Ozone sensitivity study — evaluation of the efficiency of the legislations for the year 2010

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Abstract

Nowadays, the impact of anthropogenic activities on the damage of air quality is well recognized. In order to reduce pollutant concentrations in the atmosphere, an action has already been engaged at the European scale with ratification of the Göteborg protocol and its relay at national and regional scales. Nevertheless the efficiency of such policies has not been subject to a precise analysis yet, in particular for secondary compounds for which formation processes are not linear. The study presented here aims to estimate by 3 dimensional modelling the efficiency of legislations for the year 2010 through simulations of a set of realistic scenarios. Results have shown that an improvement of air quality is expected thanks to the use of new technologies and adherence to these legislations. We demonstrate here that a combined action at a both continental and regional scale is complementary and necessary to efficiently reduce ozone maximal and background values on a regional domain. Nevertheless for the most extreme events, the addition of punctual and local emergency measures appears to be necessary.
Keywords: emission reduction scenarios, legislations, emergency measures, statistical study.

1 Introduction

Ozone is a secondary pollutant made from photochemical reactions involving chiefly anthropogenic precursors emitted from a variety of sources such as road transport, industrial activities, energy production, distribution of fossil fuels. While

WIT Transactions on Ecology and the Environment, Vol 86, © 2006 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR06049

Figure 1: Map of the domain.

this pollutant often overpasses its information and health recommendation thresholds of 90ppbv and 60ppbv, respectively, it has been demonstrated that an exposure to high ozone concentrations may cause respiration troubles and agricultural yield decreases. With the object of reducing tropospheric ozone concentrations, an action has been engaged at the international level with the ratification of the protocol of Göteborg that aims to reduce the volatile organic compounds emissions by 40% from 1999 to 2010. However, due to the complexity of atmospheric ozone chemistry, the impact of such emission reduction on ozone concentrations is difficult to determine and up to now still unknown. It is thus necessary to lead a complete analysis of the impacts of these legislations with integrating tools such as Eulerian modelling in order to answer to the main following questions:

- Quantitatively, what is the effect of emissions reduction policies on ozone regional daily maxima and 8-hour mean values? Can they efficiently reduce exceeding the number of observed ozone threshold?
- At a larger scale, do these policies efficiently reduce the quantity of ozone to be exported outside the domain of the study?
- How does the response of ozone to emission reduction vary from one type of dynamical situation to another?

Our study takes place in this context and aims to bring new elements to these problems.

2 Methodology

The strategy adopted is to conduct a statistical study of ozone production by simulating a large number of representative pollution events, characterized by different

meteorological situations. The study focuses on the Berre–Marseilles region, a coastal site located in the South of France, which offers the possibility to closely validate the simulations using the large 3D measurement database obtained at this site during the ESCOMPTE campaign (2001), Cros *et al.* [1]. This area is frequently exposed to severe ozone events, as a consequence of a combination of geographical, meteorological and chemical factors. First, the site presents a high density of anthropogenic activities with an urban pole (Marseilles) and an industrial pole located in the surroundings of the Berre Pond, which constitutes a significant fraction of the national industrial VOC emissions. Secondly, its topography leads to complex local air masses circulations such as sea-breezes which have been shown to be an aggravating factor during a pollution episode, Lalas *et al.* [2], Wakamatsu *et al.* [3]. Moreover, the site is often exposed to high insulation, high temperatures and low wind speeds during the summer months (from May to September). We selected 30 days of pollution episodes: the 4 Intensive Observation Periods of the ESCOMPTE campaign (15 days of pollution) and the first two weeks of August 2003 which offer the possibility to work on extreme and lasting events. We simulated these days using the 3D chemistry-transport model CHIMERE ([4]) in a configuration especially adapted to the study area (high horizontal and vertical resolution, detailed chemical scheme and emission inventory). These simulations constitute our base case and will be called SC0. The modelling strategy consists in producing emission scenarios corresponding to possible situations of year 2010, and to compare the results of the simulations with the reference case obtained with the real inventory. These scenarios have been defined in the frame of the French national PRIMEQUAL2-PREDIT project, in collaboration with the instances in charge of air quality supervision. The selection of input data for the emission inventory, such as the transcriptions of the legislations, as well as the hypothesis of socio-economic evolution, have been realized at AIRMARAIX, the local air quality network. The production of formatted emission inventories was done at LPCA using the POSTICE software, François [5]. Six emission scenarios were elaborated. They are divided into two parts: those aiming to evaluate the effects of the permanent legislations, and those simulating the triggering of emergency measures. The various scenarios aim to answer those questions:

1. Tendantial (SC1): this scenario only takes into account socio-economic evolutions from 2001 and 2003 to 2010, in order to observe what would be the situation if no supplementary policies were applied during these 7 years. SC1 will constitute the 2010 reference case for the other 2010 scenarios.
2. National Realist (SC2): SC2 aims to evaluate the efficiency of the legislations defined at the national level. It doesn't take into account the regional particularities such as the Atmosphere Protection Plans.
3. Regional Realist (SC3) constitutes the more realistic scenario as it considers the application of both national and regional policies engaged for 2010.
4. NEC scenario (SC4) aims to evaluate the situation if the NEC directive which sets emissions ceilings for 2010 (reduction of the emissions of 40%) was respected. It is considered as a poorly realistic scenario. As the work on this scenario is in progress, the SC4 results won't be presented in this paper.

Table 1: Emissions of main pollutants (ktonnes/year) for each scenario.

	2003 SC0	2010 SC1	2010 SC2A	2010 SC3
NOx	77	88.5	62.7	54.7
VOC	80	87.2	69.7	65.6
CO	418.88	464.66	366.74	336.74

The measures taken into account in the previous scenarios will help to efficiently reduce ozone concentrations in the boundary layer. Nevertheless, supplementary effort will be necessary to reduce ozone peak values during persisting and extreme events. These efforts will probably consist in daily emissions reductions, under the form of emergency measures. Such measures already exist, they are classified into 4 levels according to the severeness of the episode. They concern the industrial and traffic sectors and can be triggered in case of an event forecast. The emergency measures will be tested through our emission scenarios on the basis of the 2010 most realistic scenario SC3 and compared with the 2001–2003 reference cases (SC0). If the actual planned measures don't show a sufficient efficiency, we will test and propose complementary measures.

In order to quantify the simulation scenario results and to define their efficiency on different aspects of the pollution episode, we developed specific statistical indexes which describe the simulated impact on the ozone maximal and mean values, on the total quantity of ozone exported out the domain of study, on ozone cumulated values, and on number of exceeding threshold values.

3 Results: projection of emissions for the year 2010

3.1 Evaluation of lasting legislations

3.1.1 Emissions of primary pollutants

The primary pollutant emissions calculated for the 2010 scenario are presented in table 1. This table shows an increase in the emissions for all the pollutants from SC0 to SC1, due to the socio-economic growth. This has to be principally attributed to the evolution of the traffic sector (3% per year) and of the industrial combustion sector. The strong impact of the emission policies control is illustrated by the difference between scenario SC2A (which takes into account the engaged national legislation) and the reference scenario SC1. Compared to this 2010 reference scenario, emissions indeed decrease by respectively 29, 20 and 21% for NOx, VOC and CO. Such diminutions in the emissions are mainly driven by the respect of directives related to road traffic emissions, and the progressive implementation of new technologies (such as the catalytic converter) in this sector. Moreover, the directive related to the combustion installations (GIC in French for Grandes Installations de Combustion) contributes in a significant way to the emissions decrease.

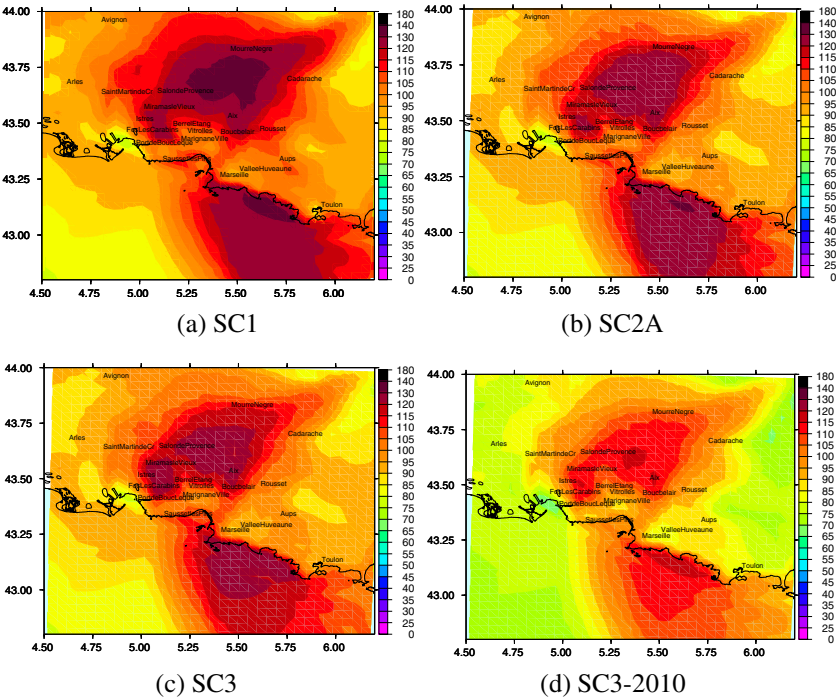


Figure 2: Ozone maximal concentrations (in ppb) simulated for the 2010 scenario for the 05/08/2003 dynamical situation.

Scenario SC3 takes into account the fact that the the Berre–Marseilles region is subject to a supplementary specific legislation. The local Plan of Protection of the Atmosphere (PPA) indeed fixes emissions reduction objectives of 40% of the industrial sources between 2001 and 2010. Even more drastic measures are specified for benzene which emissions must be reduced by 80 and 95% for 2 specific industrial sites. The industrial combustion sector is the principal concerned by this plan. Considering only the industrial sources, the PPA may induce up to 31.8% and 16.4% of decrease for NOx and VOC emissions respectively compared to SC2A.

3.1.2 Impact on ozone concentrations

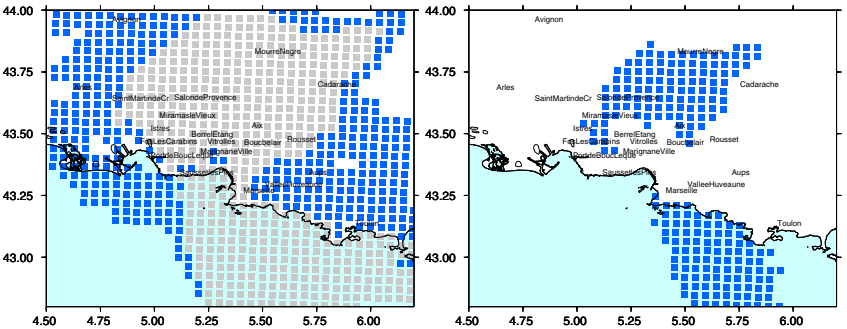
Simulations of pollutants concentrations on the domain have been conducted using the 2001, 2003 and 2010 inventories while keeping the real dynamical situations of the 2001 and 2003 events presented in the section 2. The main and most representative results of the simulations are presented here. Maps of ozone maximal concentration are presented in figure 2 for the 2010 scenario for the dynamical situation of 5th August 2003. This day is characterised by a strong local land-sea breeze circulations. At night, the land-breeze brings the pollutants emitted along the coast other the sea. In the morning, when photochemical processes start, an

ozone plume is built up over the sea and brought back by the sea-breeze towards the land. In the 2010 reference situation (SC1), we can observe 2 distinct plumes – one inland and another out at sea. The plume inland developed downwind the emission areas centered on Marseilles and on Fos–Berre. The second plume over the sea has been demonstrated to be due to nighttime emissions transported by the land-sea breeze circulation (work not shown here). We will commonly call this plume, a "re-circulation plume".

For the 3 other scenarios, differences in the intensity of the ozone concentrations can be observed. If we take into account the national legislation (SC2A), ozone concentrations decrease by 10 to 12 ppb in the plume inland. The impact is less intense on the "re-circulation plume" with a decrease of 4 to 6 ppb. If the regional particularities (PPA) are considered, a supplementary diminution of ozone concentrations is observed. The plume inland is affected by 4 ppb, in the north of the domain, downwind the industrial sources, and at sea the decrease is of 4 to 6 ppb, compared to the SC2A results. Thus, the regional policies concerning only the industrial emitters have a non negligible impact on the ozone peak, and more particularly on the recirculation plume, which highlights the participation of these emitters to the formation of a polluted air masses at sea for the sea-breeze days. In order to reproduce a more realistic 2010 situation, we have tested the impact of an application of the legislations over the whole European continent. Thus, we first simulated the 2010 situation on a continental domain with the emission inventory projected by EMEP, Vestreng *et al.* [6]. Then, we replaced our current boundary conditions by the one calculated for the year 2010. Finally, we lead a simulation on our regional domain of study considering the respect of the legislations at both European and regional levels (scenario called SC3-2010). On the map, we clearly remark a strong difference between the previous scenarios. The taking into consideration of emissions reduction in the surrounding regions and countries has an important impact on the ozone concentrations of our regional domain. Compared to SC3, ozone maximal values are reduced on the whole domain from 18 ppb on the boundaries to 6 ppb inside the plume. Moreover, analysis in progress about the cumulated ozone values have shown that the SC3-2010 scenario involved an significant reduction of this value on the whole domain up to 35%.

The whole previous results put in evidence the double problematic of local ozone production on the domain and long range transport of pollutants. Local policies of emission reductions have an impact on the ozone peak, whereas a control at the continental scale is also efficient in reducing ozone background values. Thus, the action has to be lead at regional, national and European levels as the impacts on ozone concentrations are complementary.

In an applied frame, the air quality networks and the politics refer to thresholds. In this context, we decided to assess the efficiency of the policies on the reduction of the number of exceeding information and alert threshold values. Figure 3 represents the number of exceeding threshold values suppressed in scenario SC3-2010 compared to SC1. The left one is relative to the information threshold of 90 ppb while the right figure is relative to the alert threshold of 120ppb. For this day, the model simulates concentrations above 120 ppb for a large number of boxes in



(a) Impact on the exceeding information threshold values (90 ppb)

(b) Impact on the exceeding alert threshold values (120 ppb)

Figure 3: Map of impact on the exceeding threshold values for the 05/08/2003 dynamical situation. Cells for which the exceeding value has been suppressed are coloured in blue. Cells for which no effect on the exceeding value is simulated are coloured in grey.

scenario SC1. We can notice that all the boxes are coloured in blue which means that all these exceeding values have been suppressed in scenario SC3-2010. This result shows that the legislations act in the right way, nevertheless, the efficiency on the 90 ppb information threshold is still not sufficient. Indeed, SC3-2010 only acts on the extrusions at the periphery of the plume. As a consequence, for the cells in the center of the domain, neither the regional nor the continental action allows a reduction of the number of exceeding values. Hence, for the persistent events, it is necessary to complete the lasting measures with punctual and local emergency measures.

3.2 Evaluation of emergency measures

The existing emergency measures are classified into 4 levels according to their severeness and consist in punctual emission reductions. They concern the industrial as well as the traffic and the public sectors. In the Berre–Marseilles region, they have been tested for the first time during Summer 2003. Nevertheless, their effect on primary and secondary compounds are at present unknown. The evaluation of the efficiency of these measures is primordial, especially since they are costly. In this frame, we put in place a set of scenarios aiming to assess the individual and combined efficiency of the different levels of action. In this section, we present the study conducted on the first level of measure which is the only one who had already been applied.

The first level is triggered in case of an exceeding of the information threshold. On the traffic sector, it consists in a limitation of the speed by 30km/h. On the industrial sector, a specific decree orders a stabilisation of the processes and a postponing of VOCs discharging in the atmosphere. The impact on the emissions

of such measures have been calculated. The results show a very weak effect on the primary pollutants emissions. For instance it only involves a reduction of the NOx emissions lower than 1% in the domain. As it can be expected, the model simulates a negligible diminution of ozone concentrations in the range of 1 ppb. These results show that the first level of emergency measures are not efficient to reduce primary and secondary pollutants concentrations in the atmosphere and alternative or intensified measures have to be tested.

The measures which are suspected to have a significant impact are only triggered in case of an exceeding of the 180ppb threshold (last level). It consists in an alternated circulation in the agglomeration and in more severe specific industrial decrees, and it is expected to decrease the emissions by 20% on the concerned sector. These scenarios haven't been tested yet in our chemistry-transport model, the work on the emergency measures is at present in progress. In case of persistence of exceeding thresholds, we will test a strengthen of the previous measures with a generalisation of the alternated circulation to the whole department and an emissions reduction of the industrial sector of 30%.

4 Conclusion

In this paper, we presented a study consisting in the estimation of the efficiency of legislations in 2010 through emissions scenarios. These scenarios are divided into 2 parts: one aiming to estimate the impact on primary and secondary compounds concentrations of lasting policies, and the other to estimate the efficiency of punctual emergency measures which are triggered in case of a pollution event. The analysis results have shown the necessity to respect the legislations at both continental and regional scales, as their effect was complementary and allowed together an efficient reduction of ozone maxima and background concentrations. For most of the episodes simulated this scenario lead to a suppression of the alert threshold exceeding values. However, for extreme events, the action is limited on the information threshold of 90 ppb, and the addition of punctual emergency measures is necessary. In this frame, we showed that the first level of emergency measure had a negligible impact on primary and secondary compounds concentrations. We will thus test a more systematic application of intensified measures, such as alternated circulation.

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