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HARMO22

IRSN
INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

PROJECT DIFLU: **DI**spersion du **FL**uor 18 en milieu **U**rbain

NEAR-FIELD (R<200M) ATMOSPHERIC DISPERSION SIMULATION AND SENSITIVITY ANALYSIS FOLLOWING A FULL-SCALE ATMOSPHERIC TRACER EXPERIMENT

[1]IRSN/IRSN/PSE-SANTE/SESUC/BMCA
[2]Ecole Centrale Lyon/LMFA

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MEMBRE DE ETSON

[DIFLU: DIspersion du FLuor 18 en milieu Urbain

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- **Fluorine 18** is widely used in the hospital applications. There exists potential releasing to the atmosphere during the production in the cyclotrons. To characterise its dispersion in the urban enviroment, IRSN has initiated the DIFLU (Dispersion du Fluor 18 en Mileu Urbain) project in 2019.

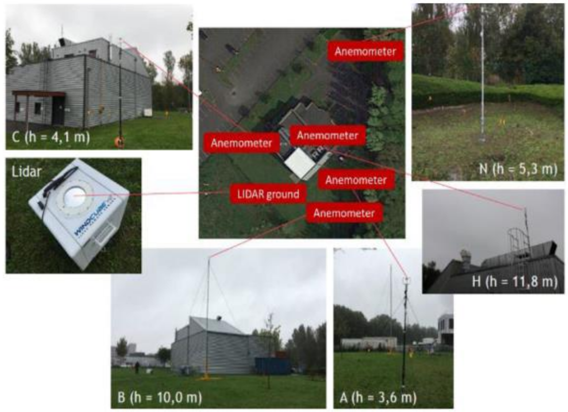
DIFLU project

Measurements	Simulation:
1) meteorological parameters	1) CFD tools
2) tracer concentrations	2) Gaussian models
	3) Lagrangian models
Completed !	Ongoing…

- Helium used as a passive tracer
- 2 campaigns (October and December 2019)

(Beuvry, France)

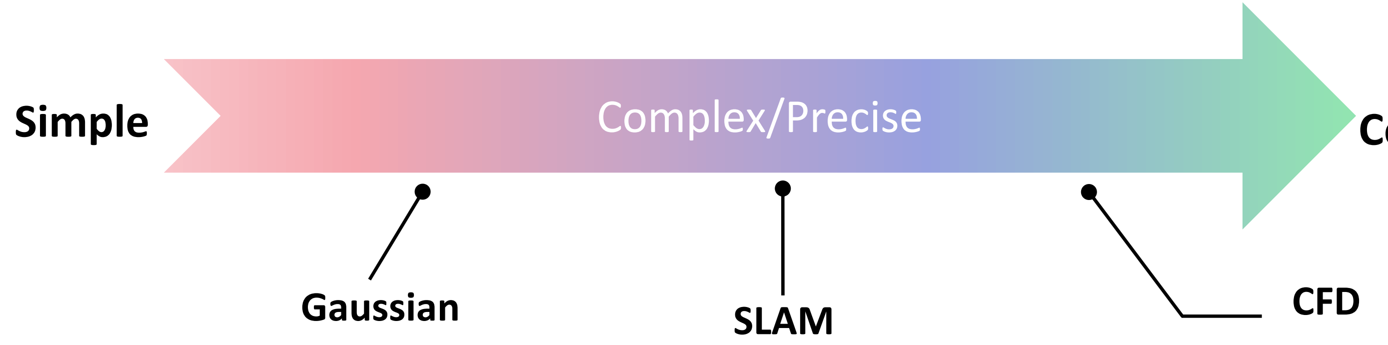

(Dispersion of smoke)



(Different test points for the meteorological conditions)

*Reference: Laguionie et al., *Atmosphere*, 2022

[DIFLU: SIMULATIONS



- Simulations include:
- CFD simulation: CALIF^{3}S (IRSN/PSN-RES/SA2I/LIE) (ongoing), PANACHE (Fluidyn)(done), FDS (Fire Dynamics Simulator) (INERIS) (ongoing)
- Gaussian plume models: ***pX* (IRSN in-house solver)**
- Lagrangian model: **SLAM** (developed by Ecole Centrale Lyon) (ongoing)
- **<u>Subjects of the work:</u>**
- Simulation of the atmospheric dispersion of the radionuclides in the near-field with **<u>SLAM</u>** and ***<u>Px</u>***
- Senstivity analyses of the factors impacting the near-field simulation of atmospheric dispersion with **<u>SLAM</u>.**

[SLAM

SLAM (Safety Lagrangian Atmospheric Model)

ÉCOLE CENTRALE LYON

<u>SLAM calculation process</u>

CFD simulation (work by Ecole Centrale Lyon)

- Pre-calculated CFD database based on FLUENT (includes 126 Wind direction)

SLAM* (work by IRSN)

- Perform Lagrangian dispersion simulation based on the CFD database

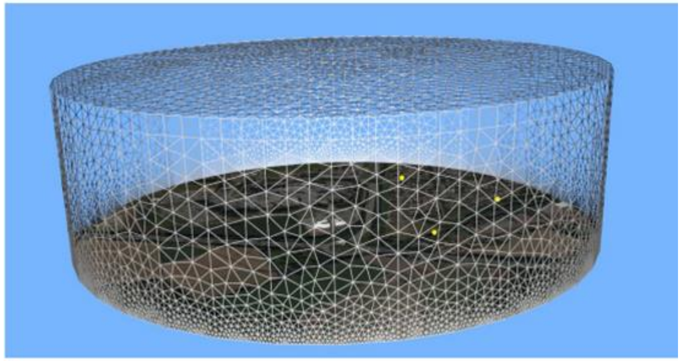
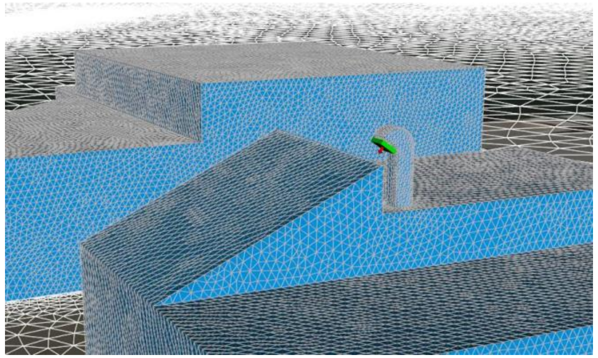
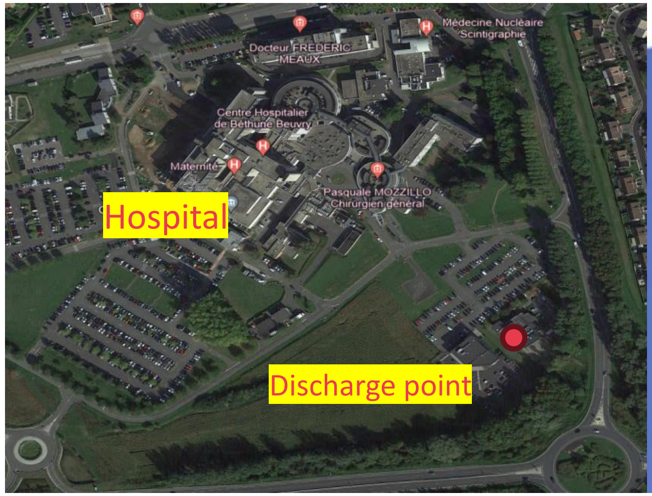
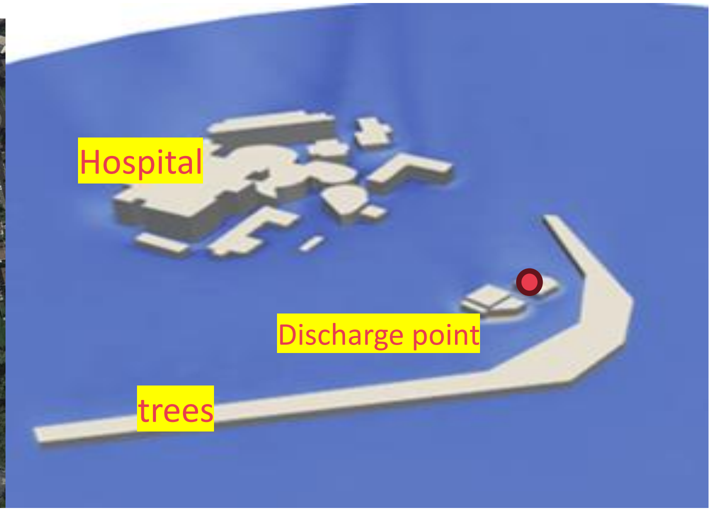


Illustration du domaine d'étude 3D - Maillage



- CFD mesh





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*References: Florian VENDEL, PhD thesis, 2011; Volta, P. et al. HARMO2020

[pX (IN-HOUSE OPERATIONAL SOLVER)

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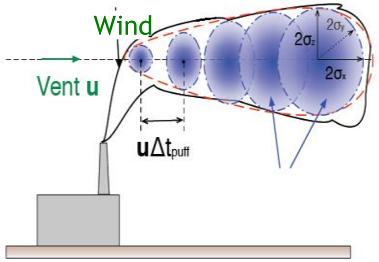
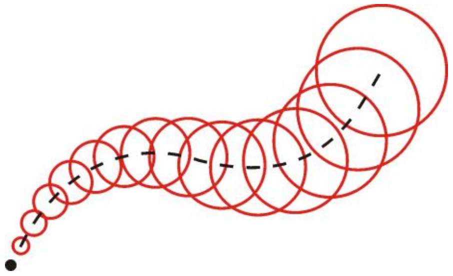
pX (Gaussian puff model)





- Gaussian plume dispersion model.
- Gaussian distribution of the concentrations in each direction of the puff.
- Each puff carries a given quantity of pollutant, the advection and diffusion appear at the center of the puff.

$$\bar{c}(x,y,z,t)=\frac{Q}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z}\exp\left[-\left(\frac{(x-x_0)^2}{2\sigma_x^2}+\frac{(y-y_0)^2}{2\sigma_y^2}+\frac{(z-z_0)^2}{2\sigma_z^2}\right)\right]$$

Standard deviation of dispersion in three directions

- Doury
- Briggs rural / urban
- Pasquill
- Similarity theory

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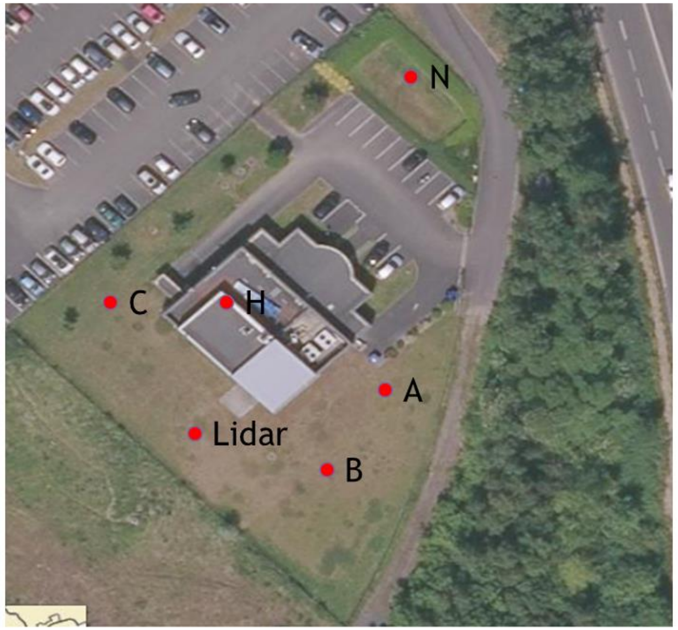
*Reference: Soulhac, L., and D. Didier. "Projet pX, note de principe pX 1.0." Note technique. IRSN (2008).

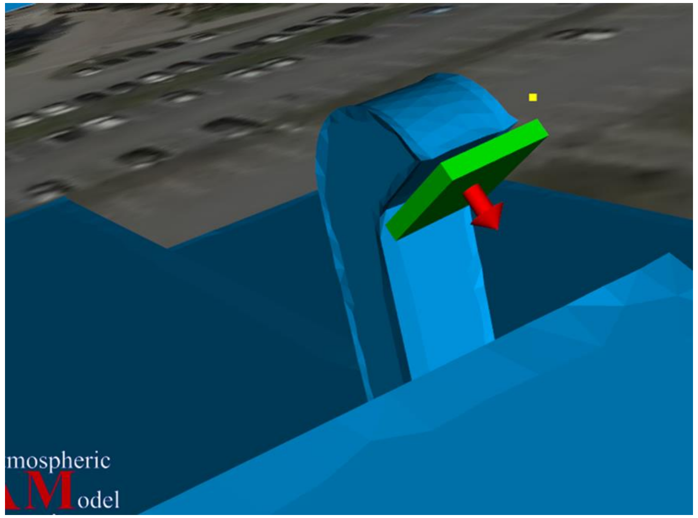
SLAM SIMULATION SETUP

- Source configuration: box (0.65m*0.65m*0.1m)
- Injected number of particles: 100000

Météo Station ID	Météo station height (m)	Source rejet location
Lidar	40	H



- Meteorological conditions measuring stations



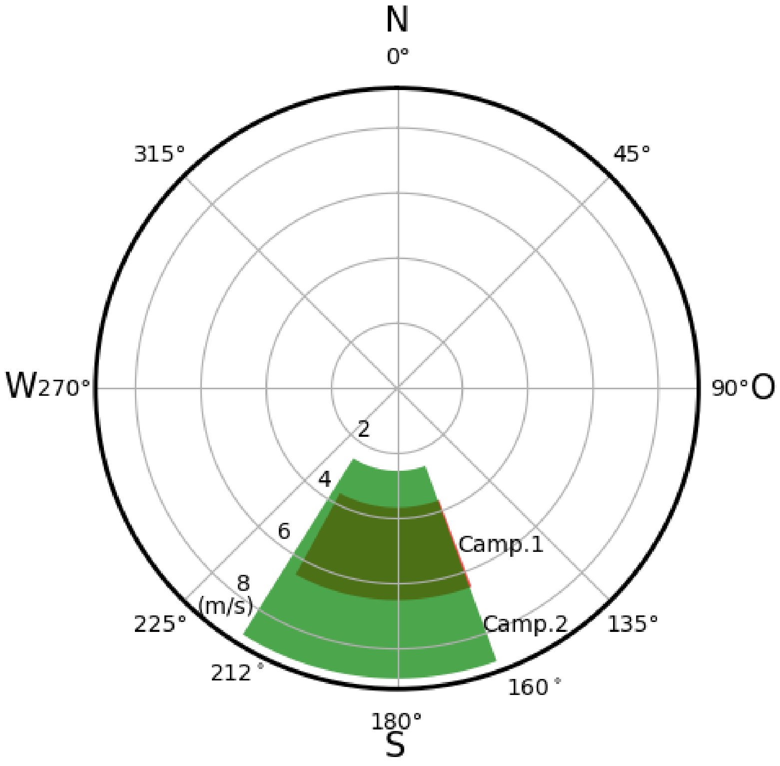
- SLAM injected source configuration

METEOROLOGICAL CONDITIONS, LIDAR@40M

#Campaign 1 (#1-1:9) 15-17 October 2019

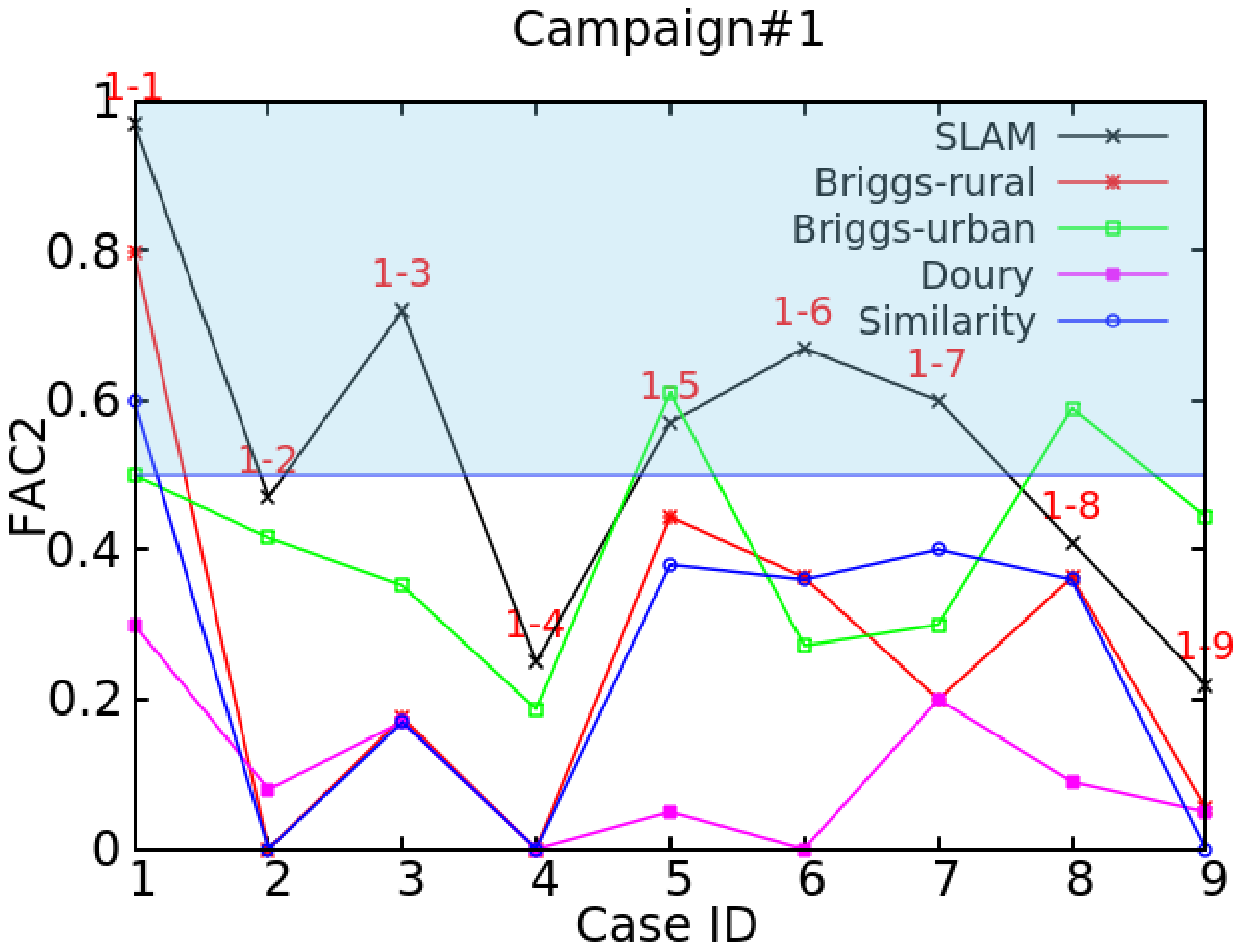
#Campaign 2 (#2-1:10) 10-12 December 2019

- Wind direction (#1,2): 160°-212°
- Wind speed (#1): 3.6-6.5 m/s
- Wind speed (#2): 2.5-8.91 m/s



- Most cases are in almost neutral stability (Pasquill-Turner classes C-D)
- Cases #2-4, #2-5, #2-8 are in unstable conditions (class B)

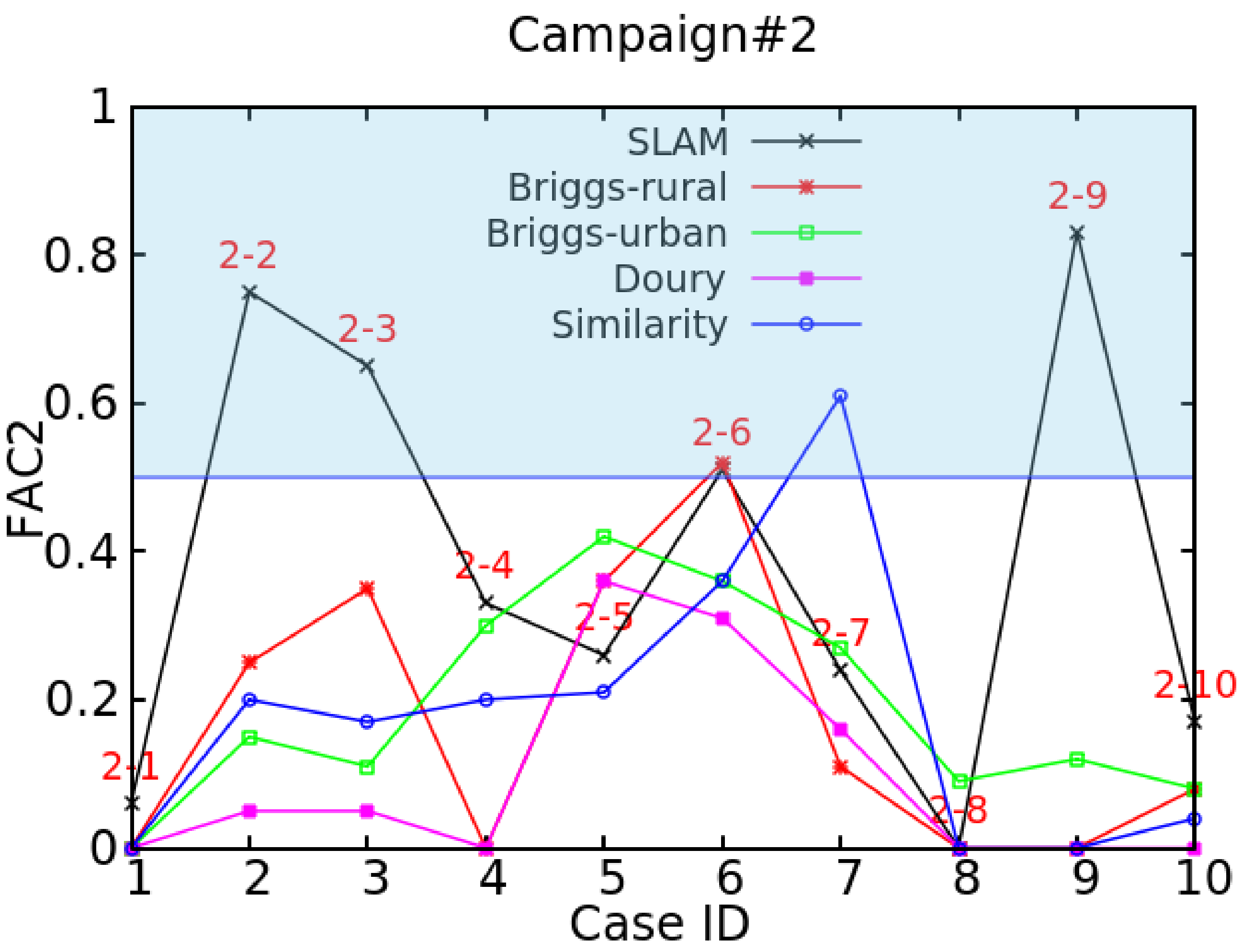
RESULTS: FAC2 COMPARISONS BETWEEN DIFFERENT MODELS



- SLAM outperforms pX in general
- Briggs Urban is correct
- Cases 1-4, 1-8, 1-9 with FAC2 < 0.5

- **Fraction of predictions within a factor of two of observations (FAC2):** $0.5 < \frac{M}{S} < 2$ **(**M**: measurement;** S**: simulation)**
- **Perfect model index: FAC2=1, Acceptable model index: FAC2** ≥ 0.5 **(blue shadow region in the figure)**

RESULTS: FAC2 COMPARISONS BETWEEN DIFFERENT MODELS



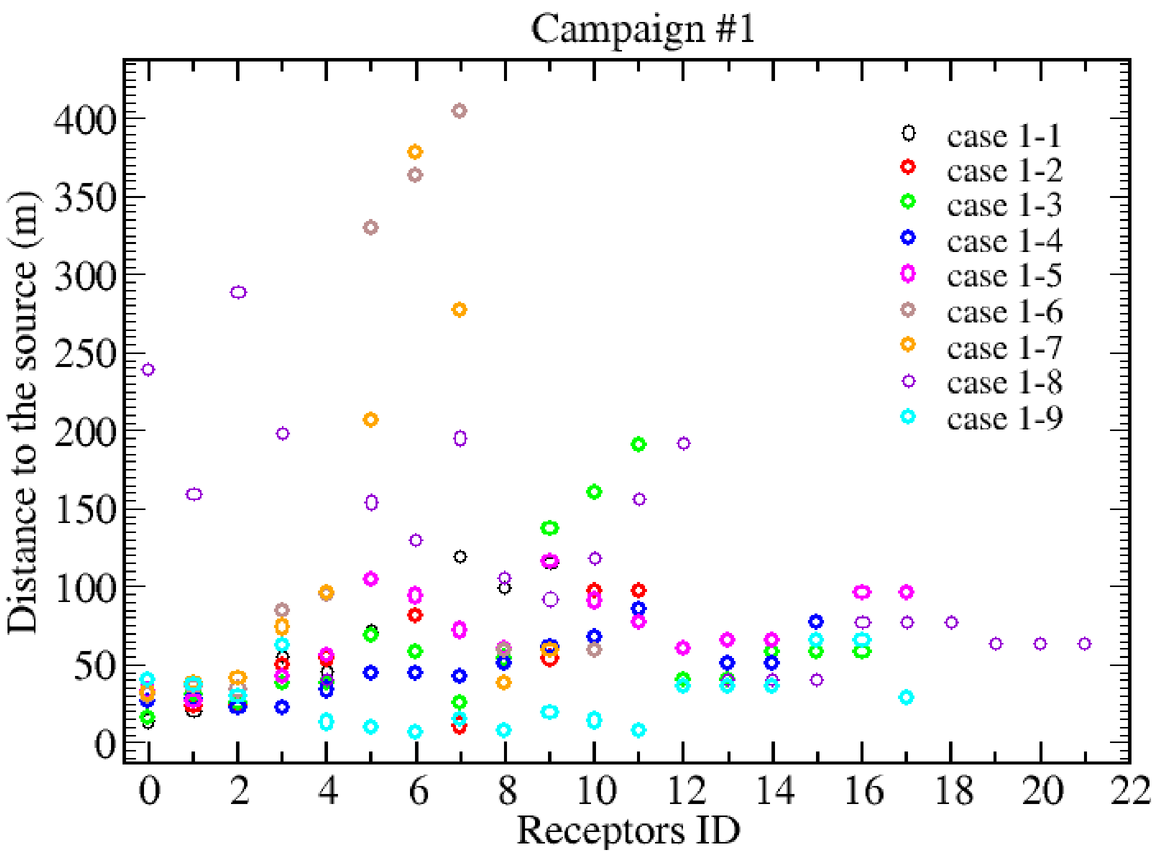
- SLAM outperforms pX in general
- Lower performance for Campaign #2 than Campaign #1

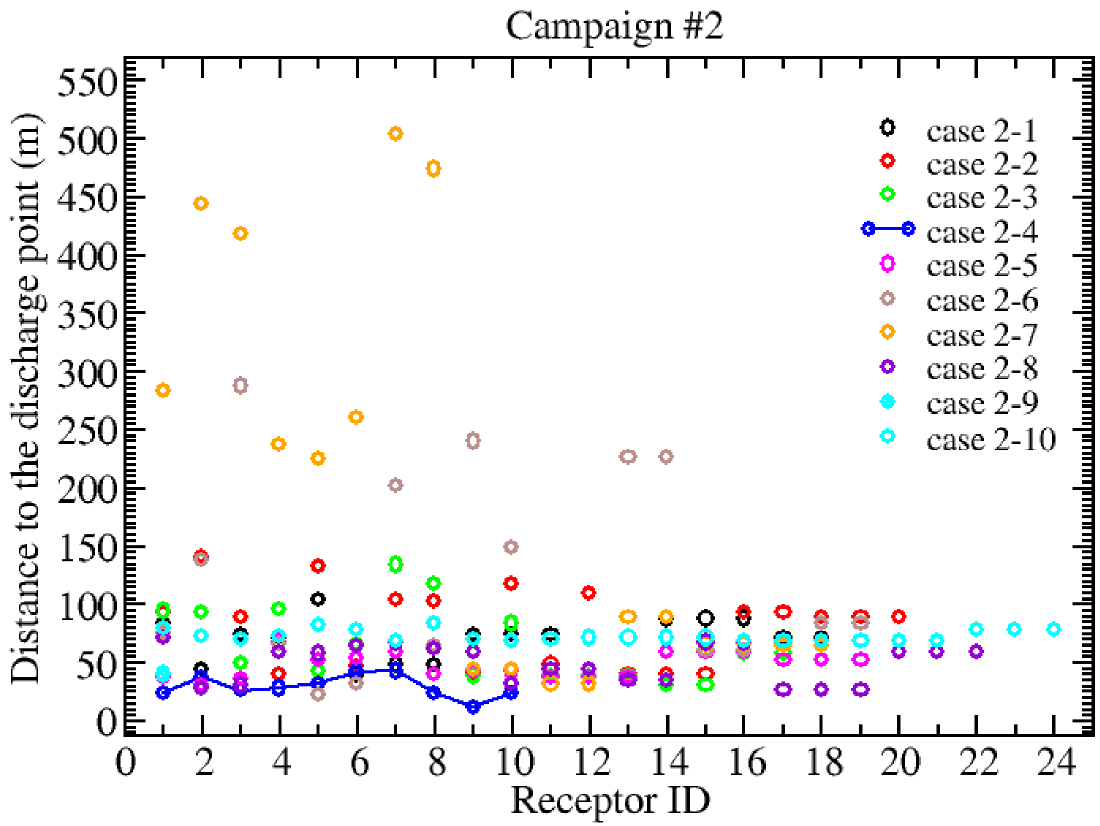
Acceptable models (FAC2>0.5):

- SLAM (46% cases)
- Briggs-urban (16% cases)

- **Fraction of predictions within a factor of two of observations (FAC2): $0.5 < \frac{M}{S} < 2$ (M: measurement; S: simulation)**
- **Perfect model index: FAC2=1, Acceptable model index: FAC2 ≥ 0.5 (blue shadow region in the figure)**

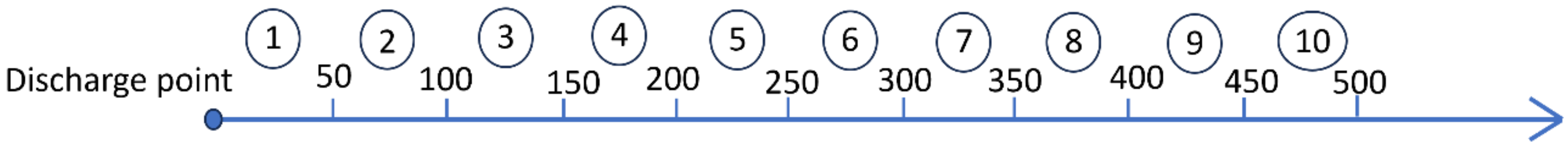
LOCATIONS OF SAMPLING RECEPTORS IN THE MEASUREMENTS



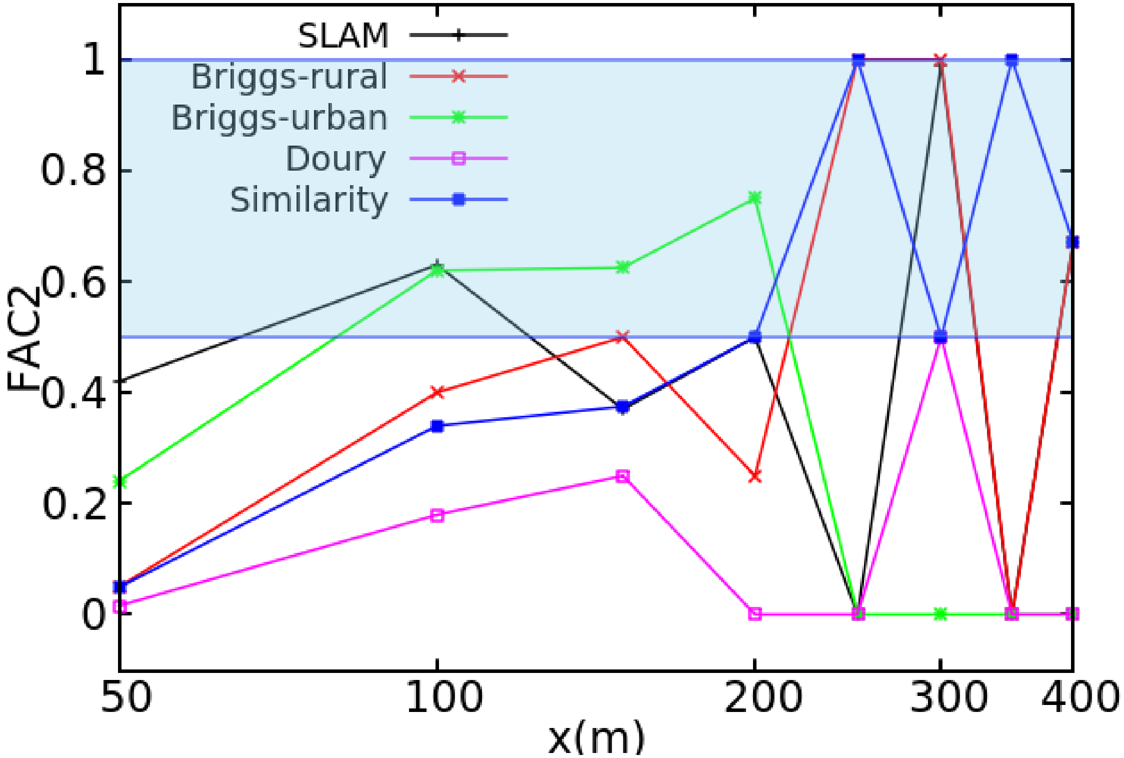


All sampling receptors were located within a 500-meter arc from the discharge point, with 88% of camp #2's receptors within 100 meters—6% more than in camp #1.

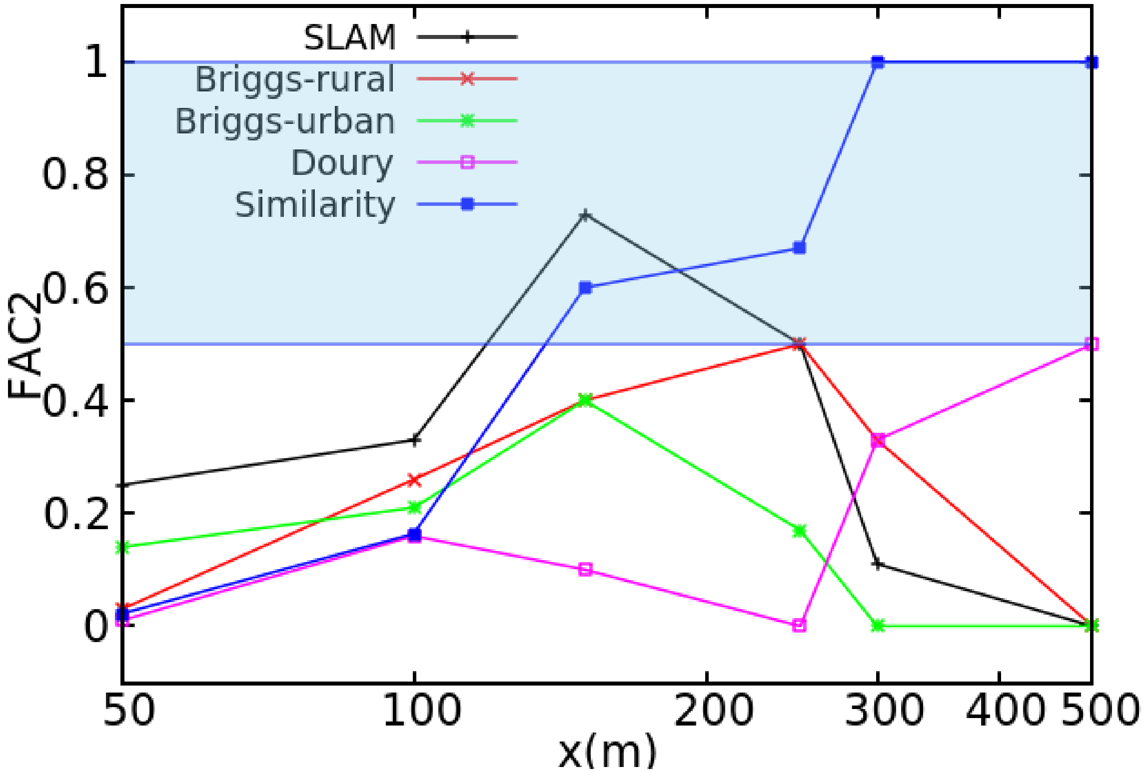
FAC2 COMPARISONS BETWEEN DIFFERENT SIMULATIONS



Campaign#1



Campaign#2



- In the very near source region (x<100), SLAM outperforms the Gaussian models.
- Among Gaussian models, Briggs-urban has good performance in the near-field region (x<200), in the far-field, Similarity model behaves better.

SOBOL SENSITIVITY ANALYSES FOR CASE 2-4

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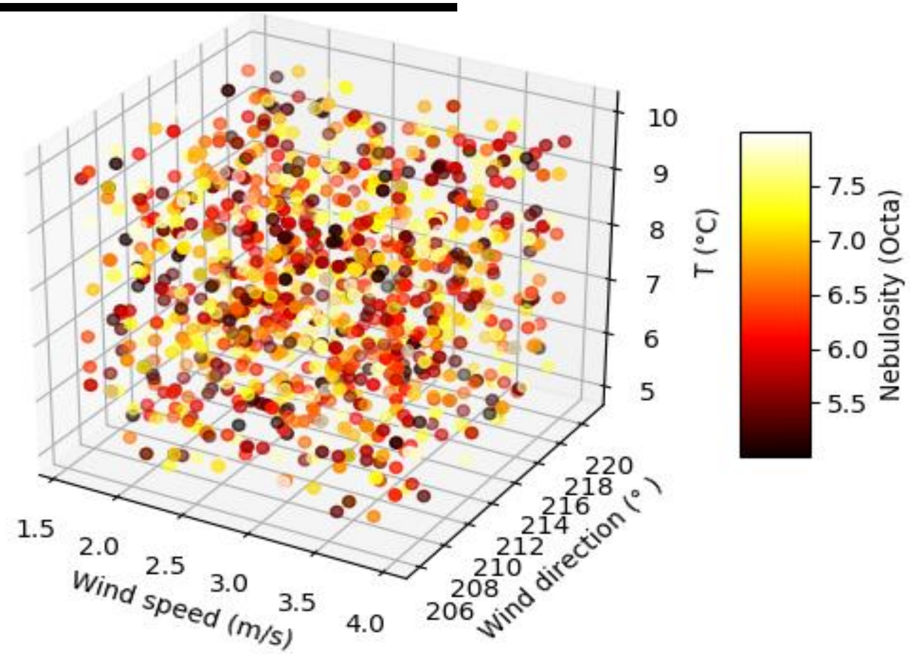
- **Sobol sensitivity study**: quantitative, variance-based method
- **Goal**: to understand the effect of each input variable on the output parameters.

- **Case 2-4**: **unstable** condition, **low wind** speed, very close to the source (**R<50m**)
- Input parameters varying range (based on the measurement errors):

Parameter index	(x_1)Wind speed (m/s)	(x_2)Wind direction (°)	(x_3)Temperature (℃)	(x_4) Nebulosity (Octa)
Variation range	[1.56, 4]	[206, 221]	[5, 10]	[5, 8]

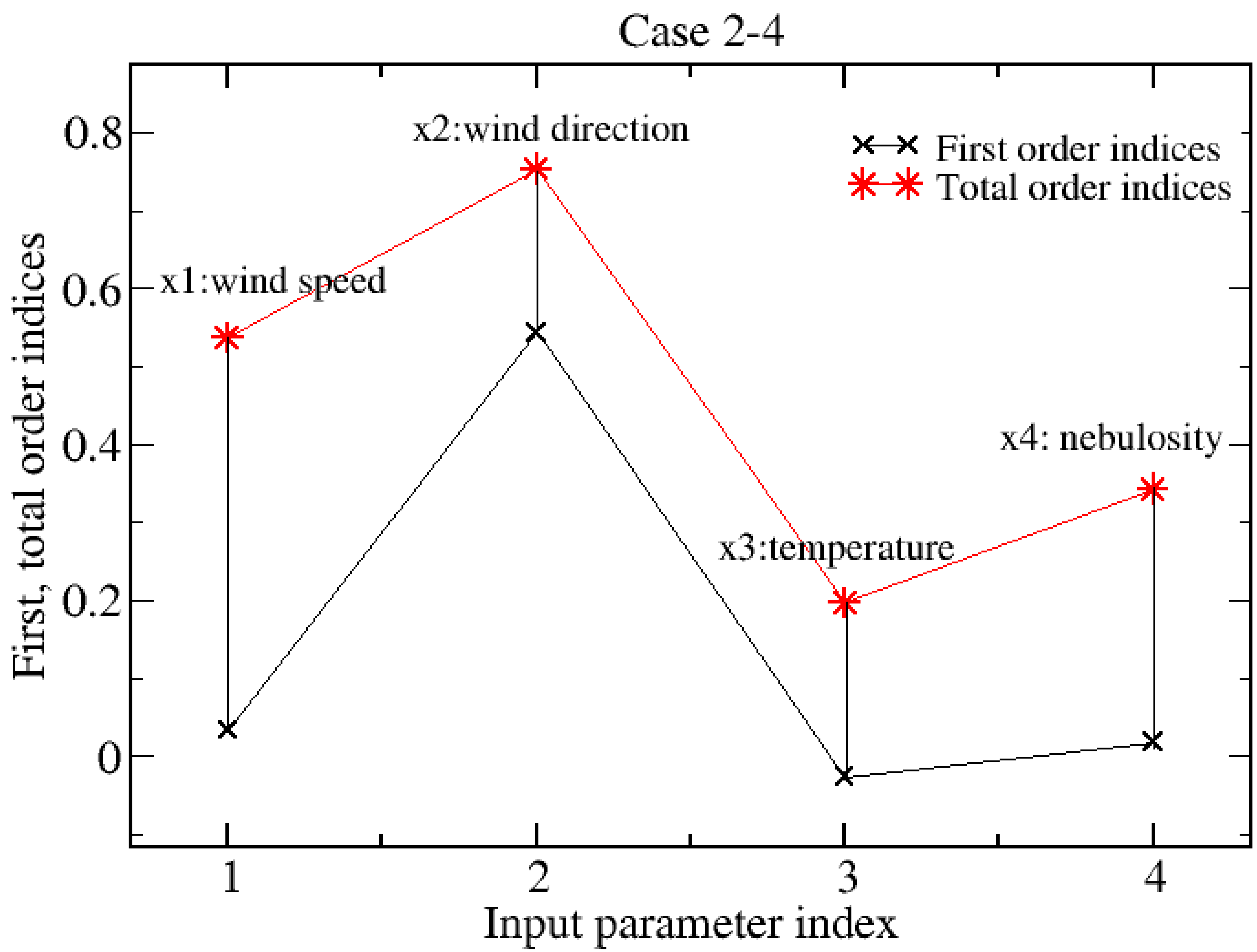
- Output parameter: FAC2
- Sample space distribution: Saltelli's scheme*
  - **1280** sample points (SLAM simulations)
  - 8 hours on 8 CPUs

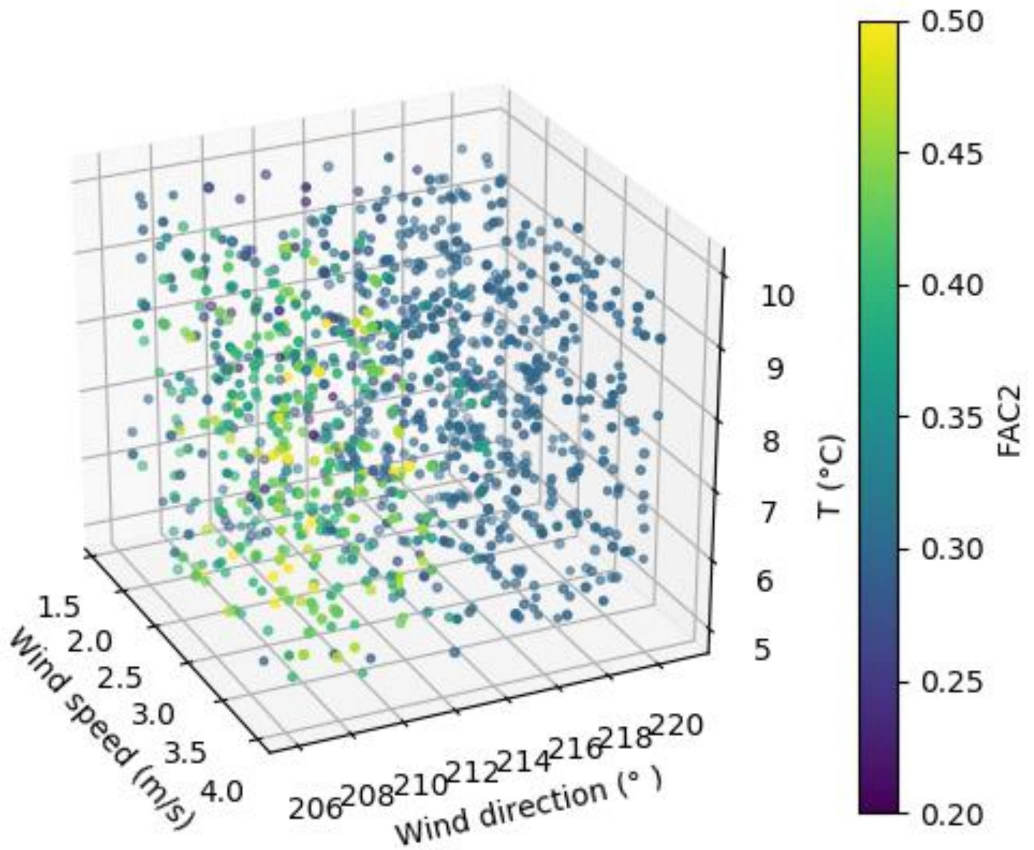


*Reference: Saltelli et al,2018

RESULTS OF SOBOL SENSITIVITY ANALYSES FOR CASE 2-4

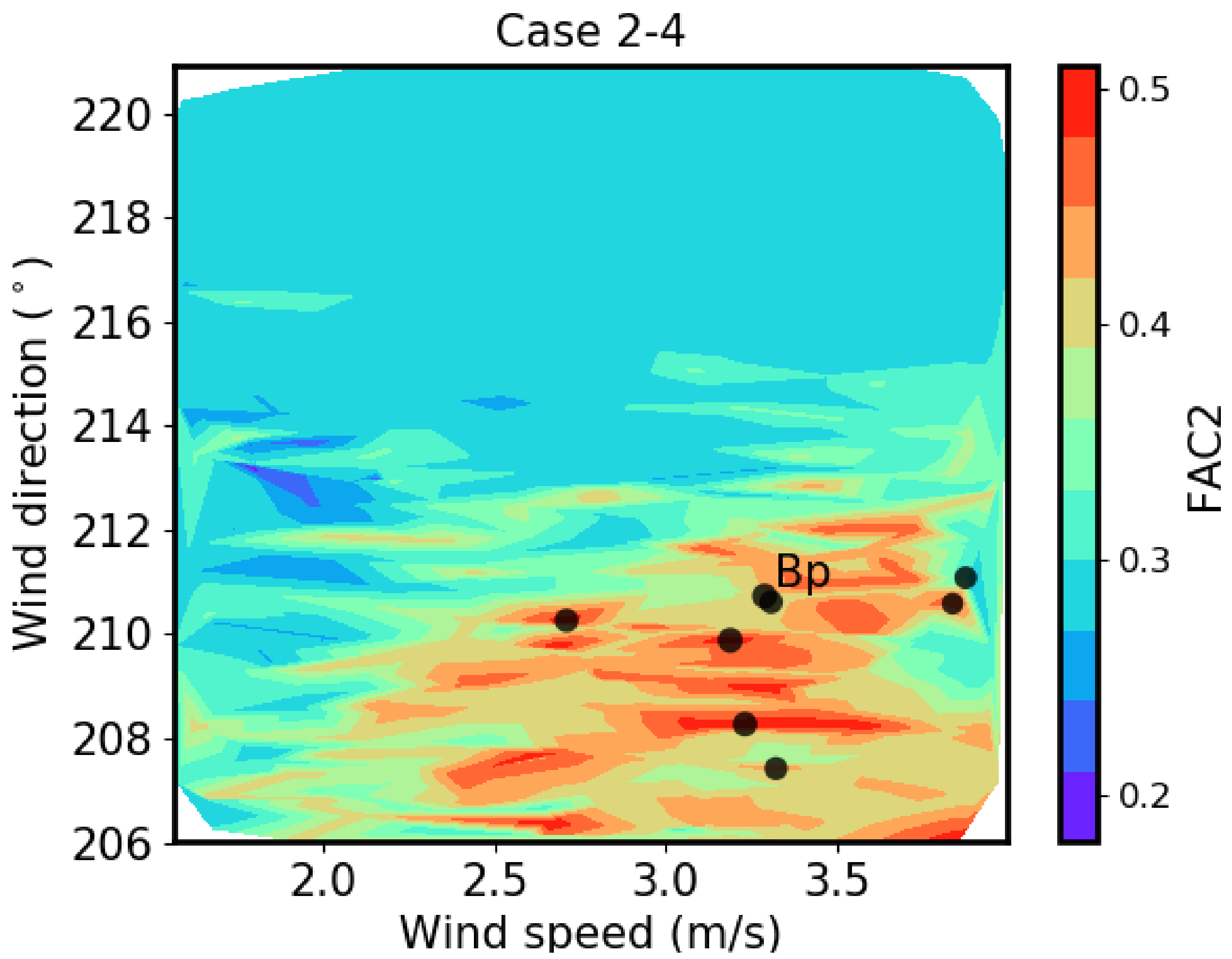
- **First order indices**: direct effect on the output variance
- **Total order indices**: include interactions & non-linear effect





RESULTS OF SOBOL SENSITIVITY ANALYSES FOR CASE 2-4

Bp: best points for FAC2



- Wind direction and wind speed explain most output variance
- The best FAC2 is **0.5** (vs. **0.33** *before*)
- Additional parameters to investigate: turbulent scheme, source uncertainties…

CONCLUSIONS AND PERSPECTIVE

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- SLAM exhibits significant advantages in simulating **near-field dispersion (x<200 m),** surpassing traditional Gaussian models.
- The Sobol global sensitivity study, showed that **wind speed and direction** are the two dominant factors impacting the near-field concentration, with **strong interactions**.
- By making wind speed and direction vary according to measurements uncertainties, we were able to significantly improve the model's performance in most cases.
- **Low wind speed** conditions cases were the more difficult to accurately simulate.
- Future work will extend the uncertainty analysis to incorporate additional input variables (turbulence diffusion in CFD model, source term, etc) and benchmark with more models.

[TO GO FURTHER ON THE TOPIC…

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- Presentation H22-089 (Erwan Rondeaux) – on the comparison of SLAM and Gaussian approach in the transition distance
- Presentation H22-030 (Hanane Bounouas) – on turbulence in low wind speed conditions

Charvolin-Volta, P., C.V. Nguyen, L. Soulhac, G. Lamaison, P. Laguionie, O. Connan, J. Chardeur, O. Cazimajou, L. Solier, I. Korsakissok, S. Vecchiola, A. Mathieu, M. Le Guellec, A. Tripathi, 2021; Evaluation of a Lagrangian dispersion model coupled with a CFD wind field database against a new full scale atmospheric tracer experiment. In *20th Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*. Tartu, Estonia

atmosphere MDPI

Article

Investigation of a Gaussian Plume in the Vicinity of an Urban Cyclotron Using Helium as a Tracer Gas

Philippe Laguionie [1,*], Olivier Connan [1], Thinh Lai Tien [2], Sophie Vecchiola [3], Johann Chardeur [1], Olivier Cazimajou [1], Luc Solier [1], Perrine Charvolin-Volta [4], Liying Chen [5], Irène Korsakissok [6], Malo Le Guellec [5], Lionel Soulhac [4], Amita Tripathi [5] and Denis Maro [1]

.https://doi.org/10.3390/atmos13081223