5.21 NUMERICAL EVALUATION OF DIESEL LOCOMOTIVES CONTRIBUTION IN THE SURROUNDING AREA OF THE RAILWAY STATION "GARE DE L'EST".

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INTRODUCTION

In the urban areas of Paris, air pollution is mainly caused by motor vehicles. But in some urban places, local sources may contribute significantly to a local increase of pollution. These "hot spots" have to be studied with specific tools in order to differentiate responsibility of every type of pollutant sources. Diesel locomotives traffic embedded in a complex urban area is a perfect example of such an issue.

In this paper, a numerical evaluation of the local impact of Diesel locomotives is described in a downtown area. This study follows an intensive monitoring campaign (*AIRPARIF*, 2001). The objective of this study is to evaluate the contribution of Diesel locomotives in the surrounding area of the railway station.

METHODOLOGY

The general methodology that we propose by using numerical modelling in order to find an answer to the above mentioned questions, is divided in five steps:

(1) Emission inventory and all sources evaluation
(2) Definition of the meteorological cases
(3) Computation of the "background profile" at the boundary conditions, running a mesoscale model on all the Ile-de-France Region
(4) Set up of a local operational mesh taking into account buildings and local topography.
(5) Run of scenarios and interpretation of results i.e. pollutant concentrations inside the neighbouring streets with and without the pollution due to the locomotives.

COMPLEXITY OF POLLUTANT EMISSIONS

We consider inside the domain (figure 1) two kinds of sources :

(1) Traffic sources based on morning rush hour peak and COPERT III for vehicle emission factor
(2) Railway station considering a "standard" scenario: Three locomotives are considered with 3 different engine modes: locomotives in departure phase, warming up phase, standing idle phase and arriving phase (knowing that the arriving phase and the standing idle phase give the same emission: no real traction)

Others sources than road traffic or railway station are supposed to be negligible over the target domain. Main pollutant of interest is NOx because Diesel locomotives release a large quantity of this pollutant during all running phases (Table 1). For example, in warming up phase, a locomotive engine releases 7500 g/h of NOx, to be compared with 30 g/h for a private car and 165 g/h for a truck (at speed of 50 km/h). With 80 movements per day, daily contribution of locomotives can be estimated at 68 kg for NOx and 3.4 kg for particles. This amount is nearly the same amount than one kilometre of "boulevard Magenta ", a main road nearby the railway station (with 50 000 vehicles/day, this road releases 60 kg of NOx and 6 kg particles per day).

Table 1. Emission factors used for CC72000 locomotives (source SNCF)

Pollutant	Idle/Arriving	Warming up	Departure (1 min)
CO	3103 g/h	1600 g/h	1480 g/h
NOx	577 g/h	7500 g/h	10420 g/h
Particles	259 g/h	350 g/h	425 g/h

METEOROLOGICAL CASES

The frequent meteorological situation is directly deduced from the annual wind rose computed for the most representative wind station. As emissions take place very close to the ground level, the "worst" case is related to low winds. As the site is downtown of a large city, very stable cases are not considered. So, based on the two prevailing wind direction, 4 meteorological cases are used: South-western wind (220°) with two speeds (2 and 5 m/s), North-eastern wind (20°) with two speeds (2 and 5 m/s).

WIND AND POLLUTANT PROFILES AT BOUNDARY CONDITIONS

These meteorological academic cases are run first in the meso-scale SIMPAR (*Mietlicki F. 1999*) suite with 500m of resolution to give significant profiles for wind, temperature, and pollutant concentration to be used in the "Gare de l'Est" micro-scale model.
For the micro-scale, the ARIA Local CFD software package including the MERCURE processor is applied using the meso-scale output to give the boundary and initial conditions for flow and concentration (kind of "one-way nesting").
This simple nesting gives a more accurate meteorological profile and avoids to start the micro-scale modelling with a "pure" air in and at the boundary of the domain box. For instance, the typical profile of NOx background is 70µg/m3 near the ground and 15 µg/m3 at 200m above ground level.

MESH GENERATION

Mesh generation is one of the most difficult and sensitive part of the modelling. Considering real topography and high density of buildings, it was a challenging issue to build an operational micro-scale mesh.
The general methodology that we are using consists of:

(1) taking into account terrain topography using curvilinear coordinates. Topography gives the low boundary condition and defines the "following terrain coordinate"
(2) generating buildings and obstacles as full or semi-full cells. Buildings are in fact full or partially full meshes. Local modifications of the "rough terrain" are done to make sure that the ground (and so the roof) is horizontal under every building.

These two processes can be done "automatically" by importing numerical geographical data as French IGN DEM and 3D DXF format files (DXF is the AUTOCAD exchange format). Naturally, it is important that the mesh "automatically" generated be carefully investigated, and simplifications such as elimination of non significant obstacles or merging of buildings situated very close to one another, have to be undertaken.

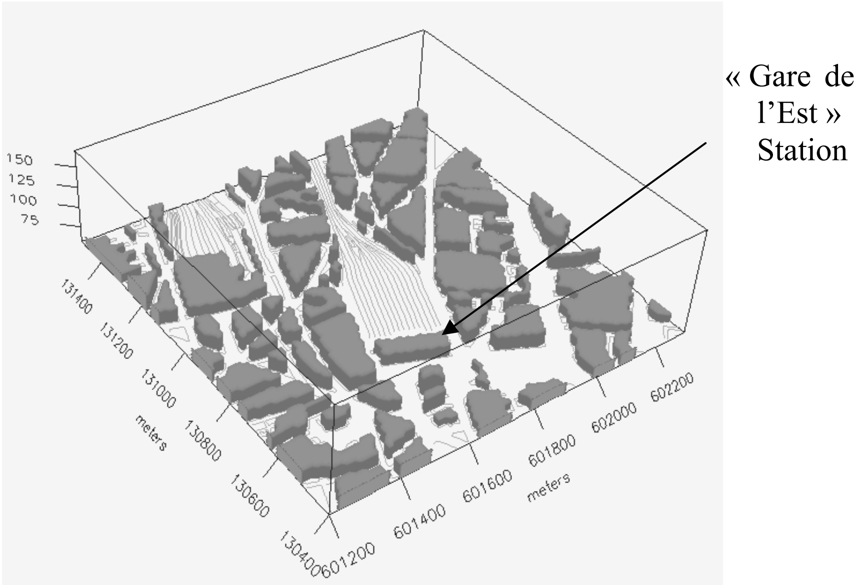

Figure 1. Domain 1100 m x 1100 m x 170 m with a mesh 10m in horizontal and a stretching mesh in vertical from 1 m close to the ground to 40 m at the top of the domain.

RESULTS

Wind field

The flow around building is very complex, due to the high density of obstacles. There is a combination of several 3D flow structures affected by the wakes behind buildings, by canyon circulation and by Venturi speed-up. Figure 2 shows the streamlines 2m above ground level. The wake of the building "Gare de l'Est" could be clearly identified.

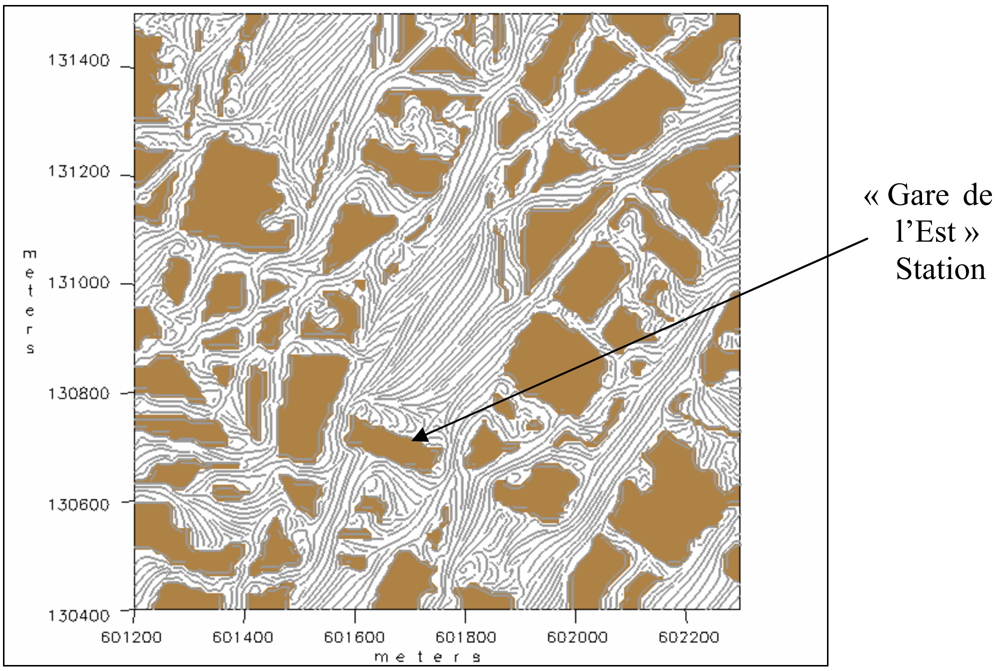

Figure 2. Streamline for South western wind 5m/s

Concentration field

Without locomotives, concentrations computed in streets are realistic compared with level measured in roadside station of AIRPARIF network. Some high values can be detected where

the wind and turbulence are very low. When locomotives are turned on, concentration of NOx increases significantly in the station vicinity and for the district in downwind direction.
For each mesh, percentage of impact is calculated using the ratio between the NOx concentration due to locomotives and the total NOx concentration (locomotives + road traffic + inlet boundary conditions).

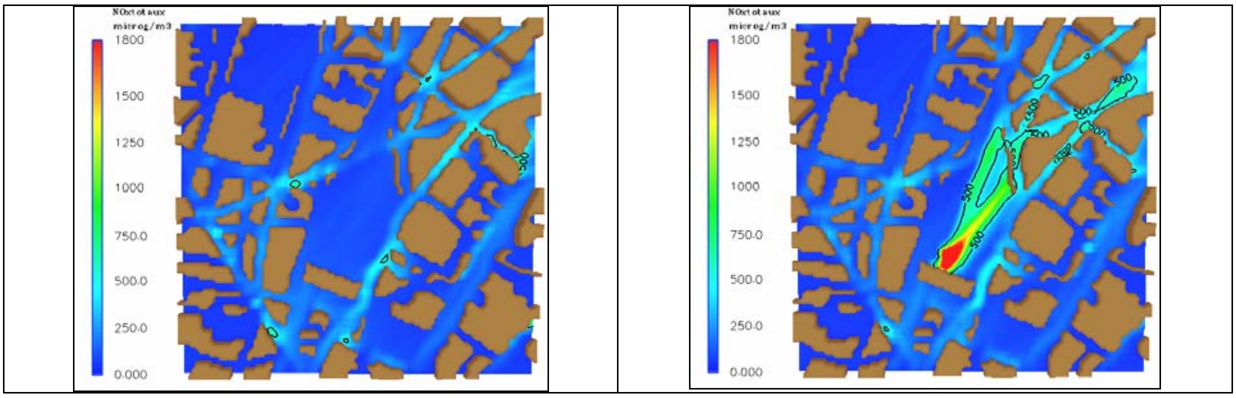

Figure 3. NOx concentration (wind 5 m/s SW) left : without Diesel locomotives right: 6 minutes after locomotives engines running (with 500 µg/m³ isocontour)

In case of South-Western wind (most frequent in Ile-de-France Region) the total plume due to Diesel engines follows the railways before spreading in the main street at the North East part of the domain. The NOx contribution of the station could be, at peak level, between 60 and 70% in this area, with spatial extension of 300 metres where the contribution of locomotives is greater than 25 %. Maximum computed values are on the railway (1800 µg/m^3) and in the street of the North-Eastern part of the domain (1000µg/m^3).

In case of North-Eastern wind, we can notice the rule of the Station building itself. The total plume of Diesel engines has to go up or around the building improving its dispersion (Figure 4). Also, the contribution of the diesel engines is less for low wind because the hot exhaust rises easily and the car traffic concentrations are higher.

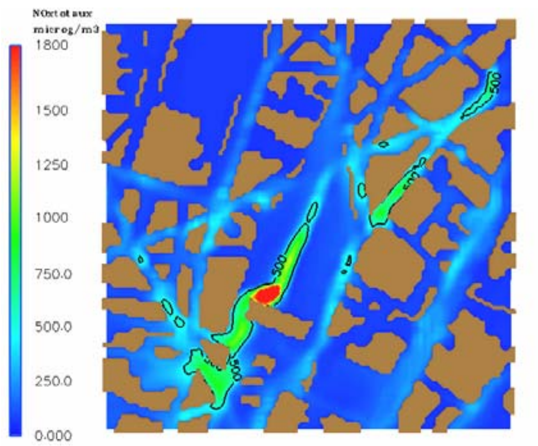

Figure 4. NOx concentration (wind 5 m/s NE): 6 minutes after locomotives engines running (with 500 µg/m³ isocontour)

TESTS OF ABATEMENT SCENARIO

A first action made by SNCF was to reduce the warming up time to the minimum (i.e. 2mn against 6mn in the previous protocol). The second countermeasure, currently under implementation, is a new motorization of engines. With new engine, locomotive emission will be reduced by 67% in standing idle mode and by 45% during warming up phase.

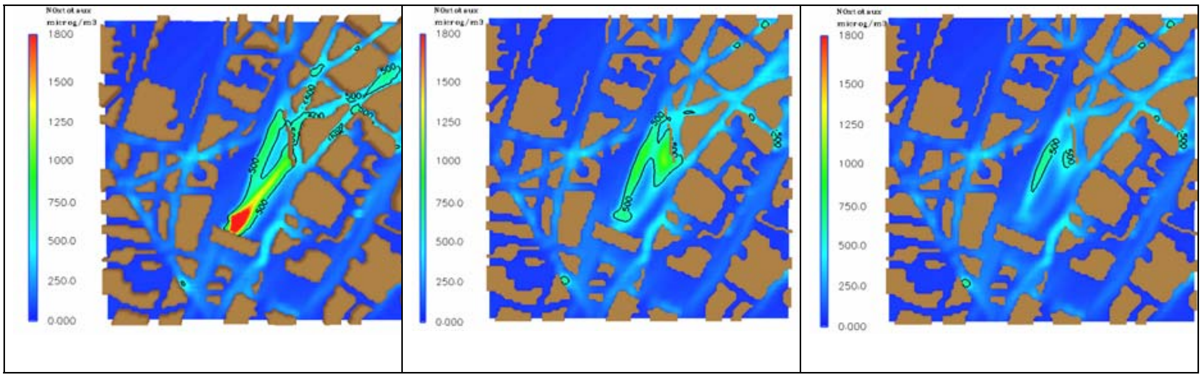

Figure 5. Impact on air quality 6 minutes after engine starts: from left to right, 1) old engines 2) new warming up protocol (reduced from 6 to 2 minutes) 3) new motorization of engines.

CONCLUSION

The modelling approach gives a reliable tool to test scenarios and gives an answer to the classical "what if" questions. This tool shows several results confirmed by the monitoring campaign:

(1) Contribution of such engine is high and can be more than 50% even at 500m of the station
(2) High dependency with the meteorological data and with a non intuitive result : due to the hot engine plume, the low wind are not the classical "worst case"
(3) Persistence of NOx Diesel Engine could reach more than 10 minutes (low winds)
(4) The double solution of new protocol limiting the warming up phase an new motorisation should improve significantly the situation

ACKNOWLEDGMENTS

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REFERENCES

AIRPARIF, **2001:** "Etude de la qualité de l'air dans le secteur de la gare de l'Est".

Mietlicki F. and Gombert D., **1999** :"Alternating Traffic Scheme : the lessons of the October 1 experiment. A Preliminary Study Using AIRPARIF Air Quality modeling Tool. 6th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes Rouen 11-14 October 1999