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Development and evaluation of emission disaggregation models for the spatial distribution of non-industrial combustion atmospheric pollutants

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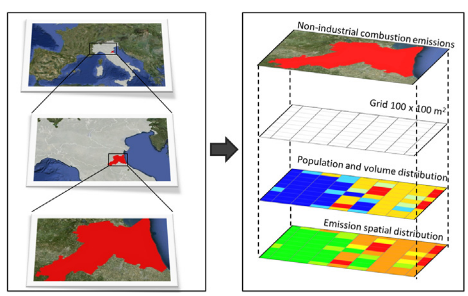
HIGHLIGHTS

- High-resolution disaggregation of non-industrial combustion emissions is performed.
- The emissions are scaled down from a provincial to a local (100 × 100 m^2) scale.
- Three top-down disaggregation models are investigated.
- Results of the top-down models are compared with results of a bottom-up approach.
- The model combining resident population and building volume shows the best performance.

GRAPHICAL ABSTRACT



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ABSTRACT

The aim of the present work is to define top-down approaches to allocate atmospheric emissions from non-industrial combustion plants (residential, institutional and commercial sectors) to a detailed grid system of 100 × 100 m^2. The conceptual model adopted permits the use of suitable proxy variables for the scaling down of atmospheric emissions from a provincial to a local scale. 'Resident population', 'building volume' and a statistical combination of both have been used as proxy variables for realizing three emission disaggregation models. The choice of the proxy variables was influenced by both data availability and relevance. The results of the emission disaggregation models have been compared with emission values resulting from a bottom-up approach starting from local data. The selected case study was located in the Emilia-Romagna Region (NE Italy), and NO_x was the reference pollutant.

1. Introduction

An emissions inventory is a database of air pollutants emitted in a region of interest. Emission inventories contain information on type, number, location and magnitude of sources of air pollution (UNEP, 2005). Emission inventories are useful for locating significant sources of air pollutants, evaluating emission scenarios and emission trends over time, and checking compliance with the obligations of international conventions and protocols, or national emission reduction targets (Aardenne van and Pulles, 2002). Moreover, inventories are frequently used as input data for air quality and atmospheric dispersion models (Andretta et al., 1993; Borrego et al., 2000; François et al., 2005; Bellasio et al., 2007; Maes et al., 2009), for providing air management scenarios

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(Borrego et al., 2000) or for developing specific databases (Brulfert et al., 2005; Waked et al., 2012).

For these reasons, the synthesis of data relating to the nature of sources and associated rates of polluting activity in an emissions inventory forms an important basis for the assessment of air quality and the targeting and justification of related policy (Lindley et al., 1999).

Generally, emission inventories are compiled through two principal approaches, namely bottom-up (microscale) and top-down (macroscale) (Loibl et al., 1993; Costa and Baldasano, 1996; Palacios et al., 2001). The first approach provides the individuation and the quantification of each emission source in the land; the second approach is a process that allows the disaggregation of emission data from large areas to small areas (Streets et al., 2003). Both approaches have advantages and disadvantages: the bottom-up approach is more accurate but it is often expensive and time-consuming, while the top-down approach is faster and cheaper, and requires fewer technical skills from the developers, but the accuracy of the spatial distribution of the emissions can be much lower (Loibl et al., 1993; Costa & Baldasano, 1996; ANPA, 2001). In fact, as highlighted by Ossés de Eicker et al. (2008), when applying top-down approaches it is necessary to be aware of the spatial accuracy of these simplified methods.

In Europe, a commonly used supranational emission inventory is the CORINAIR/EMEP database. CORINAIR (CORe INventory of AIR emissions) is a project performed since 1995 by the European Topic Centre on Air Emissions, with the aim of collecting, maintaining, managing and publishing information on emissions into the air by means of a European air emission inventory and database system (EEA, 2009; Maes et al., 2009).

In the framework of the CORINAIR methodology, pollutant sources are broken down by means of SNAP (Selected Nomenclature for sources of Air Pollution) into 11 emission categories, and the best approach to estimate the emissions for all categories is to employ an activity data factor and a specific emission factor for each type of source, for each productivity process and for each purification technology adopted. This approach is based on a linear relationship between the activity and the emission rate, through the following basic formula:

$$E_i(s) = A(s) \times \mathrm{FE}_i(s) \quad (1)$$

where: $E_i(s)$ is the emission rate (mass per unit of time) of pollutant i from a source s; $A(s)$ is the activity data for source s over a given time (for example the fuel consumption per year); finally, $\mathrm{FE}_i(s)$ is the emission factor (mass per unit of activity) of the pollutant i from a source s.

Emission inventories are becoming more and more important in order to accomplish the requirements of the European Directives concerning air quality (Bellasio et al., 2007), and those based on CORINAIR methodology are sufficiently detailed for regulatory purposes and generally comply with legal requirements for air quality administrators.

The aim of the present work is to define and assess widely applicable top-down approaches disaggregating provincial atmospheric emissions from non-industrial combustion plants and allocating them to a very high-resolution grid. Three models disaggregating air emissions to a grid system with a resolution of $100 \times 100\ \mathrm{m}^2$ have been evaluated and their strengths and limitations have been assessed. A case study in Italy was carried out to investigate the feasibility of these models. The resulting emission estimates have been compared with those resulting from a bottom-up approach starting from local data.

2. Case study

2.1. Case study area

The case study was carried out in the Ravenna Province (1860 km^2 with approximately 400,000 residents), situated in the Emilia Romagna Region (NE Italy) on the Adriatic Sea. Ravenna Province is subdivided into 18 municipalities of which Ravenna city is the provincial capital (Fig. 1). The city of Ravenna has a large industrial area and one of the more important commercial harbours of Italy. Its municipal district covers about 35% of the provincial territory and its population represents approximately 39% of the total provincial population. Despite air quality in the Ravenna Province having improved in recent decades, concentrations of some pollutants – such as particulate matter, nitrogen oxides, and ground-level ozone – are now levelling off and there remain health issues relating to air pollution, particularly in the urban area. Road transport and the burning of fossil fuels are the biggest sources of these pollutants.

2.2. Emission source category

In the present work, we consider the CORINAIR/SNAP97 source category 02, 'Non-Industrial Combustion Plants', including heating for residential, institutional and commercial sectors. The estimates are calculated from data on consumption and sales of the three main types of fuel used in Italy (natural gas, gas oil and liquefied petroleum gas) and the relative emission factors. In the Ravenna Province natural gas comprises 97% of the total fuel consumption

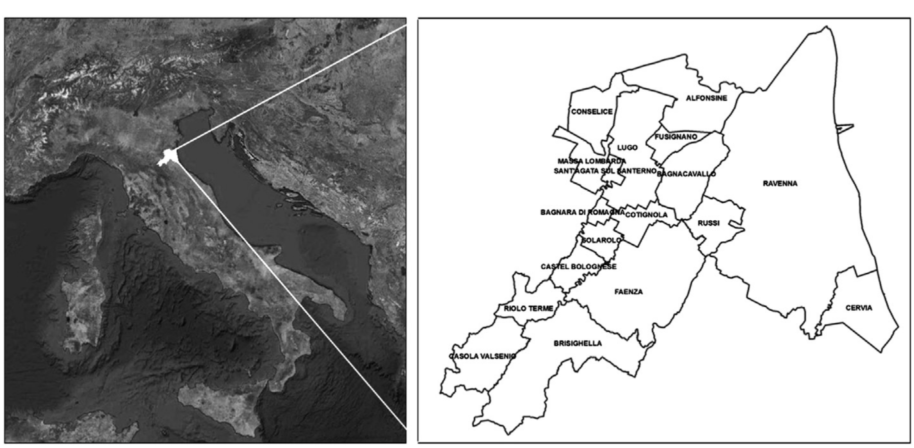

Fig. 1. Geographic location of the study area. Italy (left), municipal subdivision of Ravenna Province (right).