AIR QUALITY MODELLING OF ROAD PROJECTS USING A 3D COMPUTATIONAL FLUID DYNAMICS (CFD) MODEL

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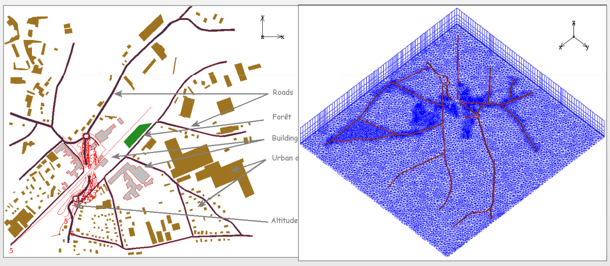
USE OF CFD IN ENVIRONMENTAL CONTEXT

Software used in environmental applications are generally of Gaussian nature. However, the Gaussian software cannot take into account strong declines (mountain areas) or urban context with many obstacles (buildings but also trenches and tunnels) which is where the strongest health impact is expected. 3D CFD software are therefore more adapted to the urban context.
3D CFD models are able to model the 3D wind field pattern on hilly terrains and over complex obstacles by solving the Navier-Stokes equations for atmospheric flow in a RANS formalism. It includes mass, momentum and enthalpy conservation, state law and equations for advection-diffusion.
The software used in this study is the 3D CFD software **fluidyn-PANROAD,** a module of fluidyn-PANACHE dedicated to air quality assessment near roads.

Railroad crossing in the city of Molsheim, France



Numerical model of terrain and 3D body-fitted mesh

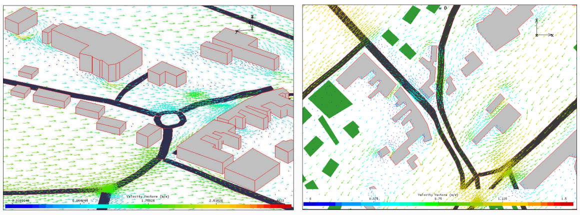
DETAILS OF MODEL SET-UP

Topography. The projected land plannings require local modifications of the terrain by road fills and excavations. The information from the topographical database is either converted into area with a roughness coefficient depending on the land occupancy (urban areas, forests, fields, water bodies, open spaces, etc.) or is explicitly described in the model. In the current study, each building near the railway crossing has been integrated in 3D.

Mesh. *fluidyn*-PANROAD builds a 3D unstructured embedded mesh, curvilinear and refined at and around road levels where a high precision is required and where the obstacles and terrain features will considerably modify the windfields and pollutant dispersion. The finer cells are mainly located near the road sectors and are of the order of a few meters.

Weather. The weather conditions are defined by a velocity and a direction at a given altitude as well as an atmospheric stability defined by vertical profiles for wind, turbulence and temperature. They are applied to the computational domain boundary, and the software defines the wind fields (velocity and direction) at any point inside the domain by solving the fluid mechanics equations. Thus the wind flow is influenced by the terrain features : buildings, urban areas, topography and fields.

Pollutant sources. The traffic data was extracted from the survey results and traffic modelling done by the city planning services. The calculation of the pollutant emissions in the atmosphere from traffic data has been done with the software IMPACT-ADEME version 2.0. Dispersion of the pollutants is then carried out in 3D on stabilized windfields for all the weather conditions defining the windrose.



Examples of 3D wind field in an horizontal plane z=1.5m

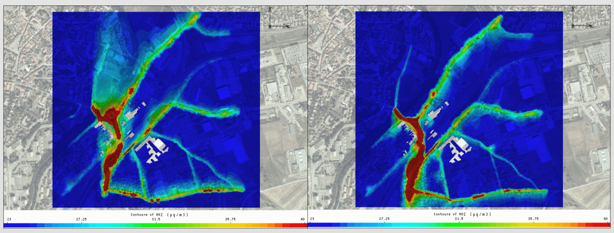
ASSESSMENT OF IMPACT IN REGULATORY STUDIES

This section presents a sample of results obtained. A comparison of experimental campaign results with numerical results obtained for the annual average shows that the standard deviation for NO_2 concentration results are between 2 and 23% with an average at 10%. These results are quite good considering that the experimental results were done over a period of 15 days whereas the numerical results have been produced for a yearly average (both for weather and traffic data).

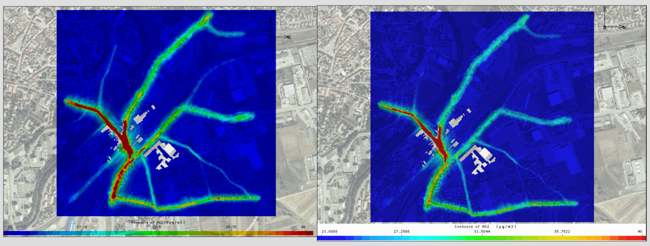
The following set of pictures shows concentration contours of NO_2 at ground level for two wind conditions at 0° and 180°N and 3 m/s. This type of results can be used to discriminate between the proposed layouts for the railway crossing.
By comparing the reference years 2022 to 2008, NO_2 concentrations decreases by 30% on the entire domain. Even if the traffic for 2022 is larger than in 2008, the more severe air quality emission norms for new vehicles, fuel specifications and the technological evolution of motors, estimated to be less polluting and more environmental friendly in future years have contributed to this decrease.

Comparison between numerical results and experimental campaign at monitoring stations

Monitor	Experimental results (µg/m³)	Numerical results (µg/m³)	Standard deviation (%)
1	28,7	35	19,8
2	44,3	35	23,5
3	58,4	55	6,0
4	36,8	43	15,5
5	65,2	67	2,7
6	38,2	37,4	2,1
7	37,6	32,6	14,2
8	31,0	31,8	2,5



NO_2 concentration at z=1.5 m for 0° and 180°N wind direc tions



NO_2 concentration at z=1.5 m for 2008 and 2022