Modelling setup for assessing the impact of stakeholders and policy scenarios on air quality at urban scale

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Abstract

ClairCity, a project funded by the EU Horizon 2020 research and innovation programme, developed an innovative quantification framework aiming to assess environmental, health and economic impacts. The quantification framework consists of i) an integrated urban module based on the household and dwelling characteristics, ii) emission rates linked with on-road transport, iii) emission data linked with the industrial, residential, commercial and institutional sectors, iv) daily and hourly consumption profiles based on the energy and power generation data, v) air quality patterns and related population exposure, vi) health-related impacts and costs, and vii) carbon footprint estimates. This framework was applied for the baseline situation of 6 pilot cities. In particular, the second-generation Gaussian model URBAIR was setup and ran to simulate NO_2 and particulate matter concentrations for distinct computational domains covering the urban area of each case study for the full baseline year of 2015. The ClairCity impact assessment framework is applied to evaluate the impact of scenarios for 2025, 2035 and 2050, namely the Business As Usual (BAU) scenario and 3 additional scenarios translating the expectations of citizens and local experts based on data collected through engagement process. The outcomes of the assessment of impacts were used to inform the Policy Workshops for each case study to help decision-makers and local planners to define the final integrated Unified Scenario.

1 Introduction

The continuous growth of population living in urban areas worldwide has been increasing the number of air pollution episodes alarmingly threatening human health and well-being. In order to preserve healthy living conditions in urban areas, control and mitigation strategies of air pollution episodes are of utmost importance. For that, citizens need to become the key element at the centre of air pollution reduction strategies, being consider not only as a cause, but also as the main solution, making the scene for big changes in citizens' behaviour, activities and practices (Barnes *et al.*, 2018; Chatterton and Wilson, 2014). The ClairCity project – Citizen-led air pollution reduction in cities – aims to improve future air quality and carbon policies in European cities by initiating new modes of engaging citizens, stakeholders and policy makers. ClairCity is putting citizens and their behaviour at the centre of air pollution and carbon management, applying the most recent advances in social sciences.

In this work, we discuss the application of the ClairCity quantification framework to assess the impacts on air quality focus on NO_2, PM10 and PM2.5 concentrations.

2 Air quality impacts assessment

ClairCity applies a quantification framework to six European cities and regions: Bristol (UK), Amsterdam (The Netherlands), Ljubljana (Slovenia), Sosnowiec (Poland), Genoa (Italy) and the Aveiro region (Portugal). The application of the quantification framework encompassed the build-up of a ClairCity emissions database addressing distinct emission sectors, in line with statistics by sector, by time of day, establishing the link with citizen's behaviour. It includes emission rates for the 6 case studies, considering as point sources the large industry emissions, as well as, shipping emissions (in the case study of Genoa), the line sources with the road-traffic emissions, and the area sources covering the residential, commercial and industrial emissions, the IRCI module, as well as the shipping emissions for the case study of Amsterdam. The database is physically stored in the ClairCity Data Portal and will be fully public available by the end of the project.

The Gaussian model URBAIR (Borrego *et al.*, 2016) was setup and run at urban scale for the computational domain over the urban area of each city/ region with a horizontal grid resolution of 200 m x 200 m. The baseline simulations were performed using as input data the meteorological vertical profiles provided by the WRF model, which was applied to the regional domain covering the urban area of each case study using as horizontal resolution 0.05 degrees. The air quality simulations of NO_2, PM10 and PM2.5 concentrations were performed for the full-year in an hourly basis using the emission rates available on the ClairCity emission database described above.

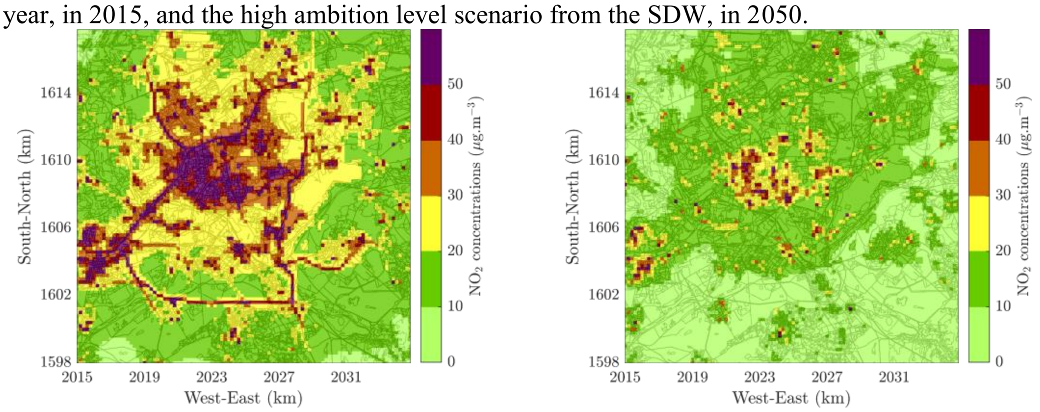
For Bristol (the pilot case study), a preliminary comparison of the URBAIR outputs with the observations pointed out an underestimation of the simulated concentrations. This underestimation was mainly associated with the lack of other emission sources contributing to the concentrations within the area, as well as the transboundary contribution. Therefore, a procedure was defined to account for the background concentrations and other remaining sources, following the background concentrations maps published by the UK's Department for Environment Food & Rural Affairs (DEFRA). The background air pollution maps made available by DEFRA are the total annual mean concentrations based on modelled data on 1 km x 1 km grid squares. The background concentrations added to the NO_2 concentrations simulated by URBAIR model included the contributions from aircraft, rail, other and rural, while for PM10 and PM2.5 the added background accounted for rail, other, secondary PM, residual and salt categories. The simulation results together with the added background concentrations were then calibrated against the measurements through an adjustment procedure. The adjustment procedure comprises the establishment of a linear regression between the measurements, including data from 107 diffusion tubes, 4 continuous measurement points and the St Paul's urban background station from the UK's automatic monitoring network, and the simulated concentrations obtained for the cells corresponding to the location of the measurement points. In case of NO_2 concentrations, the slope of 1.62 from the linear regression is applied as a correction factor over all the domain, together with a unique correction factor applied to each cell with a measurements available.

For Amsterdam, a similar procedure was defined to account for the background concentrations and other remaining sources, following the background concentrations maps for 2015 (available on http://geodata.rivm.nl/gcn/) published by the National Institute for Public Health and the Environment of The Netherlands (RIVM). The background air pollution maps made available by RIVM consist of annual average modelled concentrations at 1x1 km^2 resolution. The background concentrations added to the NO_2, PM10 and PM2.5 modelled concentrations included the contributions from the following categories: foreign sources, aviation, rail traffic, agriculture, and waste processing, based on source apportionment data from GGD Amsterdam. The resulting concentrations were again calibrated against the measurements through the adjustment procedure. For NO_2 concentrations, a slope of 1.3 obtained from the linear regression is applied as a correction factor over all the domain, together with a unique correction factor applied to each cell with measurements available. In case of particulate matter, the slope obtained from the linear regression is equal to 6.9 for PM10 and 9.1 for PM2.5 concentrations.

Based on the lessons learnt from the pilot case study (Bristol), a model adjustment procedure have been defined suited for the 4 remaining case studies. For Ljubljana, Sosnowiec, Genoa and Aveiro region the simulation results were calibrated with the measurements. The adjustment procedure comprised the establishment of the linear regression between the measurements and the simulated concentrations. The adjustment factors obtained from the linear regression for NO_2 concentrations were 2.1, 2.2, 1.7 and 2.9 for Ljubljana, Sosnowiec, Genoa and Aveiro region. These factors were applied as a correction factor over all the four domains, together with a unique correction factor applied to each cell with a measurement available.

3.1 Impact assessment of scenarios

To understand the impact of the measures that citizens and stakeholders put forward, the quantification framework assesses the impact of the designed policies on emissions, air quality, human health and related costs. Two different type of scenarios have been considered: i) the business-as-usual “BAU” scenario, which aims to capture the changes on the air quality if no further measures are taken in the expected technological and behavioural changes. It reflects the normal trend without any policy or other interventions beyond the measures already established; ii) the scenarios from the Stakeholders Dialogue Workshop (SDW) translate the vision and expectations of citizens and local stakeholders based on data collated through engagement processes (e.g. Stakeholders Dialogue Workshop, Delphi, ClairCity Skylines Game and Mutual Learning Workshop) plus evidence from the baseline policy assessment. These scenarios will be used to support and inform the development of city policy packages out to 2050. Therefore, the headline air quality of the BAU and SDW scenarios was quantified as an indicator of the scenarios’ potential impact for 2025, 2035 and 2050. Figure 1 shows an overview of the results for the city of Sosnowiec, as example, with the comparison between the annual average of NO_2 concentrations for the baseline year, in 2015, and the high ambition level scenario from the SDW, in 2050.



a) b)

Figure 2. NO_2 annual average concentrations for Sosnowiec for the baseline year (a) and for the high ambition level scenario from the SDW in 2050 (b).

For Sosnowiec, the low ambition scenario (not presented) will promote a reduction of NO_2 concentrations over the urban area of 38%, while the high ambition scenario will promote a reduction of 47%. The European legal limit value for NO_2 concentrations will be potentially exceeded within an area corresponding to 10% of the total area of the computation domain in 2015, 2.2% in 2050 for the low ambition scenario, and 1.1% in 2050 for the high ambition scenario. Therefore, the overall air quality will significantly improve in 2050 with the application of the high ambition scenario, although Sosnowiec urban area will still register some exceedances to the European legal limit values for NO_2.

4 Conclusions

This work focuses on the modelling approach to assess the impacts on air quality of the ClairCity scenarios. The outcomes were used to inform the Policy Workshop to carry out in each city/region to help decision-makers and local planners to define the final integrated policy unified scenario, including citizens' visions and behaviour. The final unified scenario is quantified as input to the ClairCity Policy Report to be delivered at the end of the process to each city.

The ClairCity framework contribute to assess air pollution through the source apportionment of air pollutant emissions and concentrations, as well as, carbon emissions, not only by technology, but by citizens' behaviour. As a further outcome, ClairCity is currently addressing the impact of citizens' behaviour on air pollution and carbon footprint.

Questions and Answers

Questioner: Peter Builtjes

Question: *You showed a range of NO2 adjustment factors, ranging from 1.3 for Amsterdam to 2.3 for Aveiro. Does the factors depend on the size of the city?*

Answer: The adjustment factor procedure comprises the establishment of a linear regression between the measurements and the simulated concentrations obtained for the cells corresponding to the location of the measurement points. The variability of the calculated factors strongly depends on the number of stations with measurements available for the regression. The NO2 observations available for 2015 include measurements from 107 diffusion tubes, 4 continuous measurement points and the St Paul's urban background station from the UK's automatic monitoring network, in Bristol; 100 diffusion tubes with valid measurements available, and 16 continuous measurements, in Amsterdam; only one background site, part of the automatic monitoring network of Slovenia, in Ljubljana; one road traffic site and two urban background sites, in Sosnowiec; eight monitoring stations in Liguria region (four urban traffic, three urban background and one urban industrial site); and three monitoring stations in Aveiro region (one urban traffic, and two suburban background stations).

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