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The biogenic volatile organic compounds emission inventory in France Application to plant ecosystems in the Berre-Marseilles area (France)

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Abstract

An inventory describing the fluxes of volatile organic compounds (VOCs), isoprene and monoterpenes, and other VOCs (OVOCs) from the biosphere to the atmosphere, has been constructed within the framework of the ESCOMPTE project (fiEld experimentS to COnstrain Models of atmospheric Pollution and Transport of Emissions). The area concerned, located around Berre-Marseilles, is a Mediterranean region frequently subject to high ozone concentrations. The inventory has been developed using a fine scale land use database for the year 1999, forest composition statistics, emission potentials from individual plant species, biomass distribution, temperature and light intensity. The seasonal variations in emission potentials and biomass were also taken into account. Hourly meteorological data for 1999 were calculated from ALADIN data and these were used to predict the hourly isoprene, monoterpene and OVOC fluxes for the area on a 1 km × 1 km spatial grid. Estimates of annual biogenic isoprene, monoterpene and OVOC fluxes for the reference year 1999 were 20.6, 38.9 and 13.3 kt, respectively, *Quercus pubescens*, *Quercus ilex*, *Pinus halepensis* and garrigue vegetation are the dominant emitting species of the area. VOC emissions from vegetation in this region contribute approximately 94% to the NMVOC (non-methane volatile organic compounds) of natural origin and are of the same order of magnitude as NMVOC emissions from anthropogenic sources. These results complete the global ESCOMPTE database needed to make an efficient strategy for tropospheric ozone reduction policy.

Keywords: Biogenic VOCs; Isoprene; Monoterpenes; Mediterranean ecosystems; Emission inventory

1. Introduction

Non-methane volatile organic compounds (NMVOCs) of biogenic or anthropogenic origin play an essential role in the photochemical processes responsible for air pollution in the atmospheric boundary layer. In the presence of nitrogen oxides (NOx) and under specific meteorological conditions (cloudless sky, strong solar radiation, high temperatures corresponding to anticyclonic weather conditions), they are usually involved in the production of high ozone levels in the troposphere. Plant VOC emissions include a wide spectrum of compounds amongst which isoprene and monoterpenes are

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both the most abundant and the most reactive in photochemical processes. Other VOCs (OVOCs) are also released, including sesquiterpenes and oxygenated compounds (ketones, aldehydes, alcohols, etc.) (Winer et al., 1992; Kesselmeier et al., 1997; Helmig et al., 1999a, b). Estimates carried out on a global scale evaluated the biogenic source at about 1000 Tg C $year^{-1}$ (Guenther et al., 1995), whereas the anthropogenic source is estimated to be 10 times lower (Müller, 1992; Piccot et al., 1992), although anthropogenic emissions usually dominate within urban areas. The estimates for biogenic sources cover a large range of values, e.g. isoprene emissions can vary by as much as five times (for Europe: Simpson et al., 1995, 1999 and France: Simon et al., 2001). These uncertainties in biogenic emission estimates are partly due to an incomplete understanding of the emission processes themselves and also to the lack of precise data, such as land cover information, which is essential in determining the geographical distribution and the total biomasses of the emitting vegetation species.

The emission characteristics of different plant species are currently the subject of intensive research. In Europe, two large measurement campaigns have focused on this topic: BEMA (Biogenic Emissions in the Mediterranean Area) (Seufert et al., 1997) and BIPHOREP (Biogenic VOC emissions and PHOtochemistry in the boreal regions of Europe) (Laurila, 1999). However, there are still large gaps in the emission factor data available for a detailed emission inventory because of the great diversity of plant species and because of the emission variability depending on climatic, demographic, geographic and biological differences at micro- and macro-scales.

In the present investigation, we have undertaken an evaluation of isoprene, monoterpene and OVOC emissions from plant species within the framework of the ESCOMPTE program (fiEld experimentS to COnstrain Models of atmospheric Pollution and Transport of Emissions) (Cros et al., 2004). The study area is centred on Berre Pond-Marseilles which is frequently subject to pollution. The hot and sunny Mediterranean climate, the abundance of high VOC-emitting vegetation and the presence of two centres of important anthropogenic emissions, the Marseilles metropolitan area (1.2 million inhabitants) and the large industrial zone located around Berre Pond, all contribute to the air pollution of the site.

The aim of the ESCOMPTE program is to create a relevant data set of parameters concerning the dynamics, physics, meteorology and chemistry of the troposphere on a regional scale in order to test and evaluate regional air quality models (Cros et al., 2004). This requires the establishment of emission inventories especially including the biogenic emissions from the vegetation. The present paper describes the construction of a high resolution biogenic isoprene, monoterpene and OVOC emission inventory for the Berre-Marseilles area using a highly detailed plant-species-specific methodology.

2. Methodology

The algorithms and databases used to estimate the NMVOC emissions described in the following sections have been incorporated into a geographical information system (GIS) software. We have used the mathematical model developed by Guenther et al. (1993) with some modifications to take into account the specificity of the study area. The algorithms and GIS procedure to obtain the spatial distributions of the emissions have been linked to a software tool to facilitate updates of the inventory.

2.1. Chemical compounds of the inventory

As mentioned in the introduction, a large amount of NMVOCs are emitted by vegetation (Fuentes et al., 2000). When we looked at which compounds, involved in the photochemical processes and given off by vegetation with high emissions and reactivity in the atmosphere, had available, existing emission factors and flux measurements covering all the major plants reported in our investigation area, only one particular compound, isoprene and one chemical group of compounds, the monoterpenes fitted our criteria. Some emission factors of other VOC (sesquiterpenes, oxygenated compounds, etc.) are also available from the literature, so it has been possible to define a third category of compounds, the so-called OVOCs.

2.2. Land-use map—assignation of plant species

The digital land use map produced by the CRIGE (Centre Régional de l'Information Géographique—French regional geographical information centre) for the year 1999 has been used in this work because it was the most relevant land use data available. The map covers 19,600 km^2 (140 × 140 km) (Fig. 1) with a spatial resolution (grid cell size) of 1 km^2. The UTM coordinates (North West corner) are the following: X (longitude) = 622,000 m, Y (latitude) = 4,877,000 m.

Ecosystems are defined using the CRIGE land use database from analysis and processing of regional cover of LANDSAT 7 ETM + satellite images and also by using statistics from the French National Forestry Inventory (IFN, http://www.ifn.fr) and the RGA (Recensement