Application of a high-resolution emission model in Valencia Community (Spain)

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Abstract

A detailed emission inventory database is not available in the Valencia Community (Spain) for its application in photochemical modelling. A high-resolution emission model has been applied for this region, located on the eastern Spanish Mediterranean coast for year the 2000 that includes biogenic and road traffic emissions. The emission inventory has been developed with a 1-h temporal and 1 km^2 resolution in a bottom-up approach for primary pollutants: NO_x, NMVOCs, SO_2, CO and PM. The model is implemented into a Geographical Information System (GIS), using the methodologies described by Parra and Baldasano (2003a,b) that estimated biogenic emissions following the guidelines of Guenther *et al.* (1993) and for road traffic emissions following the guidelines of Ntziachristos and Samaras. Biogenic emission inventory depicts emissions for NMVOCs summed up to 53.9 kt/y (41.5% monoterpenes, 36.7% isoprene and 21.9% OBVOCs). Emissions from road traffic show that SO_2 contribute 0.7 kt/y, NMVOCs 42.4 kt/y, NO_2 36.9 kt/y and CO 213.4 kt/y. The spatial emission distribution shows that traffic emissions present an elevated concentration mainly in the coastline and Valencia city areas, while most biogenic emissions are located inland. The major contribution of this work is the improvement of information regarding major emission sources and their processing so they can be used in photochemical modelling applications.
Keywords: emissions inventory model, Valencia community, biogenic emissions, traffic emissions.

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1 Introduction

In the Valencia Community (Eastern Spanish Mediterranean coast) the ozone threshold of the European Union Directive for damage to vegetation (65 μg m^{-3} as a 24-h average) is exceeded systematically in several locations for more than 6 months in a year, the one for human health (120 μg m^{-3}, 8 h average) for at least 4 months in a year. The threshold for the information to the population (180 μg m^{-3}, hourly average) can also be exceeded sometime from April to August (Thunis and Cuvelier [14]; CEAM [1]).

In summer, sea breeze combined with upslope winds creates recirculations of pollutants along the coasts and within the western Mediterranean basin with residence times in order of days. Under strong insolation these recirculations become a "large natural photo-chemical reactor" where most of the NO_x emissions and other precursors (mainly NMVOCs) are transformed into oxidants, acids compounds, aerosols and ozone (Millán *et al.* [9]).

In order to improve knowledge about the ozone formation process, in the frame of BEMA project (Biogenic Emissions in the Mediterranean area), modelling study of the impact of biogenic emissions on ozone formation in Mediterranean area, was made in the Burriana area, north of Valencia, and the biogenic and anthropogenic emissions were estimated. The biogenic emission inventory was built considering three soil types, namely: sea, forested areas, and citrus plantations. The results of the model simulations were validated and comported with the data collected during the BEMA field campaign, 1997 (Thunis and Cuvelier [14]).

The anthropogenic emission inventory emission was done for an area of 100 km^2 for road-traffic emissions and industrial emission sources for NO_x, NMVOCs, SO_2, CO, NH_3, and CO_2, CH_4, N_2O. Time and spatial resolution of the inventory were 1-h and 1 km^2, respectively. Road traffic emissions estimates were done from mass balance depending on the pollutant type, driving mode and vehicle age and cylinder capacity, according to the modified version proposed in CORINAIR94. The industrial inventory included the nitric manufacturing power plant at Sagunto, the thermal power plant near Burriana, and about 300 ceramic industries mainly located in the surroundings of Onda. (Martin *et al.* [8], Salazar *et al*. [13], Thunis and Cuvelier [14]).

The current inventory includes the whole Valencia Community (23,000 km^2) in a grid of 216 x 344 km^2, with a spatial resolution of 1 km^2 for year 2000. The emissions estimates were made for biogenic and road traffic emission sources in a bottom-up approach for primary pollutants: NO_x, NMVOCs, SO_2, CO and PM, and with a temporal resolution of 1 hour.

2 Methodology

Estimation models and methodologies used are described in Parra and Baldasano [11, 12] to estimate biogenic emissions following Guenther *et al.* [7] guidelines and to estimate road-traffic emissions following Ntziachristos and Samaras [10] guidelines.

2.1 Biogenic emissions estimates

The basic information used to develop the biogenic emission inventory was: land-cover database, biomass factors database, emission factors database and meteorological surface information (air temperature and global solar radiation).

In the present study, the CORINE land cover database described in EEA [4] was processed to reduce the 44 land-uses into 22 uses. The spatial resolution of the original database is 250 m^2, and that was processed for conversion into 1 km^2 spatial resolution, which is a requirement for the estimation model used.

Calculated NMVOCs emissions were distinguished as isoprene, monoterpenes and Other Biogenic Volatile Organic Compounds (OBVOCs). Biomass and emission factors were taken from Gómez and Baldasano [6], that were gathered for Catalonia; this area has similar natural conditions that the study area.

The air temperature and global solar radiation maps of the Valencia Community for the 2000 year were obtained with the information provided by Instituto Nacional de Meteorología (INM), Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM) and Servei Meteorològic de Catalunya (SMC). Data was processed by a kriging approach to obtain the spatial distribution. Hourly meteorological data from 18 stations for global solar radiation and 30 for air temperature were included in this process

2.2 Traffic emissions

Three kinds of emissions from road traffic were considered (hot, cold and evaporative emissions). Hot emissions are the emissions from vehicles after they have warmed up to their normal operating temperature (water temperature over 70º C). Cold emissions take place while vehicles are warming up. Evaporative emissions from the gasoline tank and carburator float bowls in the form of NMVOCs emissions.

Several parameters were needed for the emission inventory of on road traffic. The basic information is: network of roads (urban, rural and highway), vehicle fleet composition, daily average traffic and their hourly, weekly and monthly distribution profiles, driven characteristics (urban, rural and highway), air temperature and fuel characteristics. The network of roads considered is about 3,822 km in length (1,063 road stretches) and it is distributed in 20.28% highways, 72.94% rural and 6.78% urban.

The intensity of road traffic and its temporal distribution profiles were analysed and processed. 55 monthly profiles, 55 daily profiles and 13 hourly profiles were selected. These profiles were assigned to each road stretch, according to the criterion of geographical nearness and roads functionality. In the same way the driven characteristics were assigned (7 velocity class profiles were used). Average national vehicle fleet in 2000 was used from DGT [3] and driven characteristics were taken from Delgado [2]. The emission estimations were based in all available information per road stretch and the road stretch with more than 3,000 daily average traffic was considered.

According to Ntziachristos and Samaras [10] methodologies, the vehicle fleets were distributed by vehicle age and cylinder capacity, 35 groups of vehicles were differentiated.

To estimate the evaporative emissions, in addition to the previous information, temperature data from INM meteorological stations and fuel characteristics according to Real Decreto 1728/1999 were used.

3 Results

3.1 Biogenic emissions results

The current emission inventory shows that in the study area 53.9 kt/y of NMVOCs in year 2000 were emitted, (41.5% monoterpenes, 36.7% isoprene and 21.9% OBVOCs). Emissions grow in summertime as a result of the increase of biological activity. The emission was maximum in August with 18% and minimum in January with 2% of the total (Figure 1).

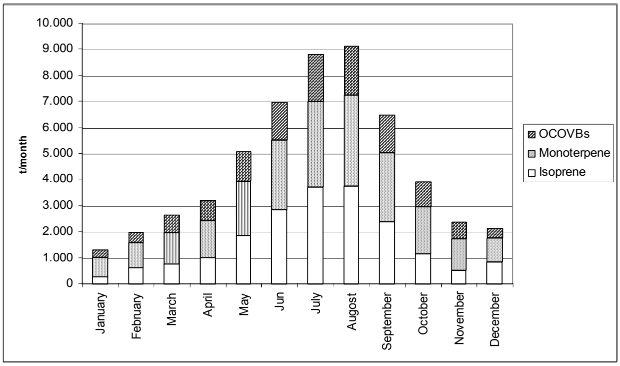

Figure 1: Monthly biogenic emission distribution.

In order to know the daily emission cycle, hourly emissions were estimated. Figures 2a and 2b show the biogenic emissions for two days, one for wintertime (15 January) and another one for summertime (15 August).

The contribution of each land-cover use to major biogenic compound is shown in Table 1. The important participation of shrub land can be observed; only this use represents 40.8% of the land-cover and 71.8% of the emissions. Other important land-use contributions were from irrigated fruit trees and coniferous forest with 9.6% and 9.1% of the emissions, respectively.

Respect to the contribution of each biogenic compounds emitted per land-cover categories, isoprene emission stands out with 98.62%, which was emitted by shrub land, owing to the important contribution of this land use and the emission factor used for isoprene (7.36 µg g^{-1} h^{-1}).

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Figures 3a and 3b show spatial distribution of total NMVOCs and isoprene emissions, respectively. Most of the biogenic emissions are located inland, related with the spatial distribution of shrub land that contribute to isoprene emissions.

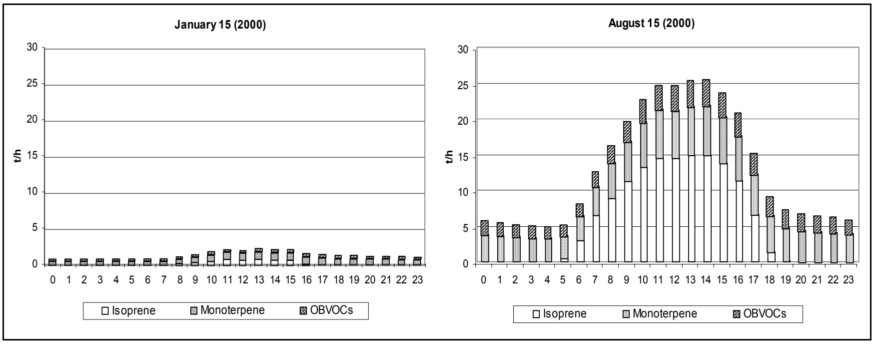

Figure 2: (a) and (b) hourly emission distribution in a winter (left) and a summer day (right), respectively.

Table 1: Biogenic emission contribution per land-cover category.

Land uses	Land cover participation %	% Contribution			
		Isoprene emissions	Monoterpene emissions	OBVOCs emissions	Total Biogenic emissions
Urban areas	1.0	0.15	0.11	0.09	0.1
Non-irrigated herbaceous crops	2.6	0.00	0.10	0.78	0.2
Irrigated herbaceous crops	2.3	0.00	6.66	9.83	4.9
Non irrigated fruit trees	20.1	0.00	2.72	3.50	1.9
Irrigated fruit trees	11.7	0.00	8.09	28.56	9.6
Vineyards	4.2	0.00	0.38	0.00	0.2
Shrub land	40.8	98.62	64.19	41.07	71.8
Sclerophyllous forest	1.1	0.33	3.59	0.33	1.7
Deciduous forest	1.2	0.70	0.27	0.55	0.5
Coniferous forest	12.1	0.20	13.86	15.22	9.1
Vegetation in damp areas	0.2	0.00	0.04	0.07	0.1
Total emissions (t/year)		19792	22383	11807	53982

Figures 4a and 4b show monoterpenes emissions and OBVOCs emissions distribution. Emission peaks of monoterpenes coincide with the sclerophyllous forest and coniferous forest location, although maximum contribution is again from shrub land. Respect to OBVOCs emission peaks are on the coastline coinciding with irrigated fruit trees (orange trees) and irrigated herbaceous crops.

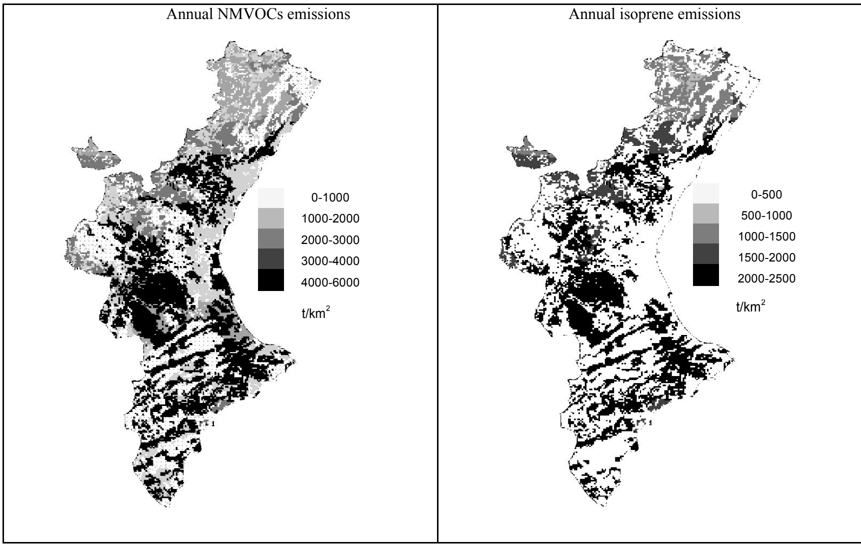

Figure 3: (a) and (b) spatial distribution of total NMVOCs emissions (left) and isoprene emissions (right) in the Valencia Community.

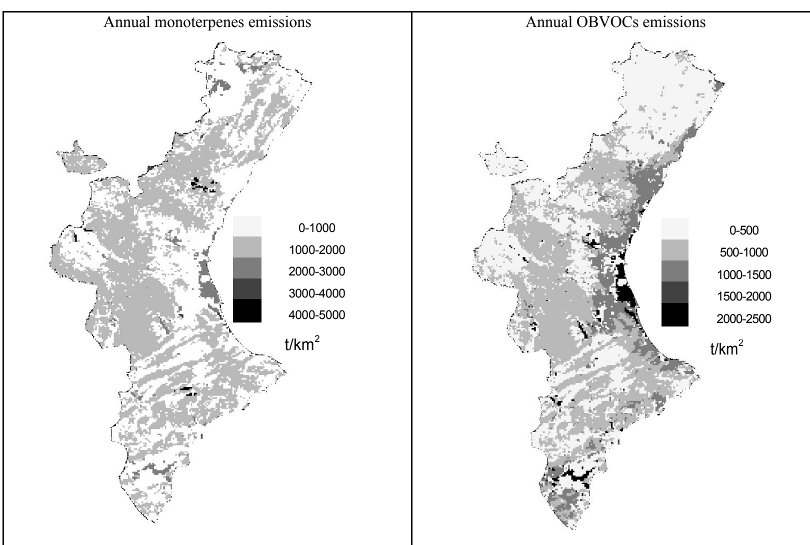

Figure 4: (a) and (b) spatial distribution of monoterpenes emissions (left) and OBVOCs emissions (right) in the Valencia Community.

3.2 On-road traffic emission results

During year 2000, the estimations show that 304 kt/y of primary pollutants were emitted in the study region, which are distributed in 70.18% of CO, 13.99% of

NMVOCs, 12.14% of NO_x, 3.46% of PM and 0.23% of SO_2. The results by emission category and pollutant compound are shown in Table 2.

Table 2: Annual emissions by type and pollution compound (t/year).

Pollutant	Hot (t)	Cold (t)	Evaporative (t)	Total (t)	Contribution %
SO_2	697	7	-	704	0.23
PM	10,424	95	-	10,519	3.46
NMVOCs	24,887	846	16,689	42,422	13.95
NO_x	36,694	214	-	36,908	12.14
CO	204,181	9,262	-	213,443	70.21
Total	276,883	10,424	16,689	303,996	100.00

Respect to daily average emission, Figure 5 shows the evolution of a working day. According to road traffic profiles, emissions present a maximum during rush hours, at 8 UTC in the morning and 20 UTC in the afternoon, and a minimum value at night-time, i.e. 4 UTC.

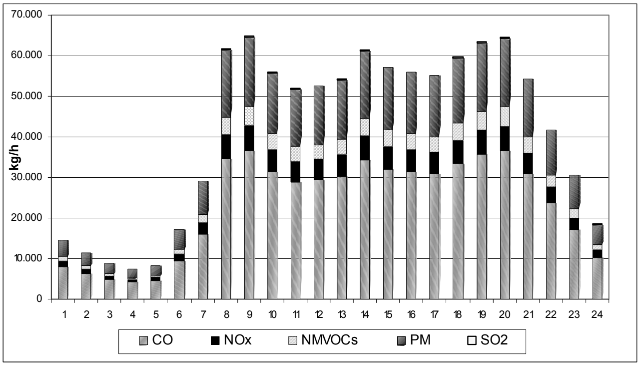

Figure 5: Daily average emission by pollutant of working day.

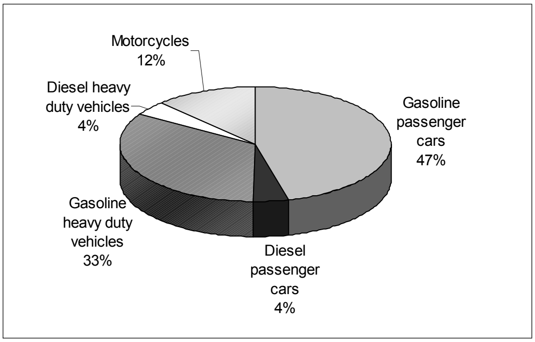

Figure 6: Total on road traffic emission by type of fleet group.

Regarding to the total emissions by type of each fleet group, Figure 6 shows that gasoline passenger cars emitted 47% of total emissions, followed in second place by gasoline heavy-duty vehicles, this represent a 33% of the total.

Spatial emission distribution due to road traffic emissions present an elevated concentration mainly in the coastline and Valencia city area as consequence of the deployment of the main roads in the region. As an example of the spatial ditribution, Figure 7a and 7b shows the emissions of NO_x and NMVOCs.

A comparison of model estimates the CO_2 emission and those given by statistics from fuel consumption was performed. Results show that modelled CO_2 emissions were underestimated by a 36%. Differences were more important in the case of diesel consumption than in the case of gasoline consumption, as it can be seen in Table 3.

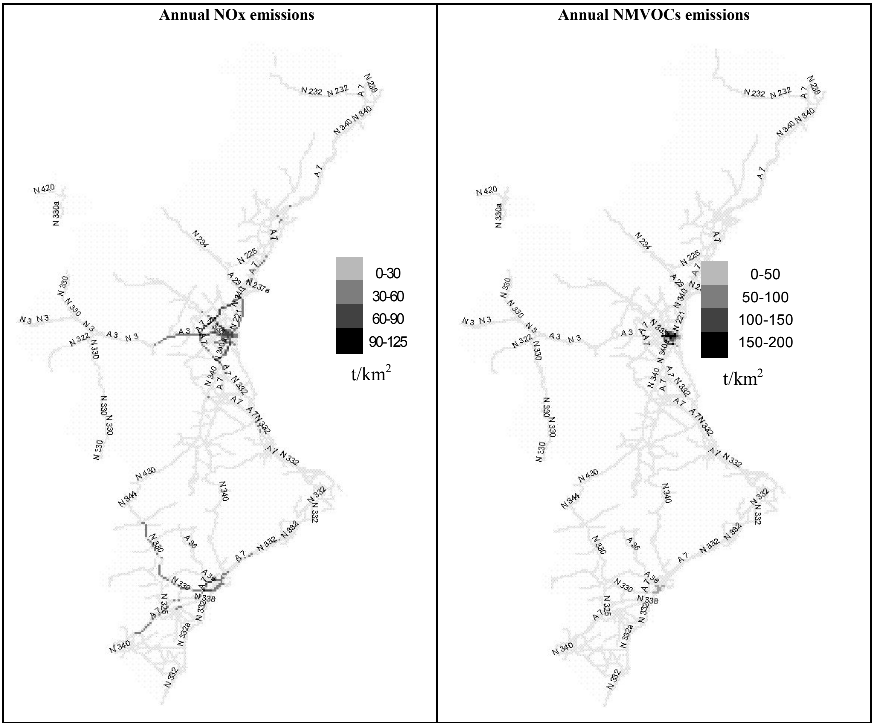

Figure 7: (a) and (b) example of spatial emission distribution: NO_x and NMVOCs.

There are several possible causes for these differences. Among them stands out the models use of the statistics of vehicular fleet to estimate emissions, per each stretch. It does not take into account that diesel vehicles travel more kilometres per year than gasoline vehicles. The model considers all vehicles to have the same probability to be found in each stretch. In this sense, the vehicular

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fleet of gasoline vehicles is bigger than the diesel vehicles fleet and this is shown in the results with the underestimation of CO_2 emissions from diesel and overestimation of CO_2 emissions from gasoline. Other considerations are related to the differences about the vehicular fleet composition on working days and weekends or/and holiday.

Table 3: CO_2 emissions estimates vs. CO_2 from fuel consumption statistics.

Fuel type	Emission model (A)	Statistics (B)	Difference
	CO_2(t)	CO_2(t)	C = (A-B)/B*100
Diesel	1,664,568	5,493,811	-69.70
Gasoline	3,574,770	2,731,933	30.85
Total	5,239,338	8,225,744	-36.31

Also, there are some differences between heavy-duty vehicles and passenger vehicles related to speed (average differences of around 12%) that are not considered in the current computations

4 Conclusions

In the present work, emissions from two of the major sources of photochemical precursors: NMVOCs and NO_x, were estimated, as well as the emissions from SO_2, CO, and PM. The computer model implemented by Parra and Baldasano [11, 12] was used, following the Ntziachristos and Samaras [10] methodologies to estimate on-road emissions; and Guenther *et al.* [7] methodologies to estimate biogenic emissions.

The principal source of biogenic emissions was shrub land with close to 72% of the total emission as a consequence of its great participation in land-cover uses (40.8%). The uncertainty related to biogenic emission was not estimated.

In respect to on-road traffic emissions, these were mainly located in the coastline and Valencia city perimeter. According to the model the major emitting sources were gasoline passenger cars (47%) and heavy-duty gasoline vehicles (33%.). The major pollutants were CO (70.2%), NMVOCs (13.95%) and NO_x (12.15%). The emission uncertainty was estimated with respect to fuel consumption statistics. According to this, the on-road emission model underestimated the emissions from fuel and overestimated the emissions from gasoline. Additional necessary features will be considered to improve the emission estimations, such as the probability of finding a vehicle type in a certain stretch, or the differentiation of the speed of passenger vehicles and heavy-duty vehicles.

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