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The representation of emissions from megacities in global emission inventories

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Abstract

We examine the representation of emissions from megacities in three global anthropogenic emission inventories. Despite the many common sources of data between the inventories, and the similarities in their construction methodologies, there are some very large differences (often a factor of two) between the emissions for individual cities, even when the total global emissions are very similar. We find that the geographical distribution of the emissions within countries plays a larger role in explaining the differences between the inventories than differences in the country total emissions. We also find very large differences between the contribution of various sectors to the total emissions from each city, and relate these differences to the respective methodologies used in the inventory construction. By and large, in OECD countries megacity emissions from the global inventories are dominated by road transport, especially for CO and to a lesser degree for NO_x. In non-OECD countries, notably in Asia, megacity CO emissions are dominated by residential biofuel use, while industrial emissions predominate for NO_x. Non-methane hydrocarbon emissions in OECD megacities are caused by industry and traffic, whereas in non-OECD countries residential biofuel use makes significant contributions. These emission signatures often result from assumptions about the distribution of emissions according to gridded population density maps rather than according to the actual location of the emitting processes. We recommend the use of an ensemble of inventories, that the geographical distribution of emissions receives increased attention, and that local inventories be integrated into global emission inventories.

Keywords: Emissions; Inventories; Megacities; Intercomparison; Global modelling

1. Introduction

Both the local effects of pollutant emissions on air quality within cities and the effects of emissions from large urban areas on remote environments have long been the subject of observational and modelling studies (e.g. White et al., 1976; Hov et al., 1978). The potential for a small number of so-called "megacities" to contribute significantly to long range transport of pollutants and thus to air quality on a global scale is also beginning to be recognised

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(e.g. Akimoto, 2003; Crutzen, 2004; Gurjar and Lelieveld, 2005). Emission inventories are important for studying anthropogenic influence on the atmosphere. As well as providing input for numerical models and helping to interpret field observations, emission inventories also aid policymakers in designing mitigation strategies. The City Delta project (Cuvelier et al., 2007) has recently used high resolution air quality models driven by high resolution emission inventories to study the influence of European cities on European air quality. In order to study the effects of megacities at the global scale, one must employ a global model of atmospheric chemistry, which must in turn be driven by a global emission inventory. Our study represents a first step in this direction.

In Section 2 we provide a description of the global inventories considered in this study. In Section 3 we describe our methodology, including our definition of "megacity". In Section 4 we compare the total emissions from megacities with the global emissions for each global inventory. In Section 5 we compare the representation of individual megacities in the emission inventories, and attempt to explain differences between the representations of cities in the inventories in terms of differences in the construction of the inventories. In Section 6 we summarise and draw conclusions from our work.

2. Description of global emission inventories

We compare three different global emission inventories with emissions for the year 2000: EDGAR; IPCC-AR4; and RETRO. All three emission inventories provide global gridded fields of reactive trace gas emissions, have previously been used in global modelling studies, and are available to the scientific community. As we shall see in this paper, the inventories are generally very similar, although occasionally there are large differences. Sometimes these differences are due to the slightly different purposes for which the inventories were designed, and sometimes they are due to differing methodologies used in the construction of the inventories. In this section we provide a short summary of the three global emission inventories used in this study, and highlight some of the key differences.

The EDGAR (Emissions Database for Global Atmospheric Research) emission inventory is aimed at providing a reference data set for global atmospheric modelling. It contains global anthropogenic emissions of many air pollutants and greenhouse gases. We use EDGAR version 3.2 Fast Track 2000 (Olivier et al., 2005), which is based on the earlier EDGAR 3.2 emission inventory (Olivier and Berdowski, 2001; Olivier et al., 2001; Olivier, 2002). The EDGAR version 3.2 Fast Track 2000 inventory can be downloaded from http://www.mnp.nl/edgar/model/v32ft2000edgar.

The IPCC-AR4 inventory is described by Dentener et al. (2005), and has been used in several recent multi-model intercomparison studies for the IPCC Fourth Assessment Report (e.g. Stevenson et al., 2006; Dentener et al., 2006a, b; Eyring et al., 2007; van Noije et al., 2006; Shindell et al., 2006). It is based on emissions at the country and sector level from the RAINS inventory (Klimont et al., 2001; Amann et al., 2004; Cofala et al., 2004; Klaasen et al., 2004), developed at IIASA (The International Institute for Applied Systems Analysis) in order to calculate least cost strategies for the abatement of air pollutants and greenhouse gases. Emissions from RAINS at the country and sector level were geographically distributed according to the EDGAR distributions and aggregated as described in Dentener et al. (2005). The IPCC-AR4 inventory can be downloaded from ftp://ftp-ccu.jrc.it/pub/dentener/IPCC-AR4/2000.

The RETRO inventory was developed by TNO (The Netherlands Organisation for Applied Research) (Pulles et al., 2007). This inventory focuses on ozone precursors, and was designed specifically to be used in the RETRO project (REanalysis of the TROpospheric chemical composition over the past 40 years, Schultz et al., 2007). The RETRO inventory can be downloaded from http://retro.enes.org.

All of these global inventories are in principle constructed according to a formula such as

$$E_{i,j} = \sum_{k,l,m} A_{j,k,l} \times \mathrm{EF}_{j,k,l} \times (1 - \mathrm{EFF}_{j,k,l,m}) \times R_{j,k,l,m}. \quad (1)$$

The emissions, E, of compound i in region j are determined by the intensity of all activities A of each activity type l in each sector k multiplied by an uncontrolled emission factor (EF). In some cases, abatement measures are considered using the reduction efficiency EFF of abatement measure m along with an implementation rate R. None of the three global inventories studied here perform a full uncertainty assessment in which quantitative uncertainty bounds are defined around specific