Lise, J and L. Carrie, 1997.

Validation of fluidyn-Panroad Model using a measurement data set made on a motorway.
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Abstract:

One of the ways to evaluate air quality near roads is to perform simulation of pollutant dispersion in atmosphere in these areas. These studies allow in assessing impact on air quality of road sections. But many parameters are involved in these simulations (road emissions meteo data terrain topography buildings vegetation etc.). Then a complete tool designed to compute pollutant dispersion in air near roads should take these parameters into account. Most of the software available for simulation of road pollutant dispersion is a Gaussian model. One of the main limitations of these models is that they cannot handle hilly terrain. Fluidyn-PANROAD has been developed to avoid limitations of the Gaussian models.

Fluidyn-PANROAD is a three dimensional CFD code designed for road pollutants dispersion in the atmosphere in semi-urban and rural areas. Fluidyn-PANROAD solves complete fluid dynamics conservation laws can handle direct pollutant emission from road traffic hilly terrain buildings urban areas etc. All the common pollutants released by car exhaust CO, CO2, particulate matter, hydrocarbons can be modelled. We present fluidyn-PANROAD validation computations made using a measurement data set on a French motorway. Measurements were made during one month along several motorway sections.

Introduction

Most of the software designed to simulate pollutant dispersion near roads are a Gaussian model like CALINE 4 developed by California Department of Transportation Hatano Benson and Pinkerman (1989) but accurate modeling of complex roads structure requires tools more sophisticated like fluidyn-PANROAD. Indeed fluidyn-PANROAD with its 3D CFD Modeling approach allows taking into account exactly all terrain features (buildings hills valleys forest and physical phenomena) we present in this paper a validation of the model by comparison with site measurements and CALINE 4.

We will first describe fluidyn-PANROAD and then will present the validation cases.
Lastly, we will discuss in detail the results in comparison with measurements and CALINE 4.

1. The fluidyn-PANROAD Model.

Fluidyn-PANROAD model is apart of the fluidyn – PANACHE family. Based on a finite volume model approach it solves fluid dynamics conservation laws. In general unless specified otherwise full Navier - Stokes equation are solved. In some cases, a second order resolution is sought to limit the diffusion. Curvilinear mesh is used if the terrain is not flat. If the terrain is more or less flat the mesh can be either Cartesian or chopped. Thermal and gravity effects are included by the inclusion of source terms. Turbulent diffusion is calculated by K-diffusion, K-E Model. The help of a modified K-E model does the flow behind obstacles buildings.

Fluidyn-PANROAD prepares automatically a curvilinear mesh to follow exactly the terrain and the obstacles. The precision required by the user is translated as accurately as possible. Though a higher precision requires a longer time of calculation.

This is a dispersion model designed to evaluate pollutants concentration near roads and motorways. The use could define the roads and all the real terrain features using a friendly graphic user interface Pollutant emission from the roads could be set directly by the user or computed buy the software. User must give information about the traffic data on the roads using these data and the emission database in the software PANROAD computes the pollutant emissions form the roads

2) **Description of the Validation cases:**

Pollutant concentration measurements were made near a French motorway to evaluate contribution coming car in total atmospheric pollution. Measurements were made during the month of March 1995 We isolated two motorway section measurements to make simulations with Panroad and Caline 4 The measurements were made for each section a two monitor points level) noted monitor A and T after. These computations will be compared with measurements. We will describe one after the other the two motorway sections (the two motorway sections will be noted after road section 1 and road section 2 We will show the location of the motorway, the meteorological condition and the traffic data.

We find in this section a toll. We choose this section because it's at this location that the pollutants concentration should be higher. Indeed, on this section there is a deceleration area (located before the toll) a low speed area (at toll level) and an acceleration area after the toll. Moreover for most of pollutants CO CO2 NOx higher emissions are observed for low vehicle speeds. For this section measurement duration was 14h30m.

Meteo conditions

For the measurements period the average meteo conditions were:

Wind speed : 1.2 m/s
Ambient temperature : 2.6 deg. C
Pressure : 1.028×10^5
Relative Humidity : 81.7 %
Prevailing wind direction : 0 deg./north

Traffic data:

Average traffic flow	: 1579 vehicles/h
Percentage of heavy duty v	: 42%

Complimentary data:

We cut this section in three parts. We made this to follow the road geometry and to specify different vehicle speed on each part. This allows a better pollutant emission modeling.

Vehicle speed at toll: 60 kmph
Vehicle speed out of toll: 80 kmph

Background concentrations (µg/m3):

CO	258
NOx	11.4
VOC	1330
PM	6.06

Road Section 2

This section is located after the toll is an interesting section because at this level of the motorway the cars should have an uniform speed. Then this section could represent arbitrary motorway section .The measurements duration for this section was 4h30m.

Meteo conditions

For the measurements period the average meteo conditions were:

Wind Speed	:	8.8m/s	
Ambient temperature	:	7.4 C	
Pressure	:	$9.98\ 10^4$	Pa
Relative Humidity	:	67.4%	
Prevailing wind direction	:	230 North	

Traffic data

Average traffic flow.	:	2 771 vehicles/h
Percentage of heavy duty vehicles.	:	33.1%

For this case the motorway is made of only one section. Indeed there is no consideration for changes in road width variation and vehicle speed is assumed to be uniform. Complementary data are listed below:

Vehicles speed. : 80 KMPH

Background concentration (Mg/m3)

CO	239
NOx	10.5
VOC	1238
PM	5.6

Results and Discussion:

We ran the simulations with PANROAD and CALINE 4 with the same input data. The pollutants considered are CO NOx Voc and Pm.

Road Section 1
The pollutants concentration (measurements PANROAD and CALINE4 results) at monitor points A and T are presented in tables 1 and 2

UNIT : µg/m3 MONITOR A

Pollutant	Monitor A Measurements	Monitor A PANROAD	Monitor A CALINE4
CO	400	425	458
NOx	209	200	376
VOC	-	1355	1340
PM	34	22	21.8

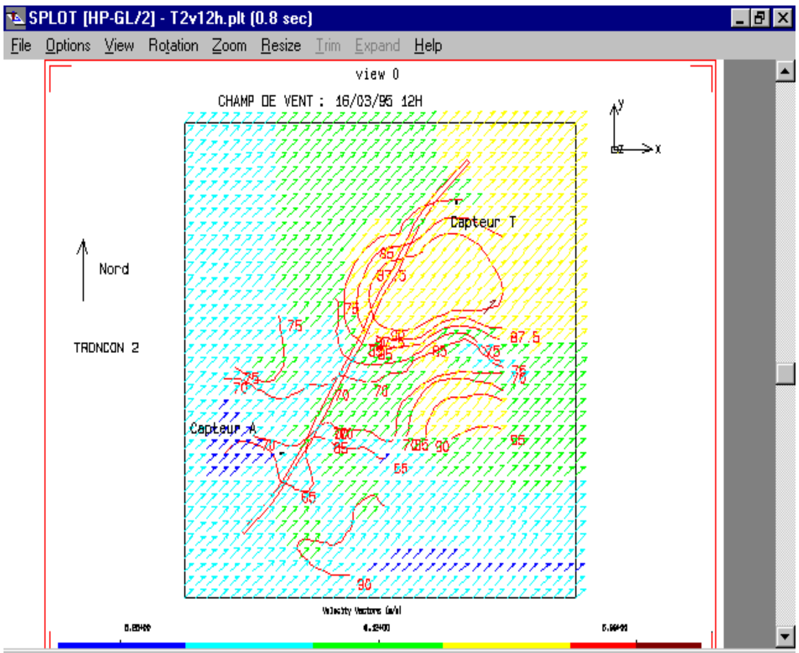
Table 1: Pollutants concentrations at monitor A location.

UNIT : µg/m3 MONITOR T

Pollutant	Monitor T Measurements	Monitor T PANROAD	Monitor T CALINE4
CO	400	258	258
NOx	89	11.35	11.35

VOC	1714	1334	1330
PM	25	6.06	6.06

Table 2 : Pollutants concentration at monitor T location

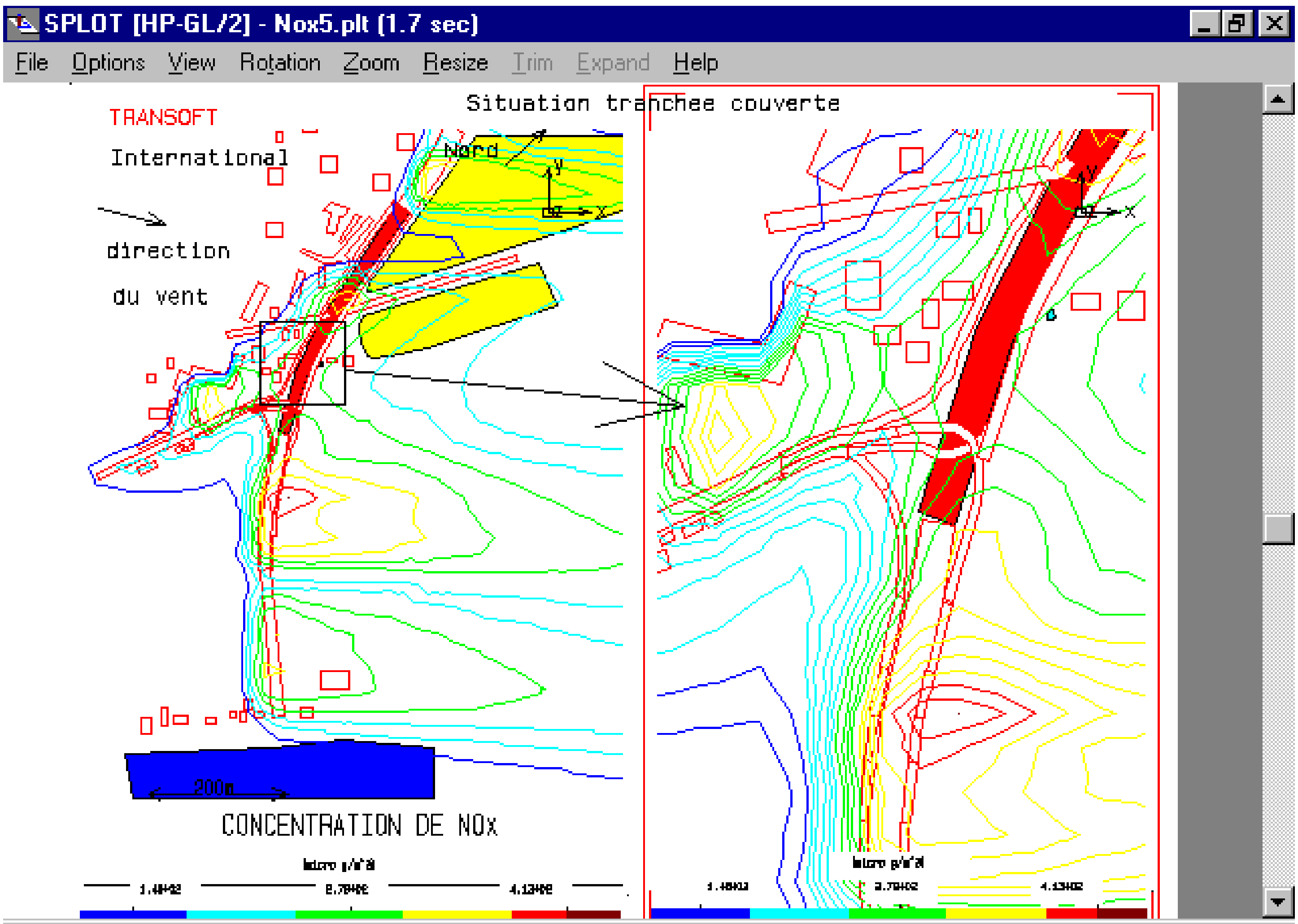


At monitor A location for all the pollutants the PANROAD predictions are closer to the measurements than Caline 4 measurements. The models (PANROAD and CALINE4) under-estimate the CO concentration. CALINE 4 error is 20% while PANROAD is 11%. For NOx PANROAD over-estimate slightly the concentration 42 µg/m3 to 32µgm/m3 But Caline 4 under estimate strongly NOx concentration (10 µg/m3 predicted in relation to 32 µg/m3 measured).

At monitor T location also PANROAD results are closer to the measurements. For CO we notice an important difference between measured concentrations and predictions. This could be like for section 1 a consequence of change in wind speed and direction. Nevertheless the concentration predicted by PANROAD (310 µg/m3) is closer to the measurement (600 mg/m3) than the Caline 4 prediction (254 µg/m3) for NOx PANROAD prediction is over estimated (110 µg/m3 compared to 68 µg/m3) while CALINE 4 prediction is underestimated (48 µg/m3) Complimentary simulation with the changes of some parameters like wind and speed will be necessary to explain the differences. For VOC predicted concentrations are lower than the measurements. This may come from an under estimation of VOC emission factor. For suspended particulates PANROAD finds almost the same value as the measurement (14 µg/m3 predicted 13µg/m3 measured) CALINE 4 prediction (8.9 µg/m3 is far form the measured value).

Conclusion:

We showed in this paper the validation of the pollutant dispersion software near roads for fluidyn-PANROAD in comparison with site measurements and Gaussian model Caline 4.The results demonstrated good agreement between PANROAD predictions and measured concentrations. Moreover PANROAD predictions in all the cases and for almost all the pollutants are closer to site measurements than Caline 4. Then fluidyn-PANROAD appears as an important improvement in modeling of pollutant dispersion near roads



Road Section 2

The pollutants concentration (measurements PANROAD and CALINE4 results) at monitor points A and T are presented in tables 3 and 4

UNIT : μg/m3 MONITOR A

Pollutant	Monitor A Measurements	Monitor A PANROAD	Monitor A CALINE4
CO	300	266	239
NOx	32	42	10
VOC	-	1269	1239
PM	-	8.4	5.6

Table 3: Pollutants concentrations at monitor A location.

UNIT : μg/m3 MONITOR T

Pollutant	Monitor T Measurements	Monitor T PANROAD	Monitor T CALINE4
CO	600	310	254
NOx	68	110	48
VOC	1428	1274	1250
PM	13	14	8.9

Table 4 : Pollutants concentration at monitor T location

The results the most representative are those computed at monitor A location. Indeed this monitor is located downwind of the road, and receives all the pollution released on the motorway. This is the opposite for monitor T that is upwind of the road. In the simulations, the pollutants transport towards this monitor is only made by diffusion. Moreover the pollutant measurement is a concentration averaged over several hours. But during these hours the meteo condition (wind speed and direction) was not constant like for the simulations. We might have for a small period a change in the wind direction, blowing the pollutants toward monitor T. The consequence of this kind of phenomenon is that we get for a small period a very high concentration at monitor T location. Then when the concentration is averaged for monitor T, the mean concentration is higher than the concentration that we would get if the wind direction were constant. Comparison of the results between simulations and measurements shows very well this phenomenon. The concentrations computed by PANROAD and CALINE 4 remain at the same level as the background concentrations while concentrations measured at monitor T are of same order as those measured at monitor A.

There is a good agreement at monitor A location, between measurement and PANROAD results. Global comparison of the results (measurements, PANROAD and CALINE 4) shows that PANROAD predictions are better than those of CALINE 4. Thus for CO, PANROAD prediction gives 425ug/m3 while the mean measured concentration is equal to 400 ug/m3. In the same conditions, CALINE 4 prediction is equal to 458 ug/m3. Then we notice that the CO concentration is more over-estimated by CALINE 4. In the same way, NOx concentration predicted by CALINE 4 is strongly over-estimated compared to the measured value (376 ug/m3 predicted in relation to 209 ug/m3 measured). This gives an error equal to 80% for CALINE 4, while PANROAD error is equal to 0.04 % (200 ug/m3 predicted in relation to 209 ug/m3 measured). Then for NOx concentration also, PANROAD results are good and much better than CALINE 4. For particulate matter the prediction of CALINE 4 (21.8 ug/m3) are close to PANROAD (22 ug/m3), but the two predictions under-estimate the measured concentration. This comes probably from inaccuracy of particulate emission factors.