Determination of background concentrations using spectrum analysis of monitoring data

O. Tchepel, A.M. Costa, H. Martins, C. Borrego
Presentation outline

• Introduction
• Objectives
• Methodology
• Application example
• Results
• Conclusions
Introduction

“Background concentration” - due to the impact of nearby sources other than the ones currently under consideration

Background concentrations for the local scale application:

1) Measurement
2) Mesoscale model

Representativeness? Uncertainty? Double counting of the sources?

???

CFD model

CFD model

HARMO12 October 6-9, 2008
Objectives

inappropriate selection of background pollutant levels could be a significant source of uncertainty in the modelling results

development of a methodology to determine representative background concentrations from air quality monitoring data to be used by local scale models

1. spectral analysis of the data → Contribution of different frequencies to the variance
2. decomposition of the time series → Remove the short-term variations
Methodology

- spectral analysis of the data

A time series $X_t$ of length $N$ is presented as a linear combination of harmonic functions with frequencies $\{f_j\}$ and amplitudes $\{A_j\}$ and $\{B_j\}$:

$$X_t = \mu + \sum_{j=1}^{\lfloor N/2 \rfloor} \left[ A_j \cos(2\pi f_j t) + B_j \sin(2\pi f_j t) \right],$$
Methodology

- spectral analysis of the data

1 year measurements at the frequency domain
2) decomposition of the data

Data filtering

**Kolmogorov-Zurbenko filter**

Multiple-pass moving average filter:

The KZ(m,k) filter of the original time series is computed as a simple moving average of m points applied k times (number of iterations):

\[
w_c \approx \frac{\sqrt{6}}{\pi} \sqrt{\frac{1-(1/2)^{1/2k}}{m^2-(1/2)^{1/2k}}}
\]

\[C(t) = C^B(t) + C^S(t)\]
Methodology

Urban background station:
Original data and after the filtering

Background concentrations
after the filtering and
Urban traffic station data

Local contribution
Application example

Simulation period:

27 - 28 of May 2006

Entrecampos urban station:

- 81 days with PM$_{10}$ exceedences in 2006
- >30% due to natural events

Mesoscale model → CFD model

AQ measurement → CFD model
Application example

Mesoscale modelling - MM5 / CAMx

Simulation domains

Portugal
9 km horiz. res.
37x63 grid cells

Great Lisbon Area
3 km horiz. res.
50x44 grid cells

Lisbon
1 km horiz. res.
38x38 grid cells
Application example

Local scale modelling

**VADIS** - Eulerian / Lagrangian CFD model

- 1500m x 1500m x 60m in Lisbon city centre
- Resolution 10m x 10m x 5m
- 29 buildings with an average height of 12 m
- 8 main roads
- TREM: hourly PM$_{10}$ traffic emissions
- MM5: meteorological conditions (wind velocity and direction, turb. kinetic energy)

Entrecampos Air Quality Station
Application example

Locations of air quality monitoring stations

PM$_{10}$ measurements
(27-28 of May, 2006)
Results

Mesoscale model results: $\text{PM}_{10}$ concentrations

PM$_{10}$ concentrations are underestimated primarily because long-range transport from North Africa is not considered in the model application.
Results

Background concentrations from the mesoscale model

CAMx → VADIS

VADIS results: PM$_{10}$ concentrations

\[ y = 37.269 + 0.1704x \]

![Graph showing PM$_{10}$ concentrations over hours, with a linear trend line.](image-url)
Results

Background concentrations from the monitoring data

VADIS

AQ monitoring filtered data

1) FFT

2) $KZ_{3,3}$
   - filter width $m=3$
   - number of iterations $n=3$
   - separation frequency $w=0.0905 \text{ h}^{-1}$

KZ filter is designed to remove short-term fluctuations with the period < 12h:
Results

Entrecampos measurements

Background concentrations

Local contribution
Results

PM$_{10}$ concentrations estimated by VADIS model

Range of the expected values is defined as a difference between measurements at urban traffic station and the background concentrations => negative values!!!
Conclusions

- A new methodology to derive background concentrations based on decomposition of time series is proposed.

- The background concentration estimated by application of this methodology allow to improve the local-scale model performance and to reduce the uncertainty of modelling results.

- Application of the proposed methodology to the episodes when background stations reveal higher values than the traffic station is limited.

- Future research is required to understand how urban background concentrations are related with the concentrations observed at street level.