vision on technology

Simulating Building Downwash of Heavy Metals by Using Virtual Sources: Methodology and Results

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Introduction

- Measurement of concentrations of heavy metals surrounding major plants ⟹ exceedances of (future) European norms
- Known sources within companies ⟹ no explanation for exceedances
- In order to be able to reduce/eliminate exceedances ⟹ necessary that source of exceedances are known.
- These exceedances could be due to unknown fugitive sources.
- Can we, based on the concentration measurements surrounding the plants, determine the sources?

Inverse modelling

- Measurements of air quality:
  - $M_{i,t}$ with
  - i: location of measurement
  - t: time of the measurement
- Substraction of effect of known sources calculated by IFDM ($\mu_{i,t}$) and background (B):
  - $M'_{i,t} = M_{i,t} - B - \mu_{i,t}$
- Compilation of list of possible sources s_j at two types of locations (each time: several sources to take into account different dependences on wind speed):
  - At places where one could expect diffuse emissions.
  - On a regular grid to account for unexpected sources.
- For each of these sources, assuming a unit value strength U for the emission, the effect on the concentrations, using IFDM is calculated: $\sigma_{i,j,t}$
- For every location and time step:

$$M'_{i,t} = \sum_j Q_j \sigma_{i,j,t}$$

- Solving using Gramm-Schmidt (Wampler, 1979). Eliminating:
  - Negative emission values (Q_j)
  - If no negative values for Q_j: The source for which the standard deviation divided by Q_j is the largest
  - Repeat procedure until all emission strengths are at least three times their standard deviation
- Remaining sources have a source strength equal to UQ_j

In general: less than 10 sources needed to describe most of validation data

Procedure is applied only on half of the available data so that validation on the other half remains possible

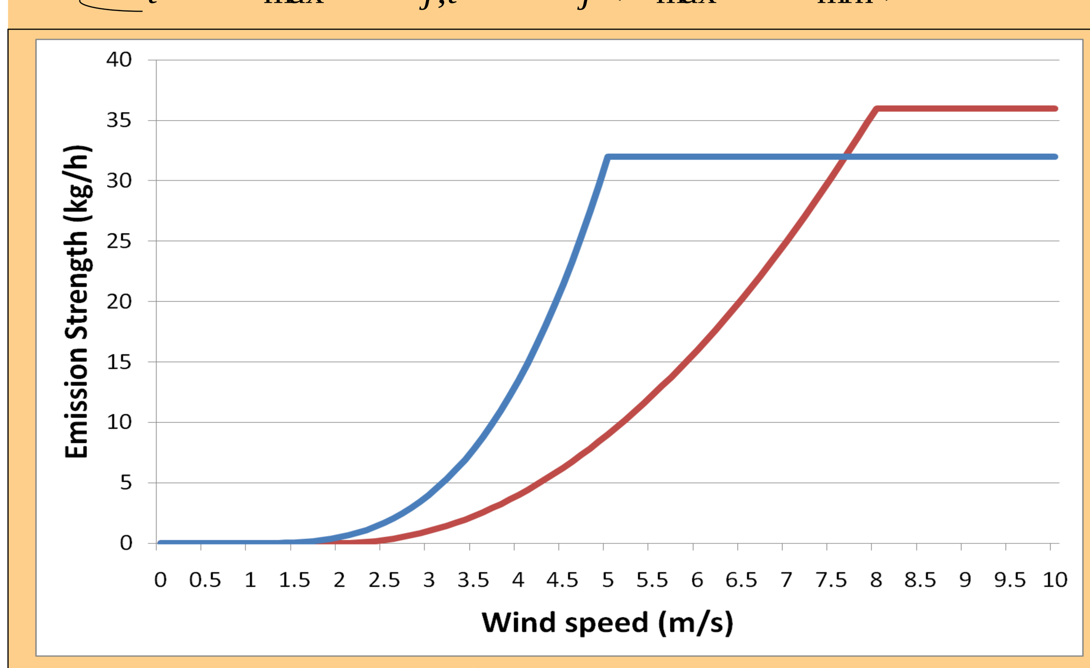
IFDM

- IFDM is a bi-Gaussian plume model
- Designed for non-reactive pollutant dispersion on a local scale
- Dispersion parameters are based on Bultynck-Malet (1972).
- Meteorological input: Luchtbal and Mol, Belgium
- More information on the model can be found in the European Model Database.

Wind dependence of sources

- Wind dependence is treated by determining four parameters:
  - Basic emission strength Q_j
  - Minimum wind value: u_{min}
  - Maximum wind value: u_{max}
  - Factor describing the form of the wind dependence p
- The emission at time t ($Q_{j,t}$) is then determined by the following equations:

$$\begin{cases} u_t < u_{\min} : Q_{j,t} = 0 \\ u_{\min} \le u_t \le u_{\max} : Q_{j,t} = Q_j (u - u_{\min})^p \\ u_t > u_{\max} : Q_{j,t} = Q_j (u_{\max} - u_{\min})^p \end{cases}$$



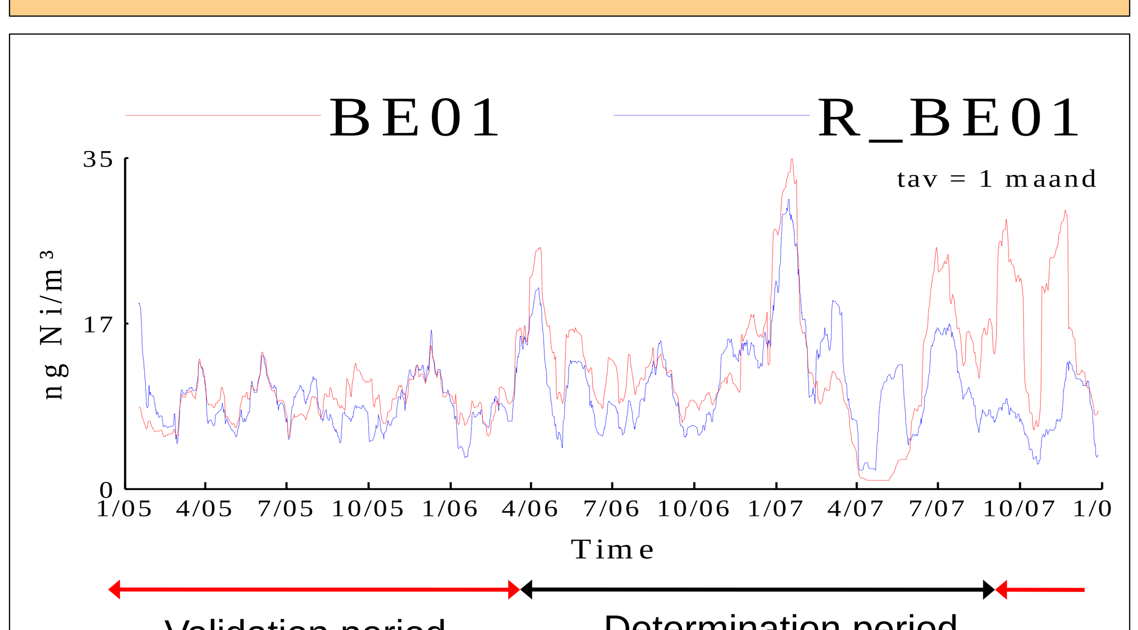
Example of emission strengths for two wind-dependent sources.

Blue line:

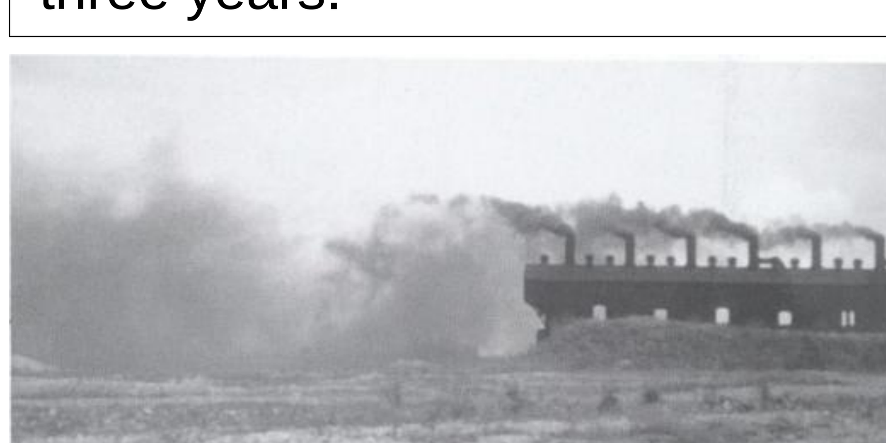
Q_j=1 kg/h, u_{min}=2m/s, u_{max}=8m/s, p=2.

Red line:

Q_j=0.5kg/h, u_{min}=5m/s, u_{max}=5m/s, p=3.



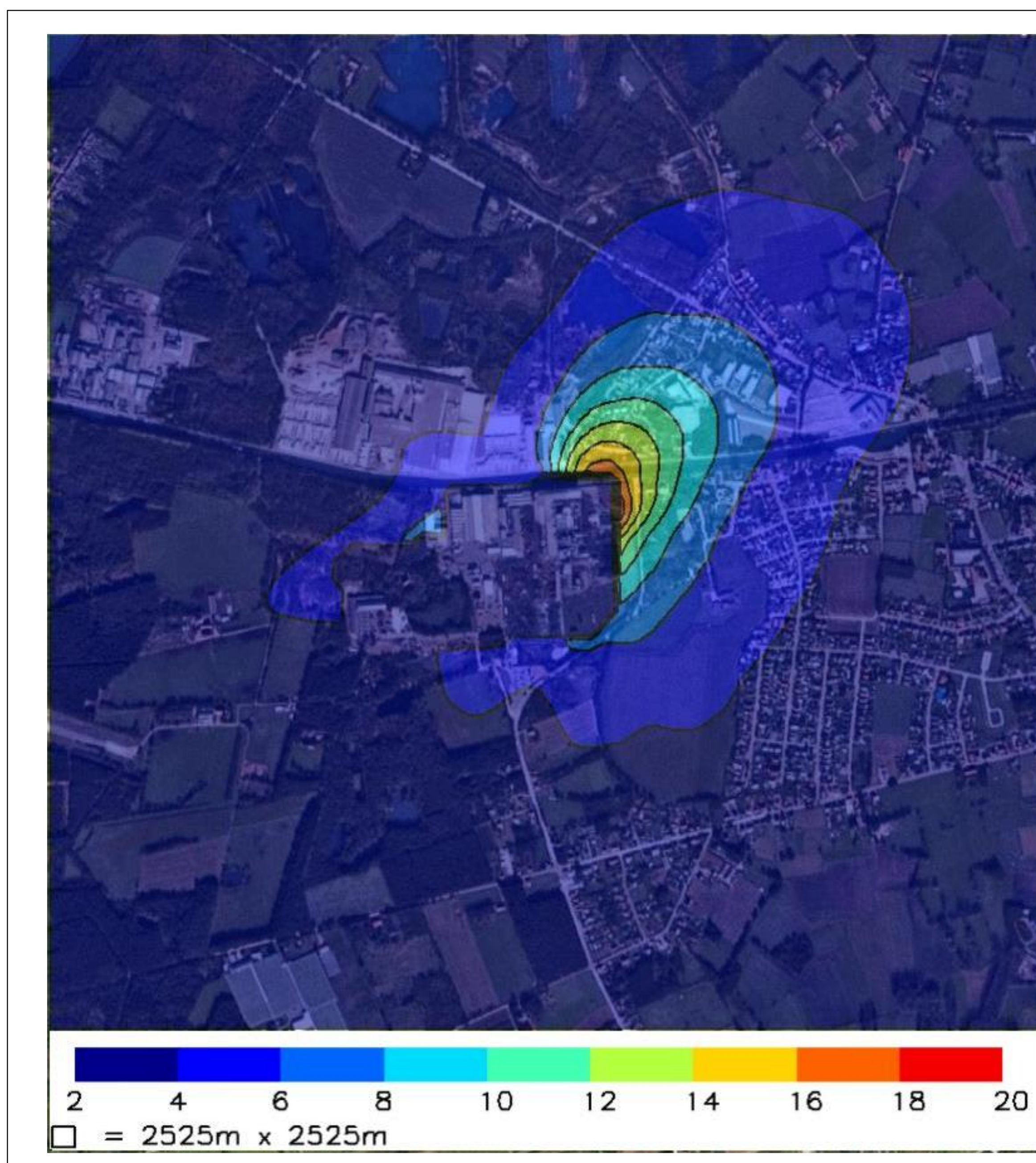
The running mean (over one month) measurement (red) and model values (blue) at the location BE01, covering three years.



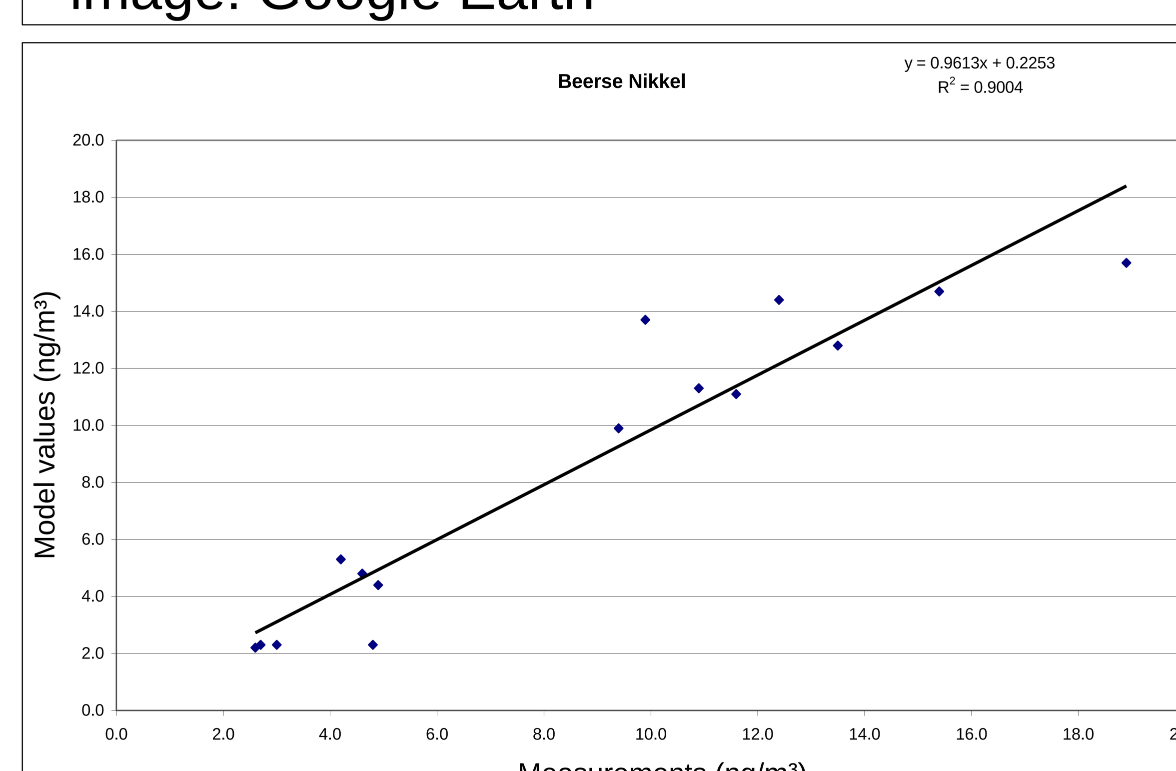
Source: Figure 2.2.8 Scorer (2002)

Results and Building Downwash

- Sources not located at storage locations of heavy metals
- Lower threshold value u_{min}=0, not in line with what's expected for wind-fugitive sources
- This is not due to fugitive emissions but to building downwash
- The inverse modelling postulates virtual sources next to buildings over which building downwash occurs. These emissions are wind-dependent (plume rise effect).
- Using these emissions, together with the known emissions, we get a correct representation of the concentration field.



Final yearly mean Nickel concentration map for 2007 (in ng/m³). Background image: Google Earth



The validation plot for the Nickel concentration. Every dot represents a yearly mean value at one measurement location in the vicinity of a heavy-metal plant.

Bultynck H. and L. M. Malet (1972), Evaluation of atmospheric dilution factors for effluents diffused from an elevated continuous point source, Tellus, XXIV.5, pg. 465-471.

Scorer R.S. (2002), Air Pollution Meteorology, Horwood Publishing Limited, ISBN: 1-898563-93-4

Wampler, R.H., 1979. Algorithm 544: L2A and L2B, weighted least squares solutions by modified Gram–Schmidt with iterative refinement [F4]. ACM Transactions on Mathematical Software 5 (4), 494–499.

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