Development of a Healthy Urban Route Planner for cyclists and pedestrians in Amsterdam

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Abstract

Cities are hotspots of air pollution and heat stress, resulting in nuisance, health risks, medication costs, reduced labour productivity and sick leave for citizens. Yet the air pollution and heat stress are spatially and temporally unevenly distributed over the city, depending on pollutant emissions, street design and atmospheric turbulent mixing and radiation. If accurately forecasted, this spatiotemporal variation offers pedestrians and bikers alternative routes to minimize their exposure.

We develop a route planner for bicyclists and pedestrians for Amsterdam (NL), that proposes routes based on model simulations of weather and air quality. We use the WRF-Chem atmosphere and air quality model at unprecedented grid spacing of 100-m (Ronda et al, 2015), with an underlying urban canopy model and NO_x and PM_{10} emissions. The traffic emissions are based on observed traffic intensities and emission factors. WRF-Chem runs will be issued daily for a lead time of 48 hours, resulting in forecast maps of temperature and pollutant concentrations that will be uniquely expressed in a metric that combines both threats. The route planner that we build, using the open source routing library pgRouting and the OpenStreetMap network heat forecast and coupled route planner. As such it is an evident example of societal geo-innovation.

1 Introduction

Each day, the citizens of Amsterdam commute through their city, i.e. going out for a walk, to work, to family and friends or for leisure. Since the streets in Amsterdam are busy and dominated by fossil fuel powered traffic (Keuken et al 2016), citizens travelling through the city are exposed to air pollution which involves a substantial health risk (Rainham and Smoyer-Tomic, 2003; Steeneveld et al 2016), causing e.g. heart diseases, lung cancer and asthma (Fischer et al., 2015). Air quality depends on the time of day, location and weather conditions. Hence air quality may vary on a finer scale than 4 km at which it is available now An individual person's exposure to that air pollution depends on his/her activity and selected departure time and route.

In addition, the urban morphology in street canyons, the low green vegetation cover, and anthropogenic heat emissions induces cities to be substantially warmer than the countryside (Theeuwes et al 2015, 2016), which has consequences for human health. labour productivity and energy demand. Observations and modelling studies (Ronda et al., 2015) found an urban heat island effect of ~6°C in Amsterdam. They also found obvious differences in heat load between (green and less green) neighbourhoods. Urban heat affects citizens health (Budd, 2001), since in warm summer episodes mortality and morbidity is raised. The frequency of adverse heat conditions is projected to increase (Molenaar et al., 2016) and adequate adaptation measures should be developed.

Now, citizens are not offered suitable information to minimize their exposure to both air pollution and urban heat in travel. Here we empower citizens to make healthy choices by means of a real-time, high resolution air quality and urban

2 Methods and Data

The first phase of the research contains the data collection of the spatiotemporal traffic intensities per vehicle type in Amsterdam (Fig. 1). On one hand all non-traffic pollutants emissions are based on the Netherlands Emission Registration for the Dutch part of the domain and on the TNO-MACC inventory outside the Netherlands.. Traffic data are gathered from the NSL database for the highway ring A10 and from the Amsterdam municipal traffic prognosis model. Road traffic counter information are used to refine the time profiles of the traffic pollutions. These data are gridded and offered to the WRF-Chem model (Grell et al, 2005)

Concerning urban heat, the WRF model has been equipped with a surface module to account for heat storage in buildings, anthropogenic heat, reduced sky view in urban street canyons. WRF utilizes input from the TOP10NL land use database, the national tree register and the national digital elevation model. In addition, daily observed water temperatures are assimilated into the WRF model that runs at the Cartesius high performance computer (SURFSARA) in Amsterdam. Based on GFS global numerical weather prediction model, each day 48 h forecasts are produced on hourly intervals and at 100 m spatial resolution. Air pollution and temperature fields are combined into a single metric that expresses the environmental quality that will act as basis for the route planning algorithm. The usability of the resulting *Healthy Urban Route Planner* will be tested by volunteers of the Cycling Association Amsterdam. The route planner uses OpenStreetMap data as network and is built with use of the open source pgRouting, an extension for PostGIS and PostgeSQL enabling geospatial routing. The routes are computed on request. Moment the user requests the route between two points, the model computes (using PGrouting in PostGIS, with network data stored in the database in PostgreSQL) at that moment the best route. The most healthy route is calculated according to the Dijkstra (1959) algorithm, where the air pollution and temperature are taken as the cost variable to minimize. The route planner will be accessible via a website.

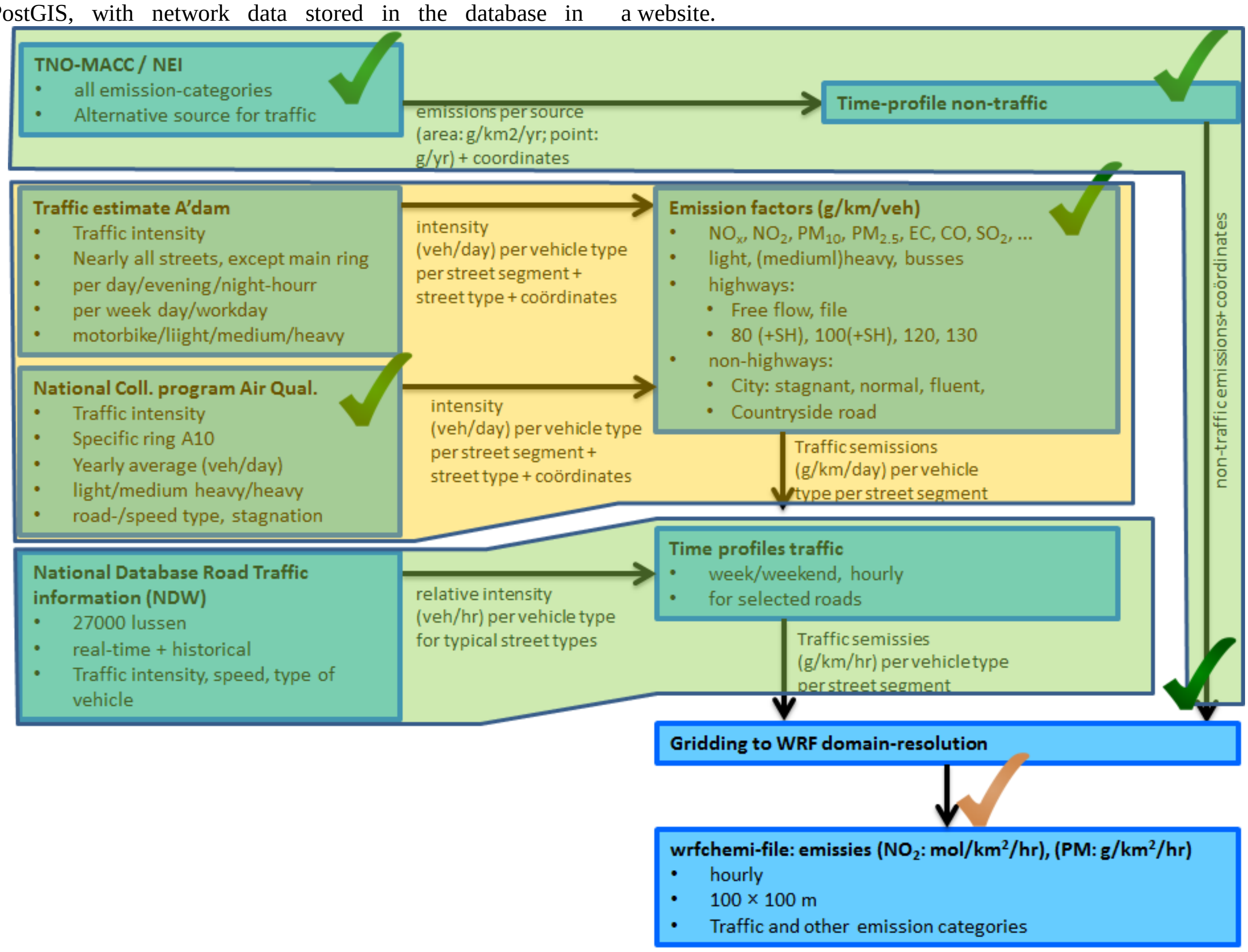

Figure 1: Data streams of air pollutions source data into the WRF-Chem model.

3. Results

At this stage only temperature forecast are available at the 100 x 100 m resolution. Figure 2 shows that the unprecedented high resolution temperature forecast results in substantial differences between neighborhoods. Urban parks, harbour areas, and canals appear in the forecast. As such this illustrates the potential for healthy route planning. Moreover, figure 3 shows results of a preliminary study on relatively coarse model resolution. For two alternative route for both a north-south and west-east commuting pattern the air quality exposure of a cyclist was modelled. It appears that the exposure on route 1a is substantially less than for route 1b, particularly for the evening rush hour. Also departure time matters herein. Analogously route 2b offers a reduced exposure than route2a. As such the modelling and forecasting strategy provides citizens travel options and helps to promote the awareness for environmental quality.

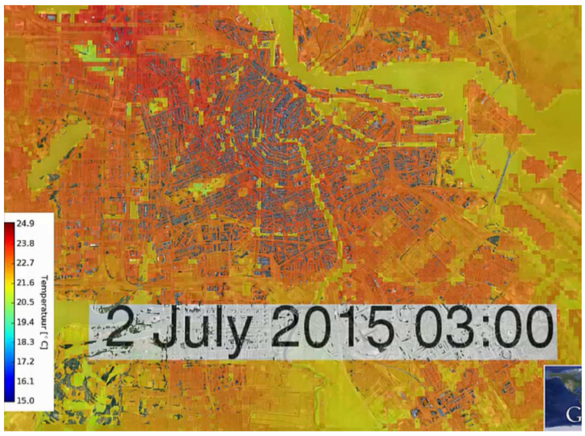

Figure 2: Example of forecast urban heat island effect across Amsterdam for a heat wave event in summer 2015. Source www.meteo.wur.nl/summerinthecity (Ronda et al, 2015).

	Route 1a	Route 1b	Route 2a	Route 2b
7h	62%	112%	65%	68%
8h	100%	144%	100%	98%
9h	109%	145%	106%	94%
10h	88%	117%	80%	71%
16h	111%	156%	103%	98%
17h	131%	195%	133%	131%
18h	137%	216%	141%	145%
19h	144%	217%	144%	151%

Figure 3: Upper panel: two contrasting bike routes for east-west and north-south. Bottom panel: the air quality exposure for each route with departure time 8.00 LT as a reference (Dekker 2014)

4 Acknowledgements

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