Dispersion of radionuclides in a urban environment: Evaluation of a CFD model

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- DIFLU Project
- Numerical model description
- Results
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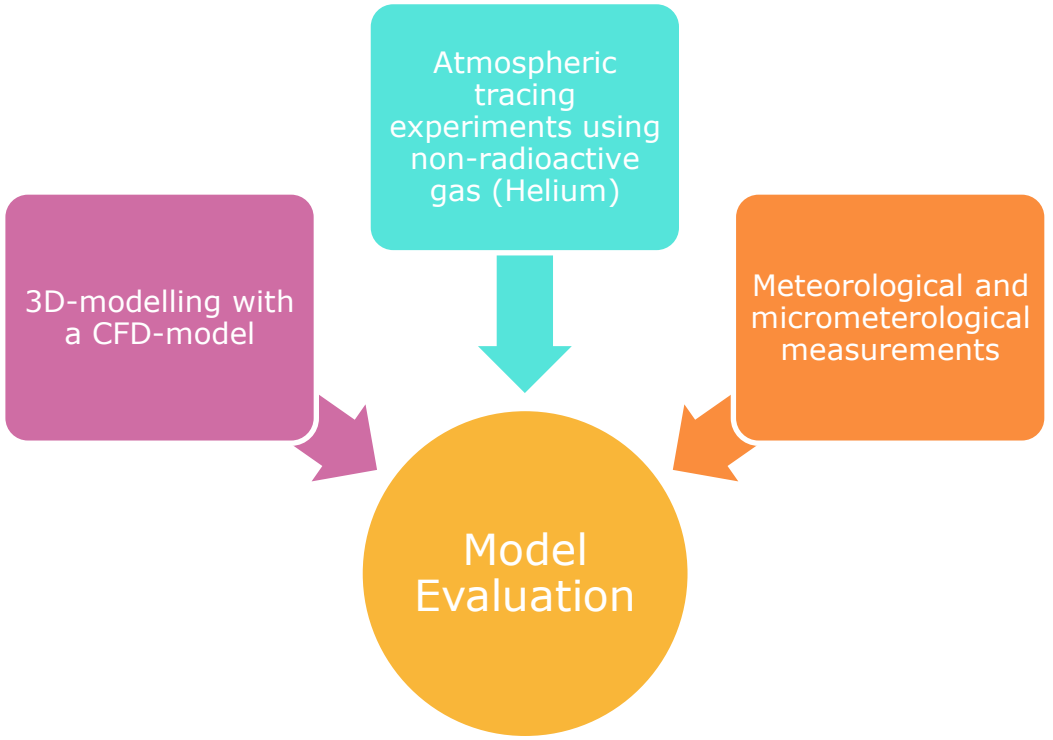
DIFLU Project

- French regulation requires a radiological impact assessment of the cyclotrons
- Impact assessment has been done so far by Gaussian type modelling ⇒ need to improve the account of local obstacles near the emission area
- DIFLU is a project run by IRSN in partnership with FLUIDYN and ECL (2019-2024)
- Objectives are:
  - Better understanding of the gas dispersion in urban area (distance up to 500 m from the release point)
  - Make sure CFD model can give realistic concentration values for radiological consequence assessment



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DIFLU PROJECT

- Experiment site : BEUVRY hospital (France), a suburban area
- Helium samplers
  - 1st data set: 9 Helium releases (10 min): 170 samplings, 8 real time analysis
  - 2nd data set : 10 Helium releases (8-10 min): 220 samplings, 8 real time analysis
- Meteorological devices:
  - 5 anemometers (Wind speed and Direction close to ground)
  - Lidar (Wind speed and direction at h=40 m, 120 m and 290 m)
  - Watchdog station (air temperature, pressure level and solar radiation)

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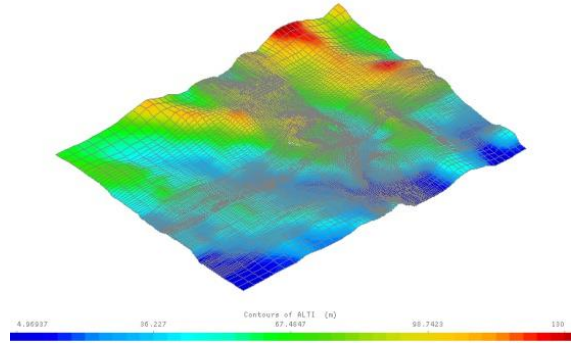
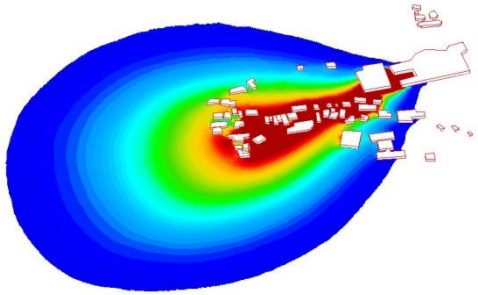
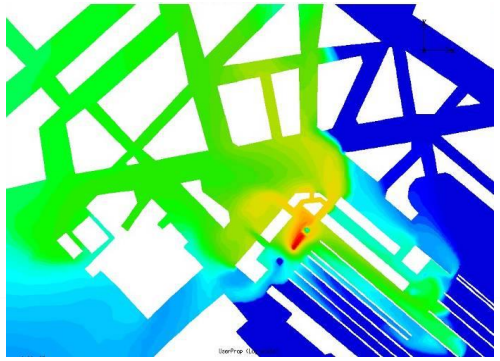
Description of the CFD Model

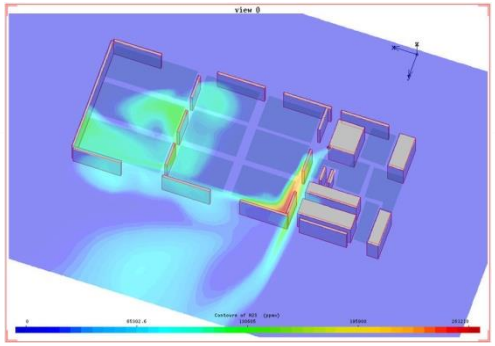
- Fluidyn PANACHE: A realistic approach for atmospheric dispersion
  - Solve Navier-Stokes equation
  - Topography and obstacles
  - Local atmospheric and mechanical turbulence



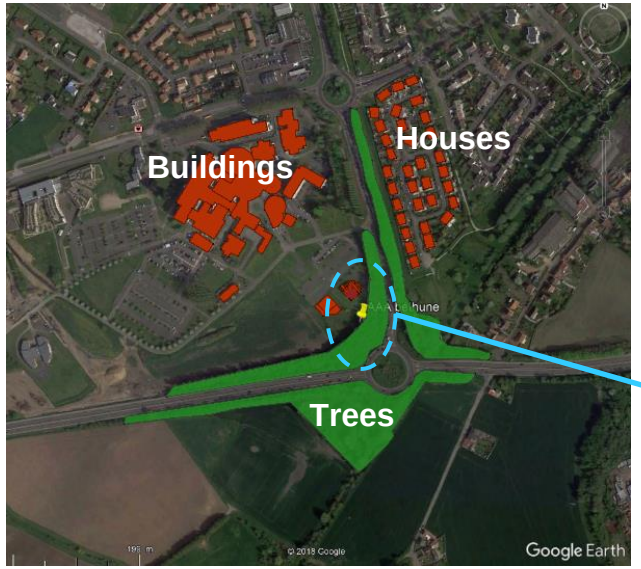
- Numerical model
  - ABL profiles from Monin-Obukhov Similarity Theory
  - RANS numerical approach
  - k-ε turbulence model
  - Parallel solver

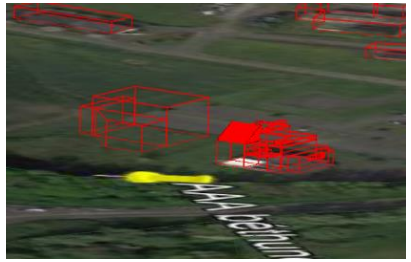


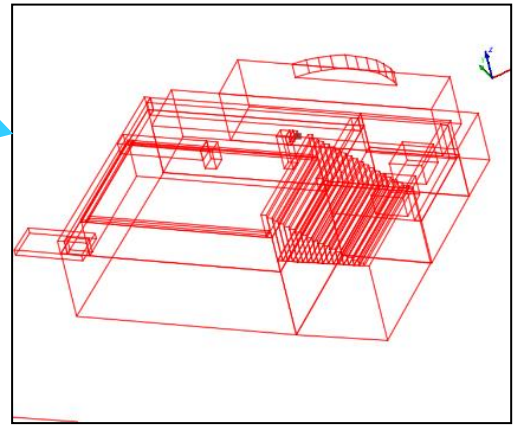


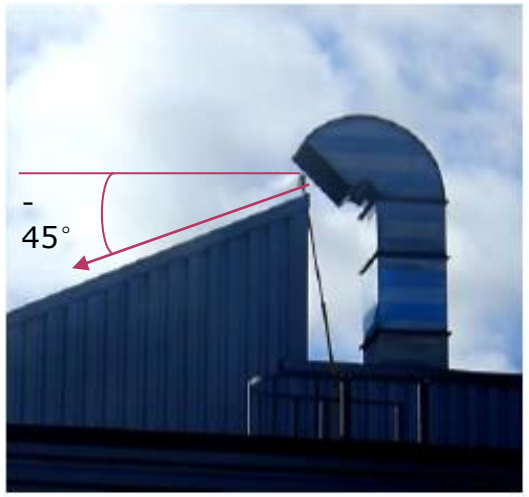


DESCRIPTION OF THE NUMERICAL MODEL





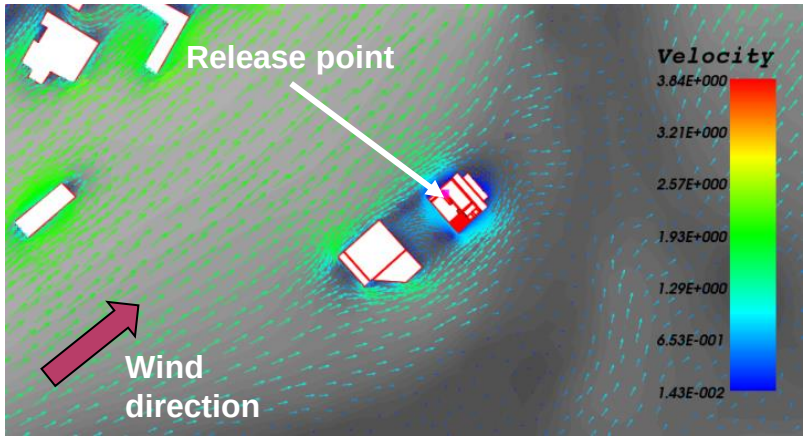


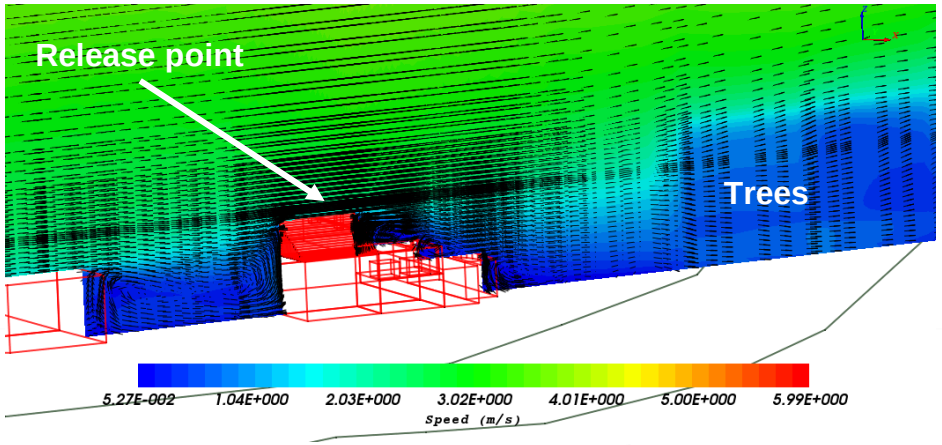


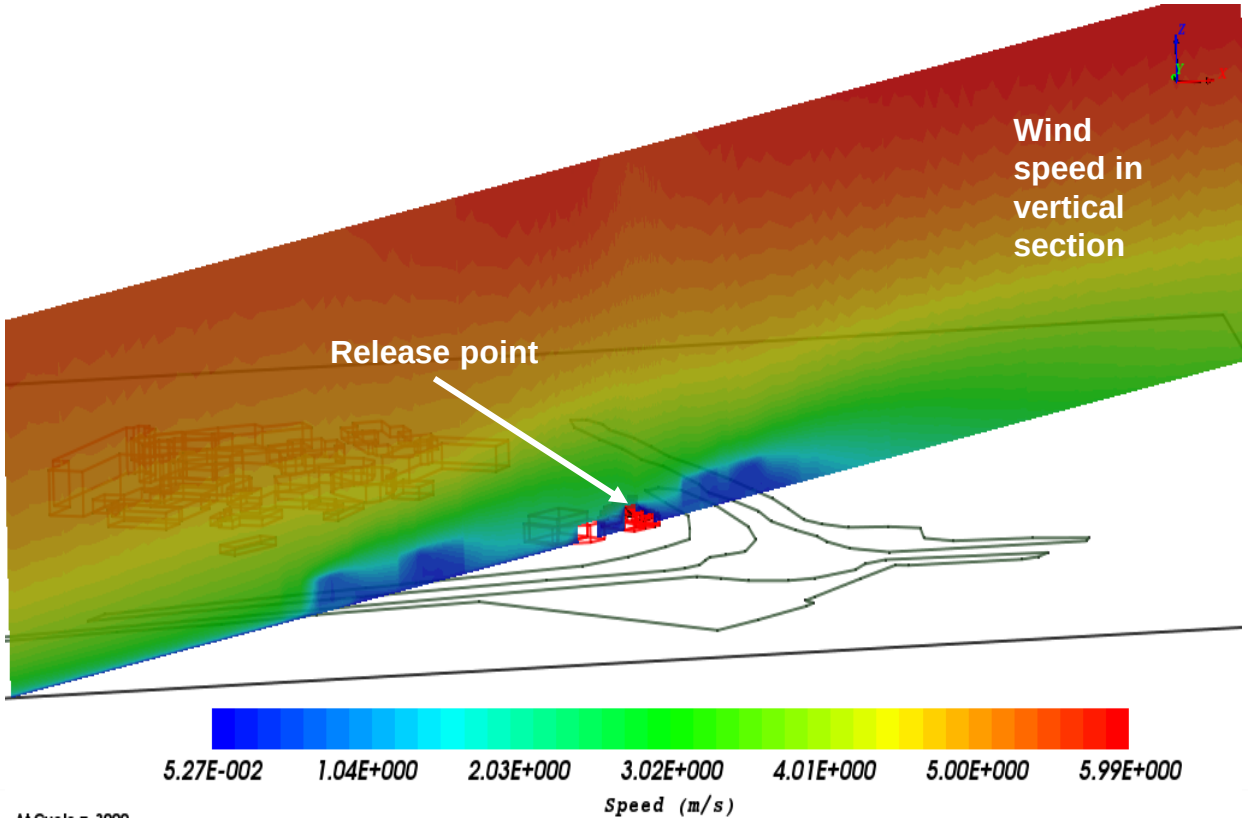
Domain	800 m * 800 m * 150 m
Default roughness height	0.1 m
Mesh	Wedge (unstructured)
Boundary Conditions	MOST profiles with Lidar measurements at 40 m Neutral atmospheric condition in most of the cases
Emission data	Height : 10 m Flow rate: 7200 m3/h

WINDFLOW

- 3D Windflow simulation in Fluidyn PANACHE

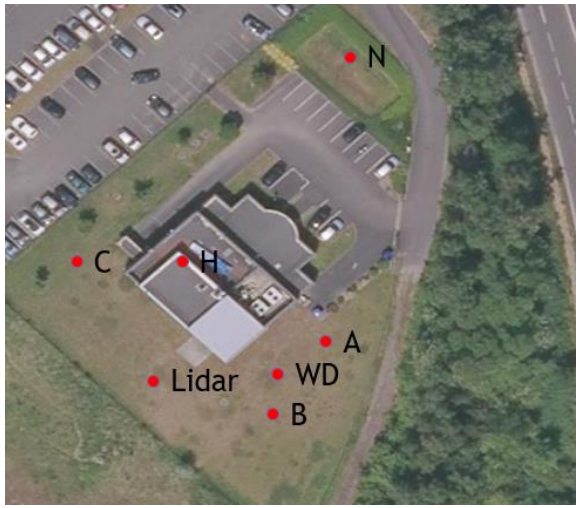


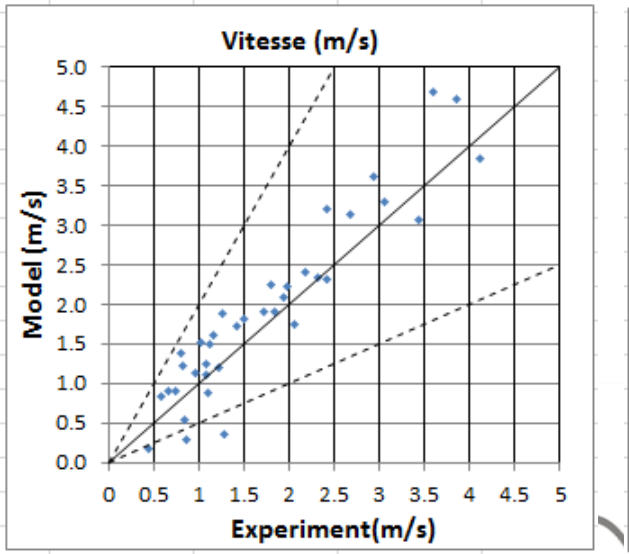


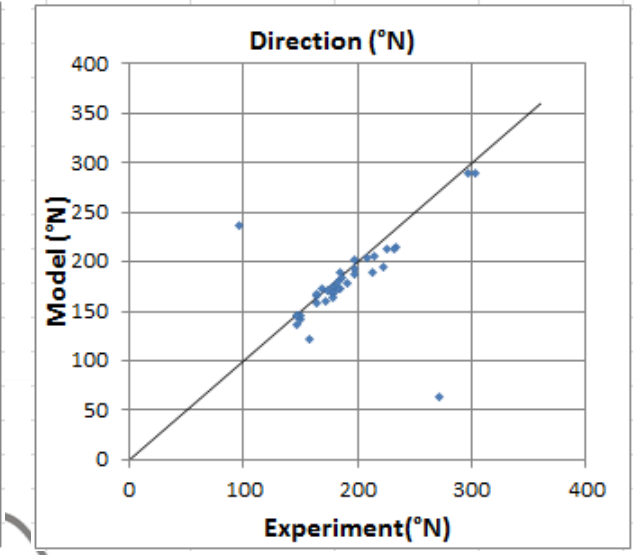


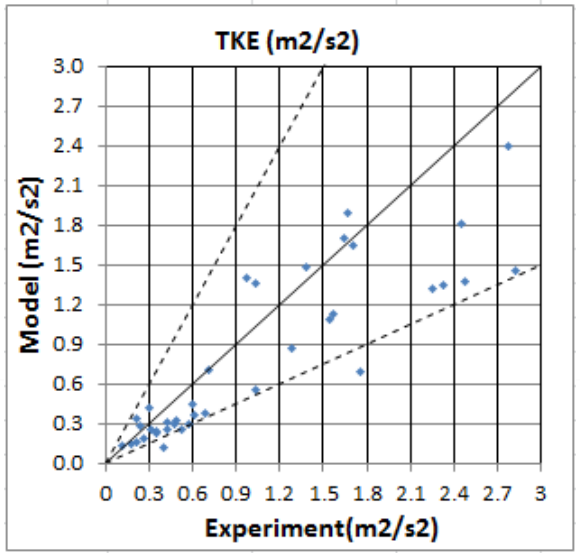
WINDFLOW

- Comparison for 39 couples of data (wind direction/wind speed) from meteological data recordings (LIDAR and Anenometers)
- FB= -0.02 ; NMSE = 0,04; FAC2=94%
- Good agreement Model/Measurements
- Slight underestimation of TKE









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DIFLU – DISPERSION

- Pairs of Cp (predicted concentration) and Co (observed concentration), which represent averages over the same averaging time (8 to 10 min);
- First analysis performed by tracing scatter plot and quantile-quantile plot;
- Second analysis of the performance of the CFD model is not conducted only for the maximum concentration on a sampling line but point to point (Pairing in space);
- Statistical performance measures recommended by Chang et al. (2004): FB, NMSE, FAC2, FAC5

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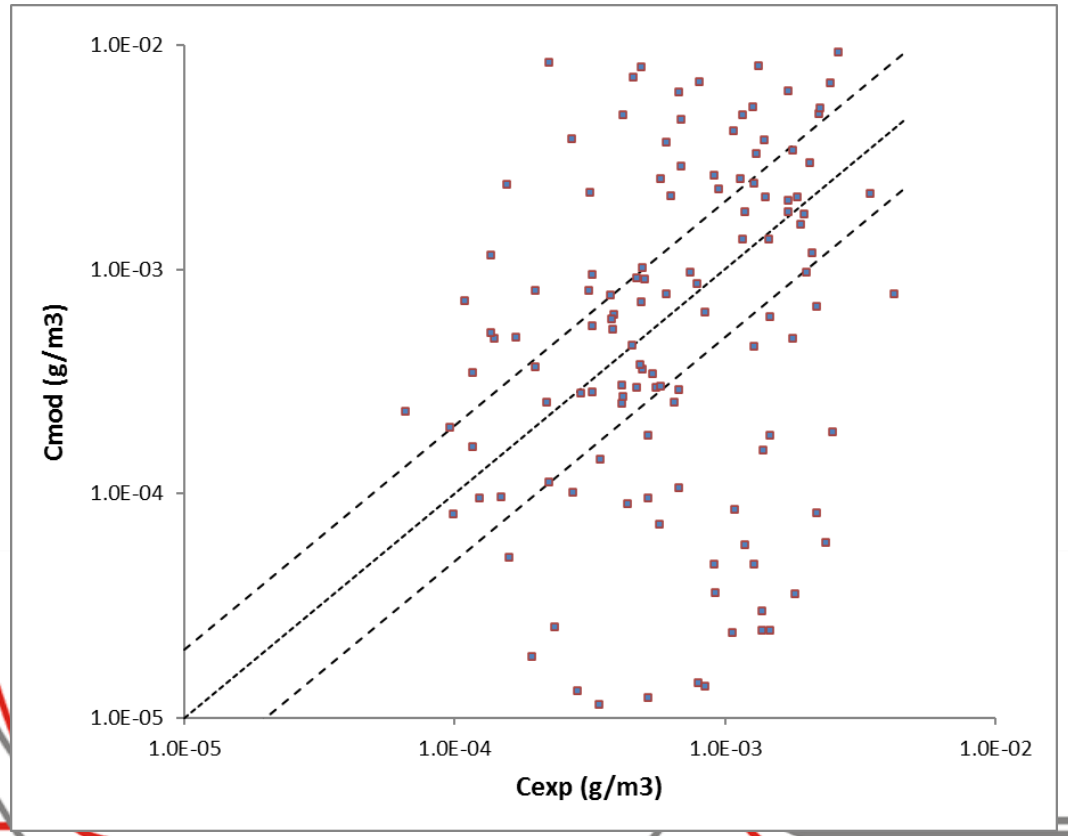
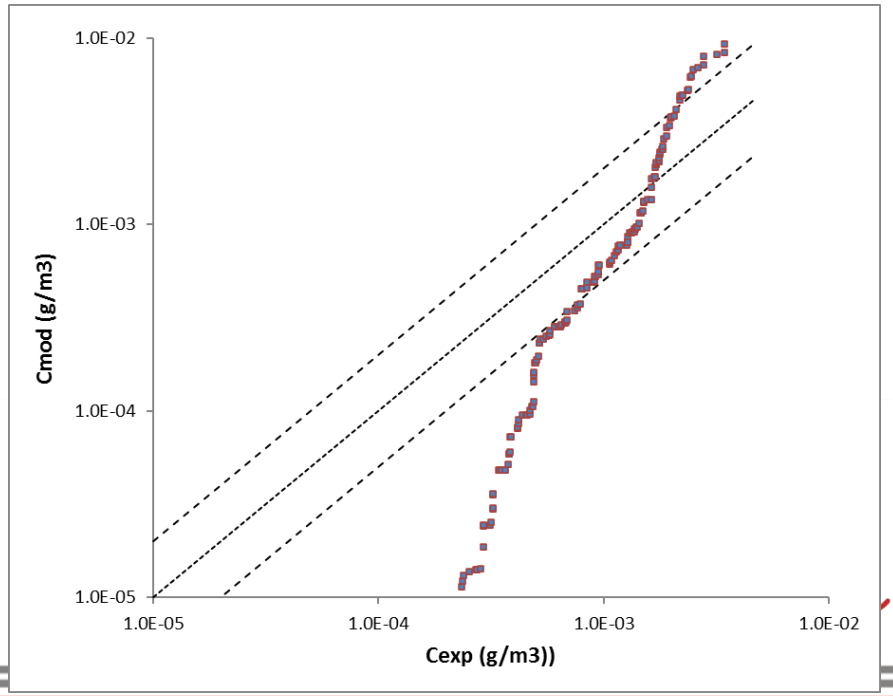
DIFLU – DISPERSION

- The results indicate inhomogeneity between the experiments of the 2nd campaign;
- Case 2-09 gives unrealistic measurements and has not been analyzed;
- FB=0.37, NMSE=3.81, FAC2=34%, FAC5=65%
- Relative good agreement between model and measurements

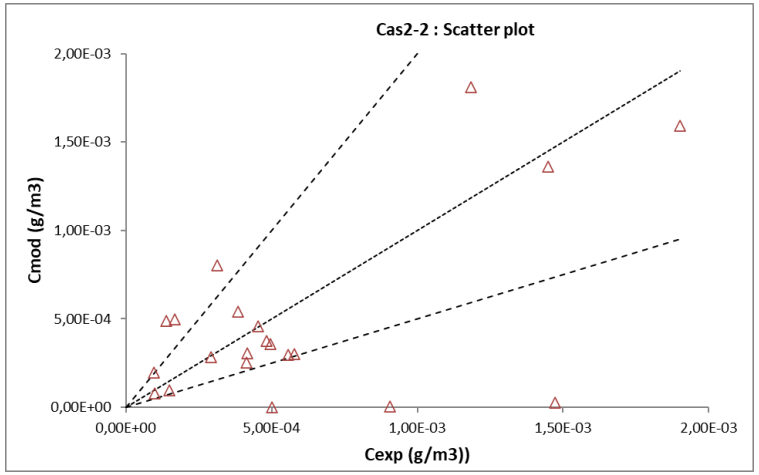
	FB	NMSE	FAC2	FAC5
2-01	1.39	6.64	5%	5%
2-02	0.23	0.73	64%	86%
2-03	-0.09	0.76	37%	79%
2-04	-0.86	7.82	18%	29%
2-05	-0.55	3.10	24%	43%
2-06	-1.04	4.04	24%	79%
2-07	-0.31	5.89	16%	37%
2-08	0.46	4.96	29%	61%
2-10	1.00	1.87	29%	54%

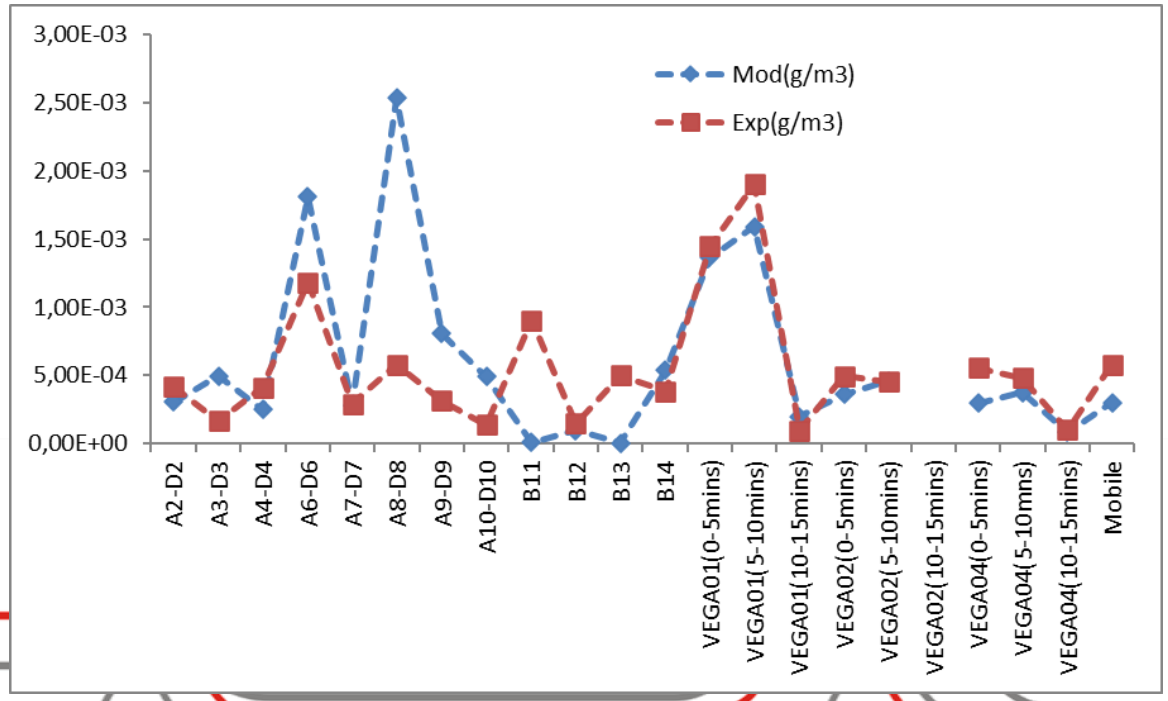


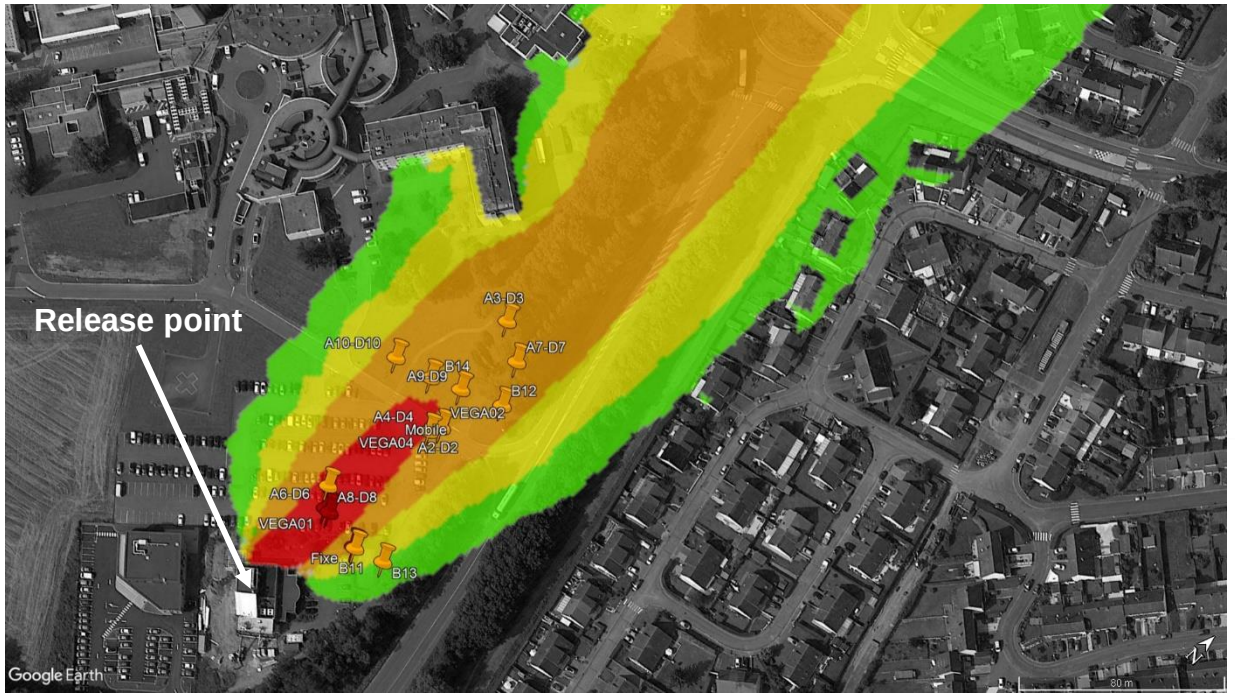


DIFLU – DISPERSION

- Focus on the case 2-02;
- Tendency to overestimate the concentration for points located on plume axis and underestimate the concentration for samples at plume side







Conclusion

- CFD model is a suitable tool for a reliable radiological impact assessment in complex areas;
- Fluidyn-PANACHE reproduces correctly the flows around buildings and gives realistic concentration in the near field where a gaussian model poorly performs;
- Results could be improved for this experiment by considering transient wind conditions at boundaries or by tuning turbulence model but it was not the objective of the DIFLU project which aims to validate the model capability in a standard approach of an impact study.

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