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Estimation of future emission scenarios for analysing the impact of traffic mobility on a large Mediterranean conurbation in the Barcelona Metropolitan Area (Spain)

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ABSTRACT

Emission modelling permits us to quantitatively assess the effects of emission abatement strategies. In urban areas, such strategies are designed mainly to reduce the emissions from the on–road traffic sector. This work analyses the impact of several mobility strategies on urban emissions in the coastal city of Barcelona, Spain, when the High Elective Resolution Modelling Emission System (HERMES) is applied at a very high resolution (1 km × 1 km and 1 h). The analysis was conducted by projecting the emissions data obtained from a base case scenario in 2004 onto three future scenarios set in 2015, where each future scenario represented a set of traffic mobility management measures. Specific developments were considered per emission sector, including power generation, industrial activities, domestic–commercial, solvents, on–road traffic, biogenic emissions, ports and airports, to best compare the present base case scenario with the future mobility scenarios generated for 2015. These emission scenarios for 2015 take into account the population projections and the variations in port and airport activities among other factors, while the main focus is on the on–road traffic sector, the types of vehicles used, such as technologically improved buses and hybrid vehicles, as well as the types of fuels used, including natural gas and biofuels. The results of the emission model indicate that the mobility management strategies, the technological improvements and the use of alternative fuels reduce the emissions from on–road traffic by approximately 75% (in terms of nitrogen oxides emission reductions in the city centre of Barcelona). This decrease leads to a 35% reduction in overall nitrogen oxides emissions, even if some sectors individually experience increases based on their specific projections.

Keywords: *Emissions management, urban pollution, air quality management, traffic mobility*

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1. Introduction

According to the European Environment Agency (EEA, 2005), air pollution is the environmental factor with the greatest health impacts in Europe. The city of Barcelona and its metropolitan area present several air quality problems that are particularly related to PM_{10} (particulate matter with a diameter up to 10 µm) and nitrogen dioxide (NO_2) in particular (Generalitat de Catalunya, 2011). In the Barcelona Metropolitan Area, 9 out of 15 stations exceeded the annual air quality limit of NO_2 (40 µg m^{-3}) during 2010. Only 1 station out of 6 in the city of Barcelona had an annual ambient air concentration of less than 40 µg m^{-3}, and that location was the urban background station of the Vall d'Hebron Park (Generalitat de Catalunya, 2011).

The largest contribution to the emission of atmospheric pollutants in urban areas today comes from the transport sector, especially from on–road transport (Chin, 1996; Cirillo et al., 1996; Palmgren et al., 1996; Oduyemi and Dadvison, 1998; Crabbe et al., 1999; Palmgren et al., 1999; Colvile et al., 2001; Ghose et al., 2004; Guo et al., 2007). In recent years, there have been significant efforts made to study the effects of strategies that are used to reduce on–road traffic emissions and the subsequent impacts of these emissions on air quality. Currently, the main objective of these strategies is targeted at reducing the emissions from each vehicle either by adopting less polluting fuels and technologies (Wang et al., 2008; Goncalves et al., 2009; Stephens–Romero et al., 2009; Brady and O'Mahony, 2011) or by reducing the speed limit (Baldasano et al., 2010). Nevertheless, despite the reduction in the emissions from each vehicle, the constant increase in traffic intensity prevents an overall reduction in total on–road traffic emissions (Moriarty and Honnery, 2008a; Moriarty and Honnery, 2008b). Therefore, there is a need for a suitable transport system that features mobility management strategies (Caserini et al., 2008; Lumbreras et al., 2008; Bandeira et al., 2011; Ozan et al., 2011).

Therefore, this study analyses the impact of the introduction of traffic mobility management strategies on on–road traffic emissions in the city of Barcelona (Figures 1a, 1b), where approximately 70% of the NO_x emissions come from the on–road transport sector.

The mobility strategies are planned for implementation in the city centre of Barcelona by 2015; red domain in Figure 1c. Each strategy is applied to three future scenarios: (1) the business–as–usual scenario, which represents what would happen if the traffic intensity were to grow without any mitigating measures taken to reduce the emissions from each vehicle; (2) the super–blocks scenario, where the road network is remodelled; and (3) the super–blocks reversal scenario, which adds some directional reversals to Scenario 2. These future scenarios were compared to a base case scenario obtained from 2004. Super–blocks are a mobility management measure that consists of transforming inner streets with light traffic into pedestrian areas to achieve a better traffic flow on the streets, delimiting the super–block (MMA, 2006). The study was made more consistent by considering specific city developments per emissions sector.

This paper starts by describing the HERMES emission modelling system in Section 2. The future mobility management measures are defined for Barcelona (Section 3), followed by the results in Section 4. Finally, Section 5 summarises the main conclusions.

2. Methods

This study is focused on the city of Barcelona and its metropolitan area, as shown in Figures 1b and 1c. Two nested domains have been defined to better analyse atmospheric emissions:

(i) Barcelona Ring Roads (BRR), an inner domain 110 km^2 in size that comprises the most populated area of Barcelona where the mobility management measures are applied.

(ii) Barcelona Metropolitan Area (BMA), an area that is 692 km^2 in size.

The emissions for these two domains are estimated at high spatial resolution (1 km × 1 km) with the HERMES emission model.

2.1. HERMES emission model

In this paper, the emission estimation comes from the application of the High Elective Resolution Modelling Emission System (HERMES) (Baldasano et al., 2008). The HERMES model estimates the emissions either for the whole country of Spain or for configurable inner domains within Spain. It runs with a temporal resolution of 1 h and a spatial resolution of 1 km × 1 km. The current version of the HERMES model refers to the year 2004. The HERMES model takes into account anthropogenic emission sources such as power generation, industrial activities, on–road traffic, ports, airports, solvent use, domestic and commercial fossil fuel use, and biogenic sources such as vegetation and uses a bottom–up approach, up–to–date information and state–of–the–art methodologies for estimating future emissions. The HERMES model is capable of calculating emissions from sector–specific sources or from individual installations and stacks. The Supporting Material (SM) provides a comparison between the HERMES inventory and the Spanish National Inventory (SNIE) for a validation of the HERMES model.

2.2. Traffic module in HERMES

A relevant module in the HERMES model was used in this study to estimate the on–road traffic emissions that will be affected by the mobility strategies. The module is designed based on a bottom–up approach and takes into account 72 types of diesel and petrol vehicles categorised according to the COPERT–EEA–EMEP/CORINAIR methodology (EEA, 2009). These vehicles are divided into various categories including the fuel type, the vehicle weight, the vehicle age and the volumetric engine capacity. Each of these categories has specific emission factors defined as functions of traffic speed, and a detailed methodology for developing these functions is provided by Baldasano et al. (2008). A detailed characterization of the uncertainty for each vehicle category, pollutant and speed is described in Kouridis et al. (2010). Traffic emission estimation considers hot and cold exhaust, evaporative emissions, particulate matter produced by brake abrasion, tire wear and pavement erosion.

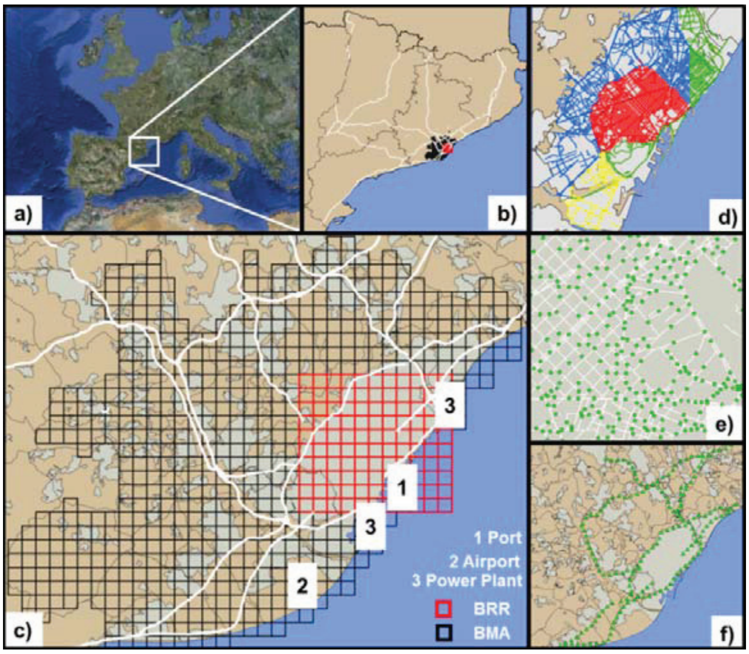

Figure 1. ***(a)*** *Location of the Catalan domain;* ***(b)*** *Detail of the Catalan domain that includes the domain of study;* ***(c)*** *Domain of study: Barcelona Metropolitan Area (BMA, black) which integrates the area inside the Barcelona Ring Roads (BRR, red) and principal sources of emissions;* ***(d)*** *District areas differentiated by the frequency of each kind of vehicle;* ***(e)*** *Detail of the 2 700 traffic points with information available for the city of Barcelona;* ***(f)*** *Traffic points with hourly information available for the city of Barcelona (green triangles).*