>
<td></td>
<td>Relative humidity</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>Daytime vertical diffusivity below 1000 meters</td>
<td>Factor of 1.3</td>
</tr>
<tr>
<td></td>
<td>Nighttime vertical diffusivity</td>
<td>Factor of 3</td>
</tr>
<tr>
<td></td>
<td>Rainfall amount</td>
<td>Factor of 2</td>
</tr>
<tr>
<td></td>
<td>Cloud cover</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>Cloud liquid water content</td>
<td>Factor of 2</td>
</tr>
<tr>
<td>Emissions</td>
<td>Major point source NOx or VOC</td>
<td>Factor of 1.5</td>
</tr>
<tr>
<td></td>
<td>All other emissions estimates</td>
<td>Factor of 2</td>
</tr>
<tr>
<td>Photolysis rates</td>
<td>Six reactions</td>
<td>Factor of 2</td>
</tr>
<tr>
<td>CBIV chemical mechanism</td>
<td>Chemical reactions</td>
<td>Factors from 1.17-2.5</td>
</tr>
</tbody>
</table>

Source: Hanna et al., 2001
Emission inventories

Totals

Major differences were obtained for LOTOS database: 20-30% lower than EMEP and INERPA PM emissions: 50%!

Similar EMEP and INERPA
INERPA is the officially reported EMEP - correction/revision made by EMEP experts

Analysis by pollutant activity shows
That major discrepancies between inventories are registered for road transport (more than 30%)
Emissions inventory
spatial distribution

INERPA

LOTOS

EMEP

NOx road transport (t.year.km^-2)

0 - 1
1 - 5
5 - 10
10 - 50
50 - 100

NOx road transport emissions

0 - 1
1 - 5
5 - 10
10 - 50
50 - 100

NOx road transport (t.year.km^-2)
1st simulation European domain

**Period**
2004 summer (1 May – 31 September)

**Boundary conditions**
GOCART climatological model

**Emissions**
EMEP inventory

**Vertical structure**
8 layers (50, 250, 600, 1200, 2000, …5000 m)

Model simulation
Model simulation

2nd simulation PORTUGAL domain
Model simulation

2nd simulation PORTUGAL domain

Boundary conditions
outputs 50x50 km

Emissions
EMEP, LOTOS, INERPA

10x10 km

290 km
Comparison of Emission Inventories
sensitivity tests

Road transport PM$_{10}$ emissions
Model grid 10x10 km$^2$

INERPA
LOTOS
EMEP
Air quality monitoring network
Model validation

O₃

PM₁₀

- background 22
- industrial 6
- traffic 11

Σ 39

- background 12
- industrial 5
- traffic 14

Σ 31
Indicators

$$\text{RMSE} = \frac{1}{N} \sum_{i} |(M_i - O_i)|$$

$$\text{bias} = \frac{1}{N} \sum_{i} (M_i - O_i)$$
Comparison of Emission Inventories

O$_3$ model results

- Overall tendency for emissions underestimation emphasised by the point sources omission

- More notorious with the LOTOS inventory, and less with INERPA on average, less systematic errors.
Comparison of Emission Inventories

O$_3$ model results

no significant discrepancies between the three emission inventories ->

higher resolution in the emission inventory do not mean necessarily better model performance
Comparison of Emission Inventories

PM$_{10}$ model results

The range of uncertainty varies with locals and pollutants
There is probably a specific PM emissions overestimation by INERPA inventory...
Two different levels of spatial disaggregation were tested using INERPA inventory:

- Original municipality estimates (APA)
- Further disaggregation to sub-municipality degree
Spatial Disaggregation of Emissions results

Further spatial disaggregation performed introduced more errors to the emission inventory, specially for the urban area and $O_3$. 

- For $O_3$, the biases at the sub-municipality and municipality levels are shown in the graphs.
- Similarly, for PM$_{10}$, the RMSE and BIAS are depicted for each level.

These graphs illustrate the performance of the emission inventory at different spatial resolutions, highlighting the impact of further spatial disaggregation.
Temporal Disaggregation of Emissions
sensitivity test

2 Different Hourly Profiles were tested with the INERPA inventory

- Nacional profile measured by field campaigns
- European profile european average profile
Temporal Disaggregation of Emissions results

road traffic temporal profiles shows influence on the air quality results, in both traffic and urban stations the Portuguese average profile is more adequate for these specific areas
Comparison of Emission Inventories

PM$_{10}$ model results

- LEÇA daily average
- LARANJEBRO daily average

PM emissions overestimation in Porto region
Final comments

Analysis of model results provided clues for improving emission inventories!

Spatial disaggregation of an emission inventory should be performed carefully, otherwise could be an additional source of uncertainty.

There are no significant discrepancies between the direct applications of the three emission inventories, indicating that higher resolution in the emission inventory do not mean necessarily better model performance.

Road traffic temporal profiles have influence on the air quality results, mainly regarding traffic hot spots and urban areas.

The range of uncertainty varies with locals and pollutants. It was found an overestimation of PM values for Porto agglomeration, which can be related to a less correct emission estimation and spatial disaggregation for this specific region of Portugal.

Globally, is the national inventory (INERPA) application that implies the lowest bias.
Future work

Future work will involve testing this methodology with other air quality modelling systems and analysing each emission source category.

The development and assessment of an emission inventory ensemble will also be the focus of future work.
Thank You