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Two-week NO_2 maps for the City of Zurich, Switzerland, derived by statistical modelling utilizing data from a routine passive diffusion sampler network

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HIGHLIGHTS

- We generated highly resolved two-week NO_2 maps for the city of Zurich.
- The used statistical models rely on NO_2 passive sampler data and geoinformation.
- Traffic activity is the most important predictor for our NO_2 models in Zurich.
- The statistical modelling augments the value of pointwise passive sampler data.
- We analysed the NO_2 concentration field w.r.t. annual limit value exceedances.

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ABSTRACT

We developed a method to generate two-week NO_2 concentration maps with a high spatial resolution (10 m by 10 m) for the city of Zurich, Switzerland, based on statistical modelling. Our models utilize data from a dense passive diffusion sampler network consisting of 49 sites that measured 14-day mean NO_2 concentrations in the year 2008. The regression analysis is based on Generalized Additive Models (GAMs) and a stepwise forward selection algorithm that leads to models relying on a small number of explanatory variables (2–3). The explanatory variables included in the regression analysis are spatially resolved information on traffic and heating systems related NO_X and NO_2 emissions, respectively, sky view factors, and topography (elevation). Deviance explained of the 26 models ranges from 0.66 to 0.79. 81% of the modelled and 77% of the predicted NO_2 concentrations, respectively, deviate less than 25% from the observations.

The modelling approach outlined in this paper augments the value of point measurements obtained from urban routine passive diffusion sampler networks by providing spatially resolved concentration fields. The derived maps allow a detailed assessment of NO_2 levels in cities and can be used in applications such as public health protection.

1. Introduction

Statistical modelling, in particular land use regression (LUR) modelling, is a widely used method to provide high-resolution estimates of air pollutant concentrations in complex urban environments (Briggs et al., 1997). These models are often used in epidemiological studies for long-term exposure assessments of participating individuals (e.g. Hoek et al., 2008; Cyrys et al., 2012; Lee et al., 2014). Typically, these models describe yearly or seasonal mean pollutant concentration fields.

NO_2 is an air pollutant whose concentration field is characterized by large spatio-temporal variations. The availability of highly resolved information on NO_2 levels would improve the data basis for many applications. Obvious examples are epidemiological studies (as conducted e.g. by Brauer et al., 2008; Heinrich et al., 2013) as well as health protection. Further, the assessment of air quality in urban environments in terms of compliance with regulatory guidelines requires information on the pollutant concentration field with a temporal resolution equal to the definition of

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the limit values. These are usually expressed as annual, daily, 8-hourly or hourly values (e.g. European Parliament, 2008). Maps showing the pollutant concentration field at high spatial and temporal resolution would provide a valuable tool for applications in corresponding fields.

A number of studies addressed the issue of increasing the temporal resolution of statistical models: Yu et al. (2011) computed monthly $PM_{2.5}$ models by the integration of LUR and a geostatistical approach. Liu et al. (2009) developed daily $PM_{2.5}$ models based on satellite aerosol optical depth data (4 by 4 km spatial resolution). Gryparis et al. (2007) investigated semiparametric latent variable regression models with daily resolution utilising surface measurements of black carbon and elemental carbon. Dons et al. (2013) investigated hourly LUR models for black carbon. Hourly LUR models were developed by Su et al. (2008) using measurements of NO, NO_2 and meteorological parameters. Janssen et al. (2008) outlined an approach where the local character of the measurement data is removed based on land-use information prior to spatial interpolation using Ordinary Kriging. Their method allows the computation of up to hourly NO_2, O_3 and PM_{10} concentrations on a regional scale (4 by 4 km resolution).

Concurrently, dispersion models are being enhanced. They represent a different approach to provide pollutant concentrations with high spatio-temporal resolution in urban environments. Oettl and Uhrner (2011), for example, discuss a hybrid Eulerian-Lagrangian approach to compute up to hourly NO, NO_2 and O_3 concentrations. Righi et al. (2009) analysed the performance of the Gaussian dispersion model ADMS for predicting hourly traffic related pollutant levels in Ravenna (Italy). Moreover, Lefebvre et al. (2013b, a) outlined the combination of a bi-Gaussian plume model and LUR.

Dispersion models stick preferably close to physical processes. They require accurate data on meteorology and emissions. Statistical models strongly rely on pollutant measurements. Their potential is tightly linked to advances in low-cost sensor technology which is encouraging (e.g. Mead et al., 2013; Williams et al., 2013). While both modelling approaches are subject to further improvements, direct model comparisons will eventually reveal their differences w.r.t. performance and application fields (e.g. Beelen et al., 2010).

Detailed air quality assessment in most cities is still based on permanent or temporary measurement networks despite all the modelling efforts. This study aims for the development of a straightforward method to generate 14-day NO_2 concentration maps for the city of Zurich, Switzerland, based on statistical modelling utilising data from a dense passive diffusion sampler network and georeferenced information. The main purpose of the mapping is the spatial extension of the information provided by the point measurements. The derived maps are used to assess the NO_2 concentrations at people's home addresses and workplaces in the city of Zurich presenting an application of such models in public health protection. The performance of the modelling approach is evaluated and dependencies of design aspects of the passive sampler network on the quality of the results are discussed.

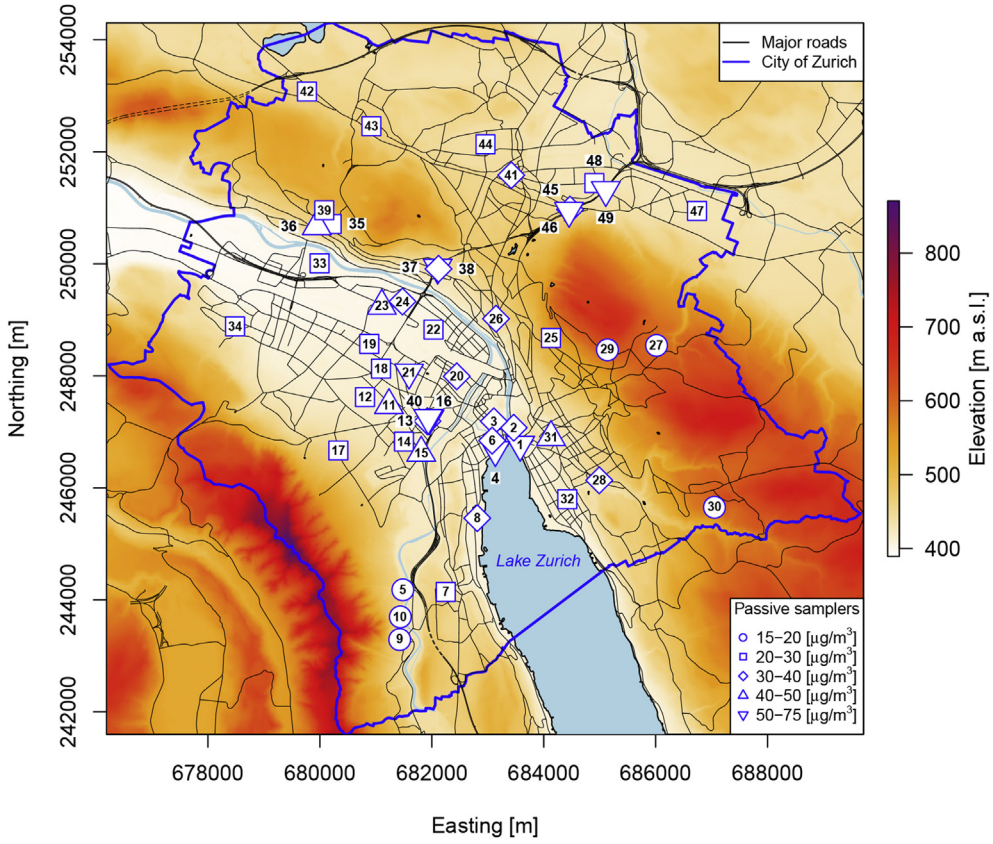

Fig. 1. Passive sampler network in the city of Zurich deployed in 2008 (symbols and site numbers). The different symbols for the passive diffusion sampler sites depict the annual mean NO_2 concentrations observed at particular locations. Note that some symbols may overlap. In addition, the figure shows the topography (color scale), the major road network (black lines), rivers and lakes (light blue), and the city boundary of Zurich (blue line). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)