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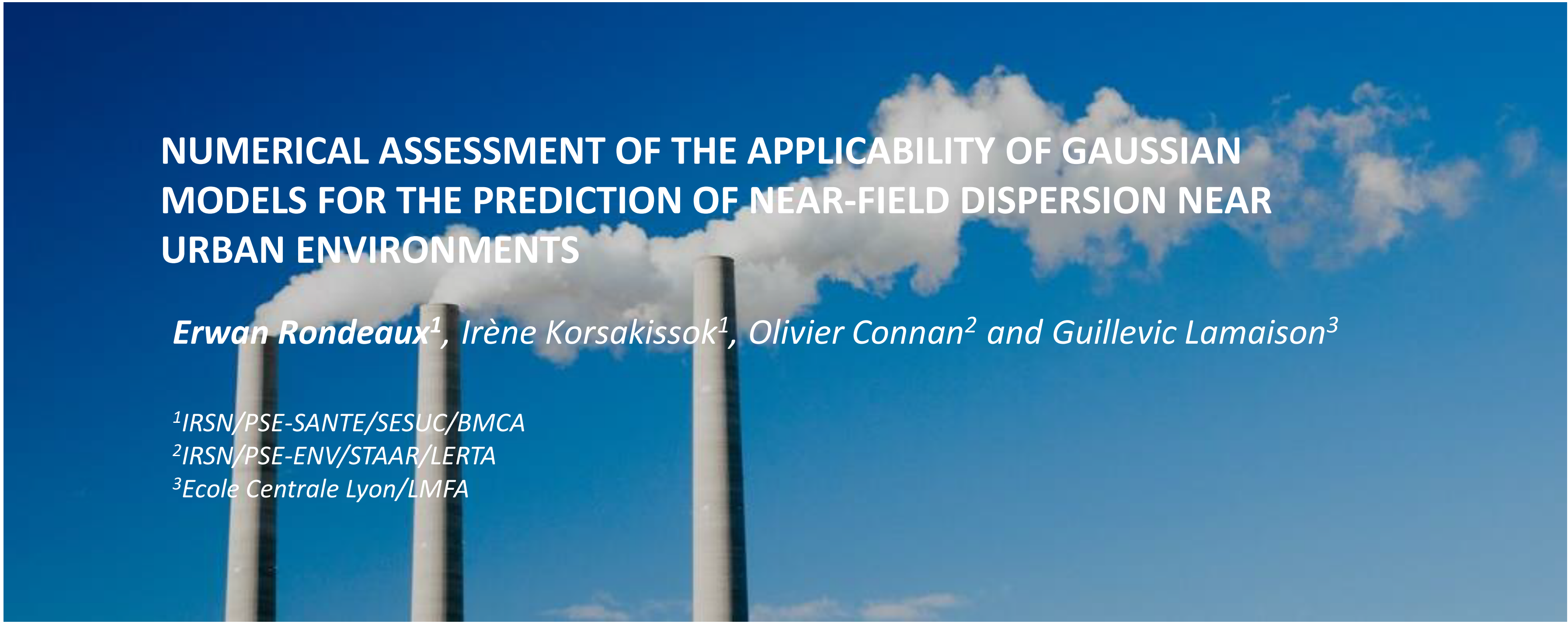

NUMERICAL ASSESSMENT OF THE APPLICABILITY OF GAUSSIAN MODELS FOR THE PREDICTION OF NEAR-FIELD DISPERSION NEAR URBAN ENVIRONMENTS

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MEMBRE DE
ETSON

Dispersion modelling for emergency response

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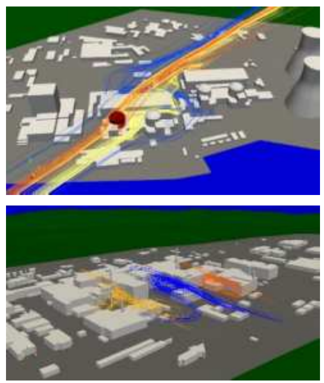
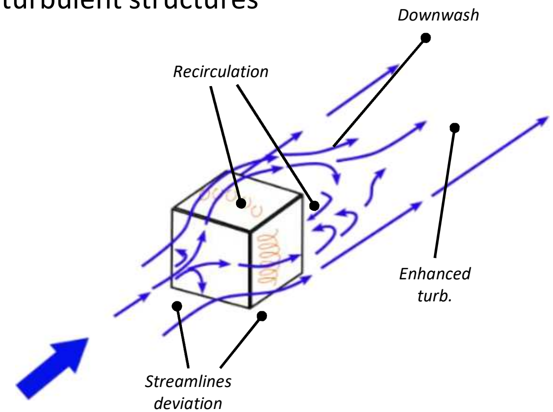
ET DE SÛRETÉ NUCLÉAIRE

In the event of accidental release of radionuclides in the atmosphere

- IRSN uses **dispersion modelling tools** to anticipate radiological consequences …
- … to advise decision makers on **countermeasures to protect the population and environment** (Evacuation, Sheltering, Stable iodine prophylaxis, Food restrictions)

Most nuclear site can be assimilated to peri-urban areas, where the **presence of buildings and obstacles may impact the dispersion of pollutants**, through complex interaction mechanisms with turbulent structures



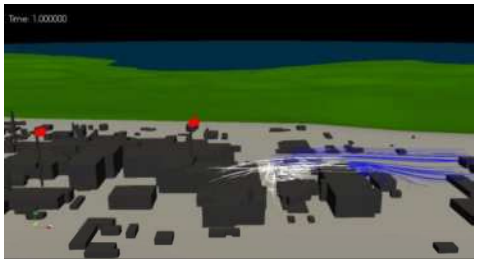


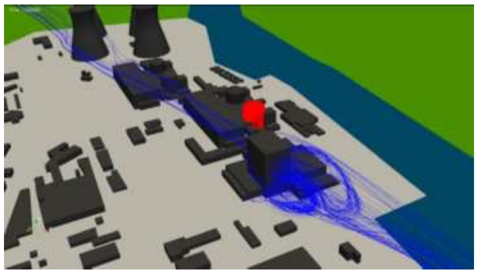
Dispersion modeling tools

Simplified models ← Complexity/Precision — **Complex models**

CFD-based models

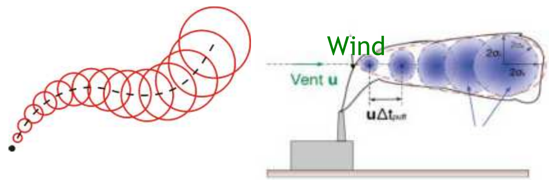
- Resolution of Navier-stokes equations
- Explicit modeling of buildings and terrain effects, account for the intricate wind flow around buildings (recirculation, blocking effects, etc)
- Time and computational ressources demanding, incompatibility with emergency constraints





IRSN Operationnal model (pX)

- Gaussian model : simplified discretization of the plume in puffs
- Empirical Gaussian laws to describe the distribution of concentration in a puff
- No explicit modeling of buildings and terrains effects



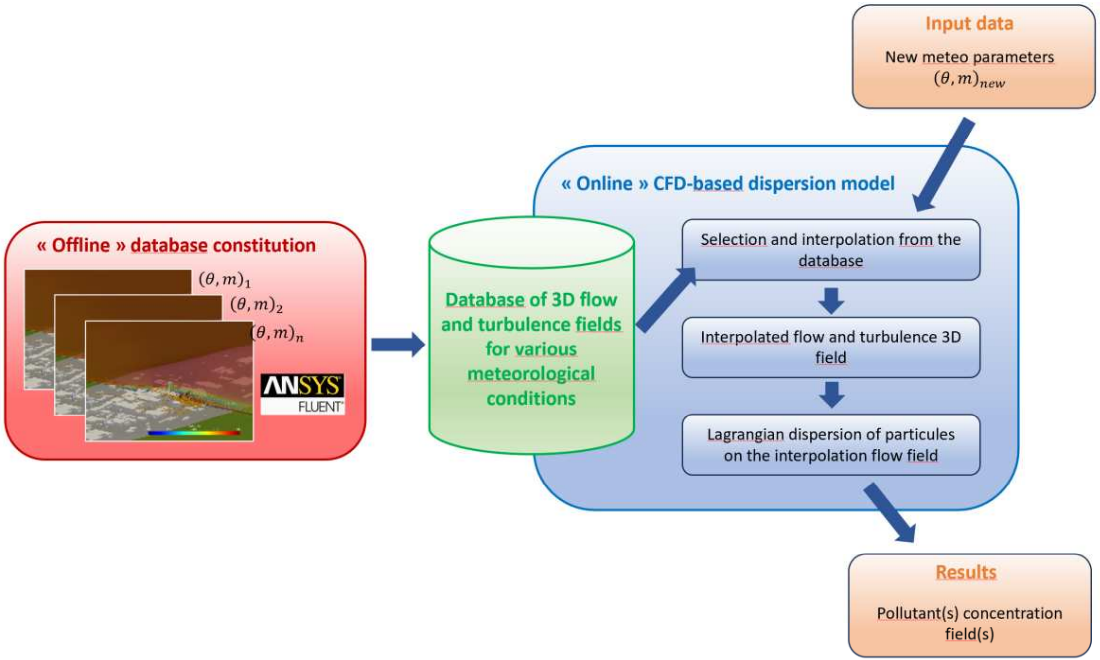
Range of validity of dispersion modeling tools

Uncertainty on the transition distance from which the Gaussian approach becomes acceptable.

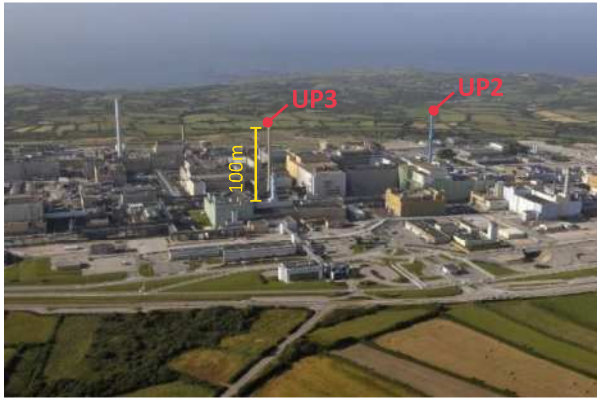
Objectives of the work:

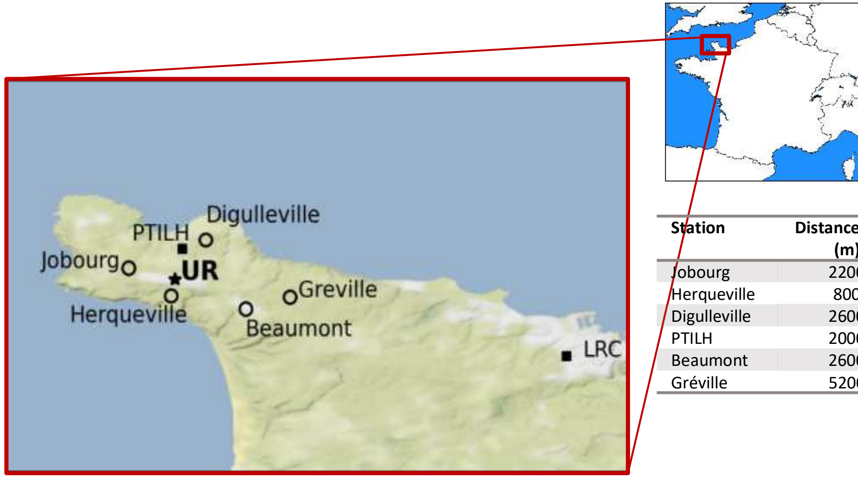
- explore the applicability of simplified approaches compared to more complex approaches against a **real case measurment campaign** at intermediate distances (few kms)
- evaluate the added value of CFD-based tools against simplified models in the **context of emergency response**
- study the **sensibility of pX to some of its parameters and meteorological forcing**, … to eventually adapt good practices

SLAM, a CFD-based approach compatible with emergency constraints



Case study – Orano La Hague RP

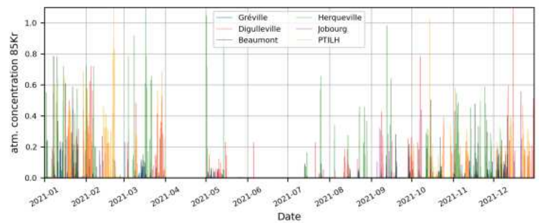




Station	Distance/UP2 (m)	Direction/UP2 (°)
Jobourg	2200	126
Herqueville	800	6
Digulleville	2600	2,6
PTILH	2000	193
Beaumont	2600	292
Gréville	5200	272

DISKRYNOC project :

- Krypton-85 is a good tracer of dispersion (neglectable deposition)
- Continuous measurements of ^{85}Kr concentration between November 2020 and December 2022 performed by Orano and IRSN $(800 - 5.2km)$ $(\Delta t = 10min)$
- Release rate at UP2 and UP3 $(\Delta t = 10min)$
- Access to complete meteorological measurments $(\Delta t = 10min)$

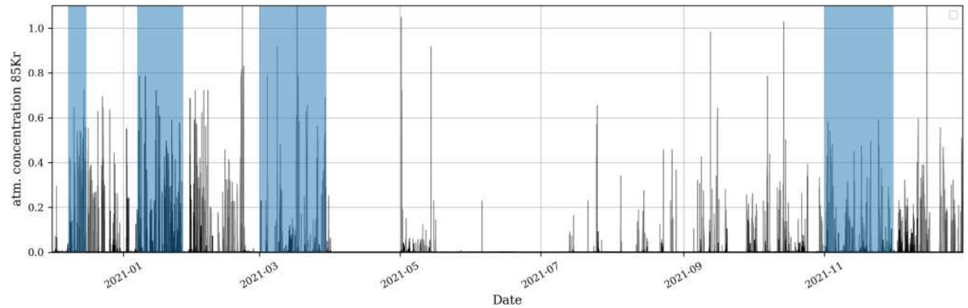


Study setup

Selection of simulation intervals

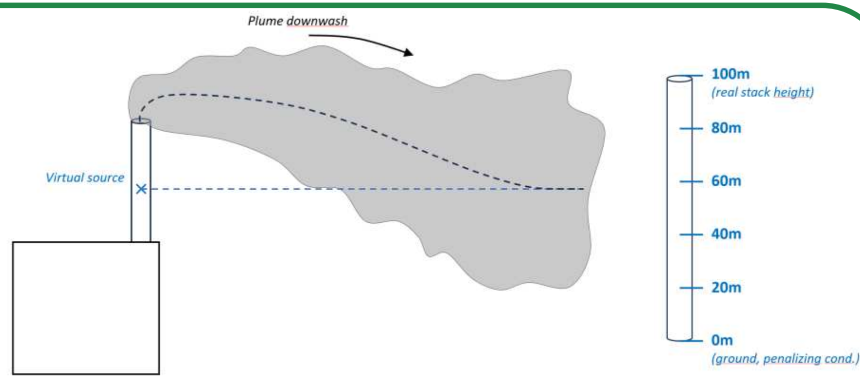
- 4 sub-periods where there are both significant releases as well as a significant density of concentration measurments
  - 8-15 Dec 2020
  - 7-26 Jan 2021
  - 1-29 March 2021
  - 1-30 Nov 2021

- Total of about 3 months simulated!



Simulations setup

	pX	SLAM
Inputs	10min meteorological and release rate time series	
Source representation	Single point source located at the barycentre of UP2 and UP3	2 cylindrical sources, UP2 and UP3
Source height	0-100m (20m increments)	Real stack height (100m)
Gaussian law	Doury, Pasquill, Briggs (Urban & Rural)	---

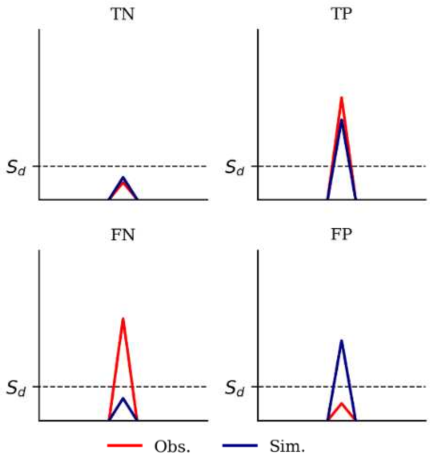


Results processing

- Results are gathered in the form of 10 min times series of concentration at the different stations and further processed to compute the 1hour integrated concentration in sliding windows (proportional to the hourly received dose)
- We are interested in evaluating the ability of models to simulate all the observed peaks → because, in emergency context, missing a radiation event could have an impact on the population health and environment

- Contingency table for successes and failures

TP : True Positive
FP : False Positive
FN : False Negative
TN : True Negative



- Failures and successes are aggregated by statistical indicators :

$$Hit\ Rate\ (HR) = \frac{TP}{TP+FN} \qquad precision = \frac{TP}{TP+FP}$$

$$F1 = 2 \times \left(\frac{HR \times prec}{HR+prec}\right)$$

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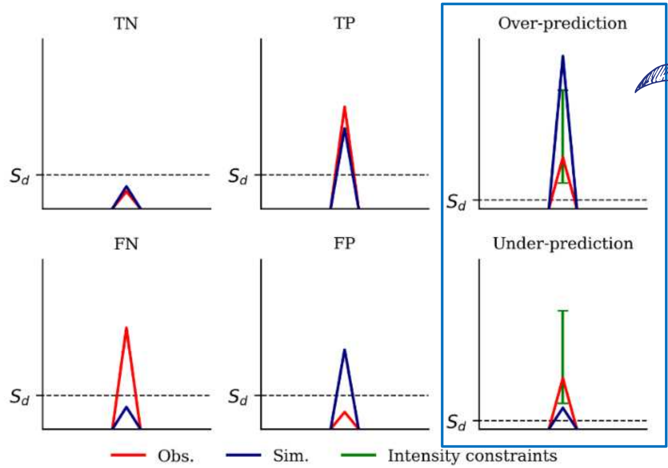

- Intensity constraints to account for risks of over- or under-estimation of ground consequences
  - TP if $0{,}5 < \frac{I_{sim}}{I_{obs}} < 10$

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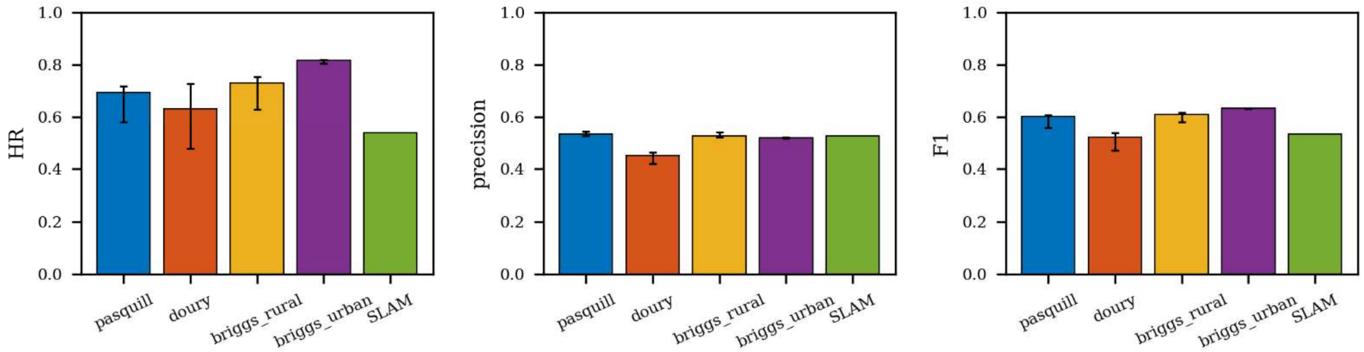
$$Hit\ Rate\ (HR) = \frac{TP}{TP+FN} \qquad precision = \frac{TP}{TP+FP}$$

$$F1 = 2 \times \left(\frac{HR \times prec}{HR + prec}\right)$$

TP if $I_{sim}, I_{obs} > threshold$

Unconstrained statistical performances

[ABILITY (MEDIAN) OF THE MODELS TO DETECT PEAKS



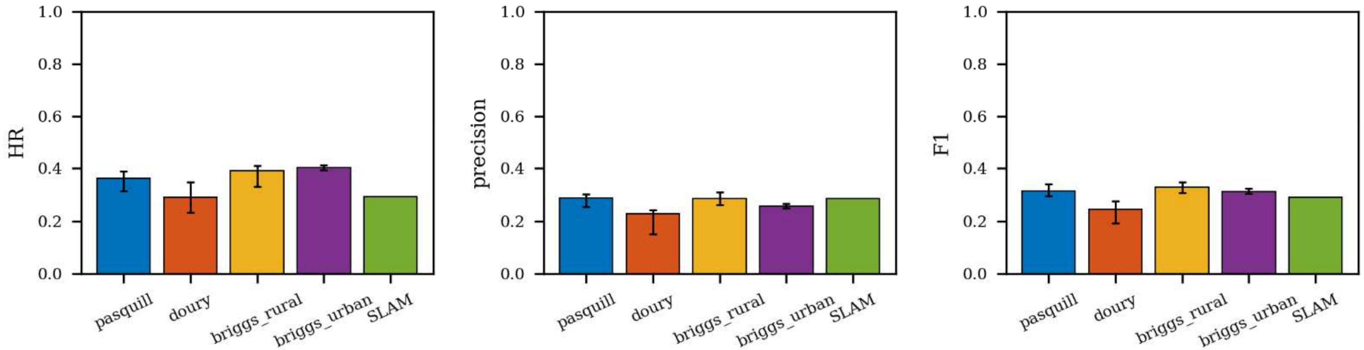
Model	HR Best estimate (%)	Associated source height (m)
pX + Pasquill	76	0
pX + Briggs Rural	82	0
pX + Briggs Urban	**88**	0
pX + Doury	74	0
SLAM	58	--

- pX best estimates detect 74% up to 88% of peaks, against 58% of peaks for SLAM
- High variability of pX performances depending on its parameterization
- pX best estimates systematicaly obtained with a source at ground

$$TP \text{ if } 0{,}5 < \frac{I_{sim}}{I_{obs}} < 10$$

Constrained statistical performances

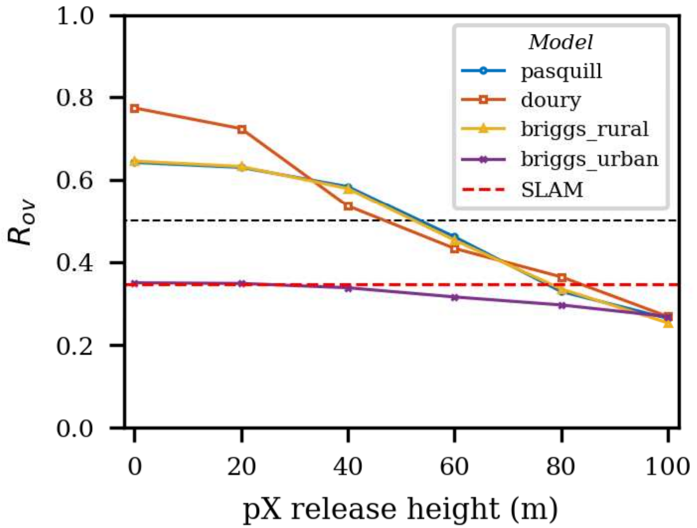
ABILITY OF MODELS TO PREDICT ADEQUATE PEAK INTENSITIES

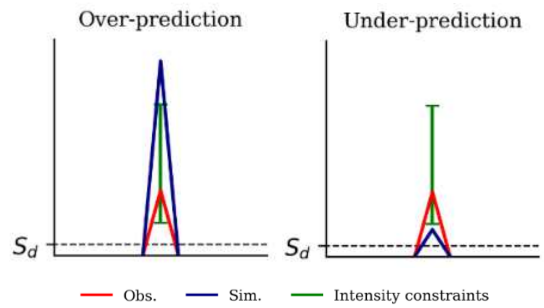


Model	HR Best estimate (%)	Associated source height (m)
pX + Pasquill	39	60
pX + Briggs Rural	**41**	60
pX + Briggs Urban	**41**	--
pX + Doury	35	40
SLAM	29	--

- A significant proportion of initially well simulated peaks do not respect intensity tolerances!
- pX best estimates are obtained with a source at approximately half the real stack height.

Impact of the source height parameter



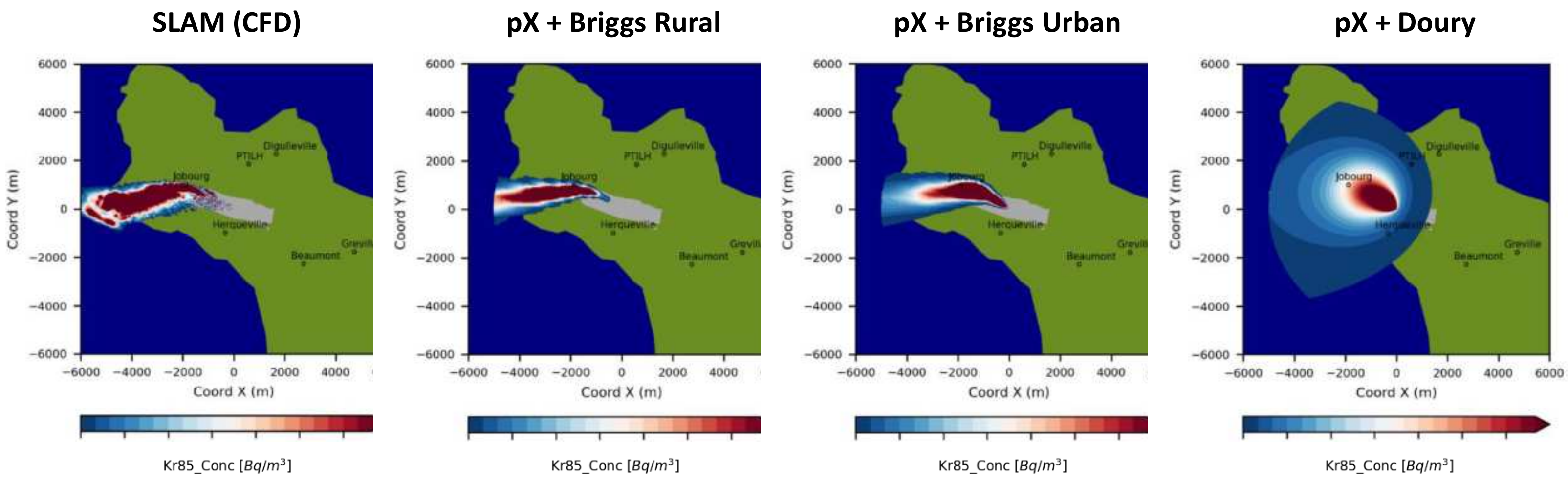


$$R_{ov} = \frac{n_{opv}}{n_{opv} + n_{upv}}$$

Interest of the source height parameter to mitigate the risk of under- or over-estimation of ground concentrations

Comparison of ground consequences maps

[STABLE CONDITIONS ON THE 15 JAN 2021 AT 17H00



- « Staggering » of the concentration map with SLAM on site, due to interactions between the emitted plume and buildings on site that are not captured with by the Gaussian model

- In stable conditions, despite a comparable Hit Rate to other laws, the law of Doury will lead to numerous False Positive

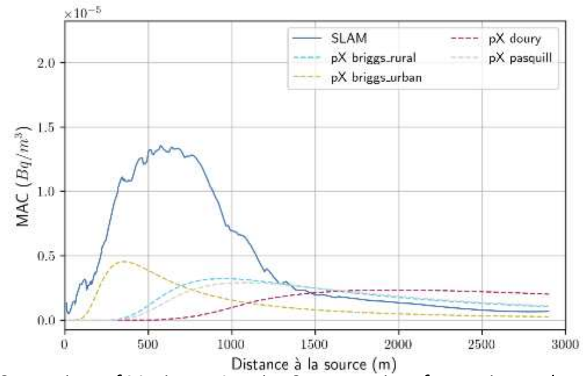
Conclusions

- Simplified approaches such as pX can lead to great statistical performances for the distances under consideration …
- … but need an adapted parameterization
  - Best performances are obtained with the laws of Briggs Rural and Pasquill, while the law of Doury leads to the worst results (especially in stable conditions)
  - A source at half the real stack height mitigate the risk of over or under-estimation of ground concentration levels
  - A source at ground maximize the probability to detect peaks and is still a reasonable choice in emergency situations

- While SLAM doesn't seem to add a real added value at those distances, it presents interest in the close vicinity of discharge sources, where the wind flow will be strongly impacted by the presence of buildings

… and perspectives

- Consolidate the comparison Gaussian – SLAM in the very near field (topic of a future field campain from IRSN and Orano) … to infer knowledge on the transition distance at which the Gaussian approx. becomes acceptable



Comparison of Maximum Arcwise Concentrations for a unitary release in neutral conditions