Air pollution forecast in Portugal: a demand from the new air quality framework directive

A. Monteiro, C. Borrego, A. I. Miranda
Universidade de Aveiro, Portugal
R. Vautard
Ecole Polytechnique, Palaiseau, France

9th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
Garmisch-Partenkirchen, Germany
June 1-4, 2004
Why air quality forecasting?

"COUNCIL DIRECTIVE 96/62/CE of 27 September 1996 on ambiente air quality assessment and management"

Article 1.º Objectives

The general aim of this Directive is to define the basic principles of a common strategy to:

- define and establish objectives for ambient air quality in the Community designed to avoid, prevent or reduce harmful effects on human health and the environment as a whole,

- assess the ambient air quality in Member States on the basis of common methods and criteria,

- obtain adequate information on ambient air quality and ensure that it is made available to the public, inter alia by means of alert thresholds,

- maintain ambient air quality where it is good and improve it in other cases.
Why this work?

There is a need to develop an air quality forecasting programme for Portugal, like it exist in many European countries...

A numerical system was chosen to performed this task, and a test application in real time was performed last summer...
The forecasting system

**Meteorology**
- AVN/ NCEP global forecasts
- MM5 Mesoscale meteorological model
- Meteorological forecast (3 days):
  - Wind velocity
  - Temperature
  - Surface pressure
  - Specific humidity
  - Heat fluxes
  - Precipitation
  - ...

**Photochemistry**
- EMISSIONS
- CHIMERE Chemistry-transport model
- OZONE forecast (3 days):
  - http://euler.lmd.polytechnique.fr/ portugal/
The forecasting system application

1st continental scale run (coarse domain)

Time period: June - September 2003

Boundary conditions: MOZART climatological model

Emissions: EMEP inventory

Vertical structure: 6 levels (50, 250, 600, 1200, 2000, 3000 m)

Map: 50x50 km, 10.5W to 22.5E, 35N to 57.5N
The forecasting system application

2nd nested run PORTUGAL domain

“simple one-way technique”
The forecasting system application

2nd nested run PORTUGAL domain

Boundary conditions
Coarse run outputs 50x50 km

Emissions
National “top-down” approach

10x10 km
290 km

9th Harmonisation Conference
The forecasting system validation

Air Quality National network

- **background** stations: 23
- **industrial** stations: 5
- **traffic** stations: 17

\[ \sum 45 \]
The forecasting system validation

O₃ exceedances in 2003

|   | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | Total |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Jan | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Fev | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Mar | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Abr | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Mai | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 7 |
| Jun | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 16 |
| Jul | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 2  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 18 |
| Ago | 58 | 0  | 0  | 0  | 0  | 0  | 1  | 6  | 28 | 28 | 2  | 11 | 14 | 3  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 172 |
| Set | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 4  | 6  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 13 |
| Out | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Nov | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |
| Dez | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0 |

Source: Instituto do Ambiente 2003
### STATION  |  O$_3$ µg.m$^{-3}$
---|---
Paio Pires | 187,0
Paio Pires | 183,5
Arcos | 195,0
Arcos | 207,5
Arcos | 194,5
Chamusca | 203,8
Chamusca | 225,4
Chamusca | 205,7
Monte Velho | 182,5
Monte Velho | 180,5
Sonega | 192,3
Ermesinde

Station | $\text{O}_3$ ($\mu g/m^3$) \\
---|---
Ermesinde | 188.1
The forecasting system validation

Daily peak ozone forecast

- Desvio padrão (µg.m\(^{-3}\))

<table>
<thead>
<tr>
<th></th>
<th>D-1</th>
<th>D</th>
<th>D+1</th>
<th>D+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- RMS error (µg.m\(^{-3}\))

- best forecast model skill for background sites
- slightly decreases with the lead time
- background (more representative of a coarse grid)
- industrial
- traffic

- days without forest fires

- 9th Harmonisation Conference
  Garmisch-Partenkirchen
The forecasting system validation
Daily peak ozone forecast

Skill scores clearly improve when the forest fire days are excluded of the statistical analysis, indicating that unaccounted sources due to these fires may be responsible for unskilful forecasts.
The forecasting system validation
1-h and 8-h averages forecast

<table>
<thead>
<tr>
<th>Days</th>
<th>1h averages</th>
<th>8h averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-1</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>D</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>D+1</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>D+2</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>
The forecasting system validation

Thresholds exceedance forecast

<table>
<thead>
<tr>
<th>Threshold (µg m⁻³)</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 µg m⁻³ (1h)</td>
<td>24</td>
<td>19</td>
<td>10</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>604</td>
<td>576</td>
<td>455</td>
<td>449</td>
</tr>
<tr>
<td>240 µg m⁻³ (1h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 µg m⁻³ (8h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8h average target are more correctly forecasted from D-1 to D+2

more correctly forecast

Successful forecast exceedances

<table>
<thead>
<tr>
<th></th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 19 10 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>604</td>
<td>576</td>
<td>455</td>
<td>449</td>
</tr>
<tr>
<td>17 39 36 33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>120</td>
<td>145</td>
<td>188</td>
<td>174</td>
</tr>
<tr>
<td>21 35 45 48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>414</td>
<td>442</td>
<td>563</td>
<td>569</td>
</tr>
</tbody>
</table>

False alarms

<table>
<thead>
<tr>
<th></th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>604 576 455 449</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120 145 188 174</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>414 442 563 569</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Non predicted events

<table>
<thead>
<tr>
<th></th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
<th>D-1</th>
<th>D+0</th>
<th>D+1</th>
<th>D+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(days with forest fires were omitted)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The forecasting system validation

Days with higher errors
18-20 August

Transboundary pollution effects?

Meteorological effects?
Thermal depression could not be correctly simulated by the model
The forecasting system validation

Days with higher errors
01-02 september

Transboundary pollution effects?
Final remarks

Besides the model properly represents the physical, meteorological and chemical processes, which makes this reliable tool for helping operational forecasters…

the results of this validation exercise calls for improving the forecasting system in several aspects such as the model grid resolution, industrial area emissions estimation, background ozone prediction…