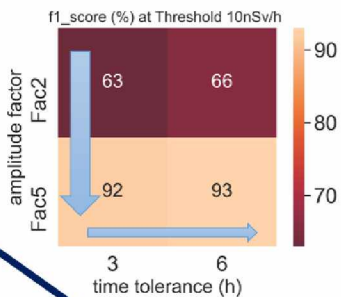


Radon-222 atmospheric transport model: Statistical evaluation and analysis for an optimized framework

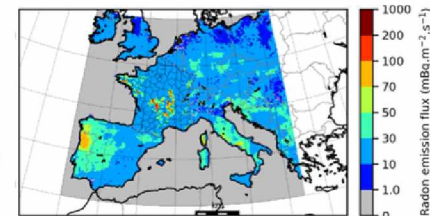
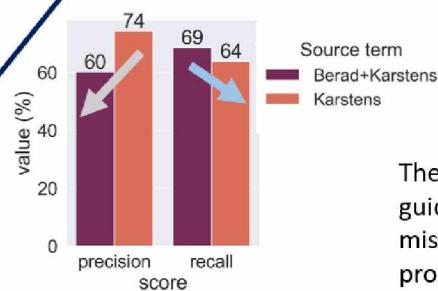
Arnaud Quérel, Khadija Meddouni, Denis Quélo, Thierry Doursout, and Sonia Chuzel

The nature of failures



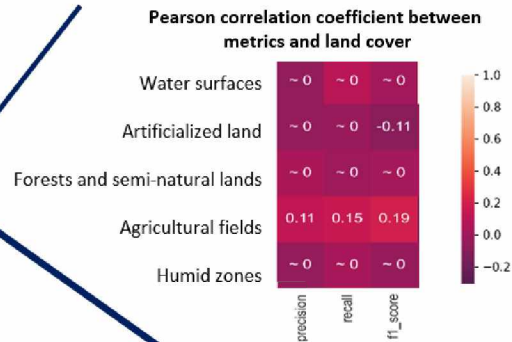
Failures are due to **amplitude gaps** rather than time delays.

The effect of exhalation flux



The choice of an exhalation flux should be guided by which aspect is more critical: missing true events (**bad recall**) or producing false alarms (**bad precision**).

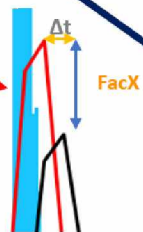
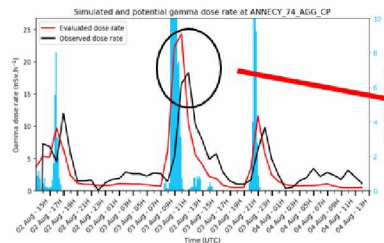
The influence of soil characteristics



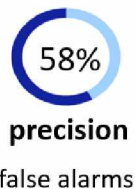
No correlations between the model's metrics and soil characteristics (soil occupancy, type and geological age) within 1km from the measurement station.

Confrontation to gamma dose rate observations:

15 000 events over 6 months



Within a Fac2 and 3h tolerance:



RADON-222 ATMOSPHERIC TRANSPORT MODEL: STATISTICAL EVALUATION AND ANALYSIS FOR AN OPTIMIZED FRAMEWORK

Arnaud Quérel, Khadija Meddouni, Denis Quélo,
Thierry Doursout, and Sonia Chuzel

vEGU 2021 April, 30th 2020

Plan

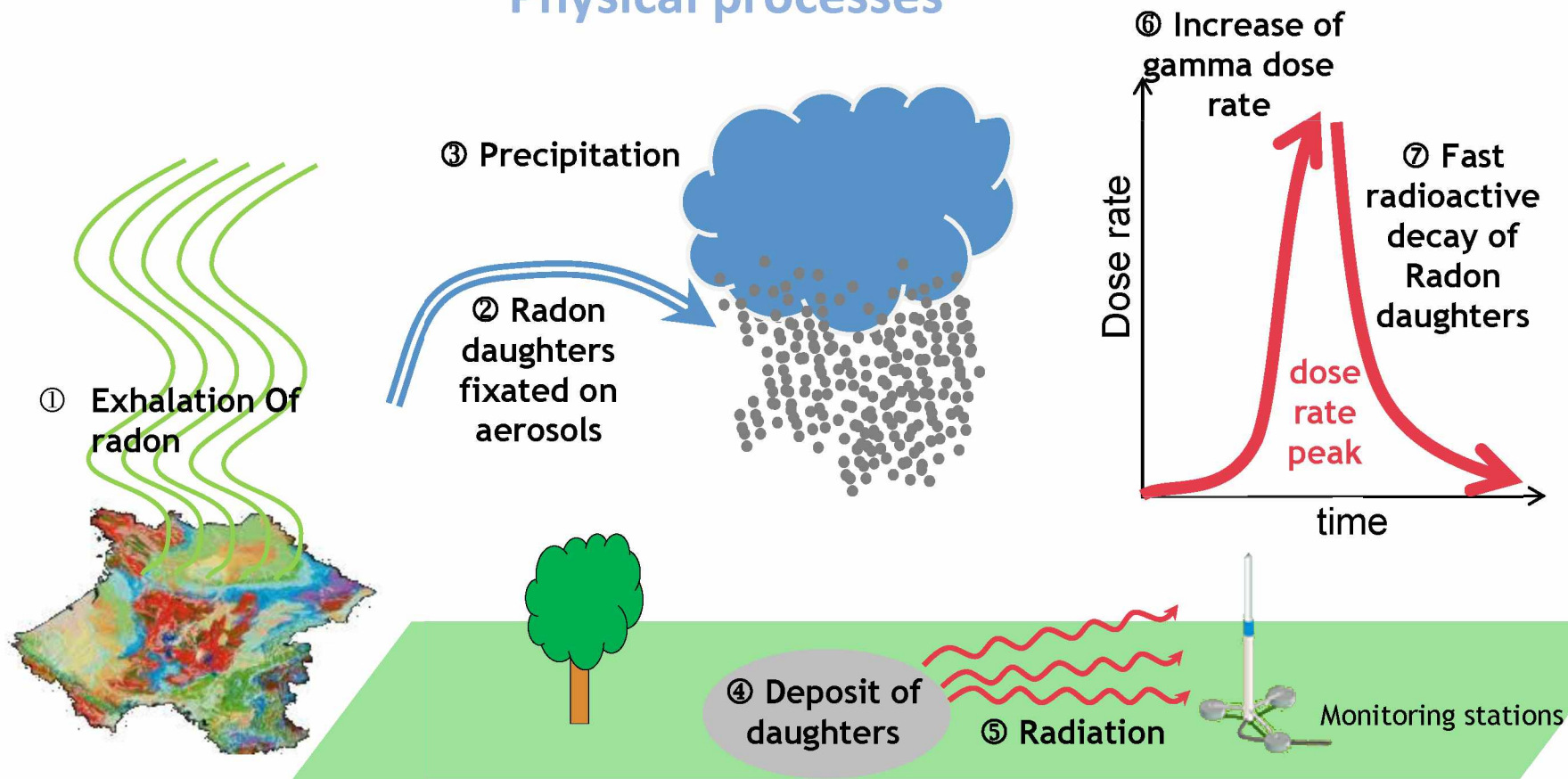
- Context
- Physical process
- Simulation framework
- Methods
- Results
- Conclusions & outlook

Context

- In the event of an incident or accident involving radioactive materials, IRSN provides guidance to public authorities on the technical, public health and medical measures to be taken to protect the population and the environment.
- The monitoring network T el eray in France: +400 of gamma dose rate monitoring stations recording data each ten minutes all year round.
- Several times a year, alarms of this emergency monitoring network are triggered: gamma dose rate peaks due to Radon-222 progeny scavenged by precipitations.
- Although these peaks do not present any risks to the population or environment, it is necessary to determine their origins: natural radioactivity or an accidental release of radioactive materials

Source: EGU2020-14940 Lessons learned on atmospheric radon modelling by statistical model-to-data comparison on gamma dose rate peaks

Physical processes



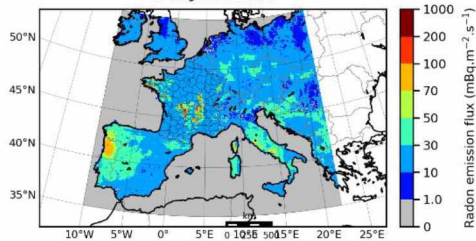
Source: EGU2020-14940 Lessons learned on atmospheric radon modelling by statistical model-to-data comparison on gamma dose rate peaks

Simulation framework

Input

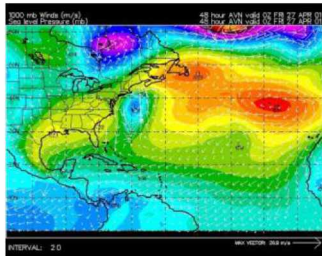
Radon exhalation flux

Radon emission flux BERAD2018 + Karstens2015
17 Aug 2020 00h00



Physical properties (decay chain, ...)

Meteorological data



Processing

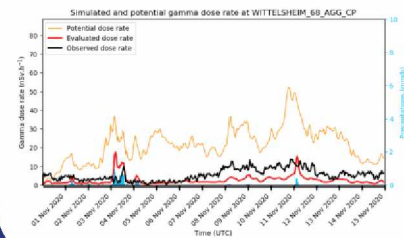
Atmospheric transport model (Ldx)

- Eulerian long-range transport model
- Mainly used in nuclear emergency response

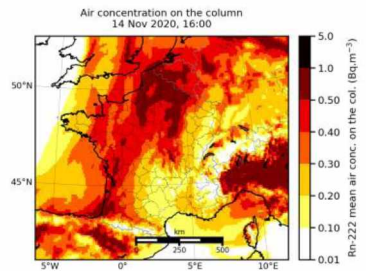
Processing

Output

Gamma dose rate series(nSv/h)

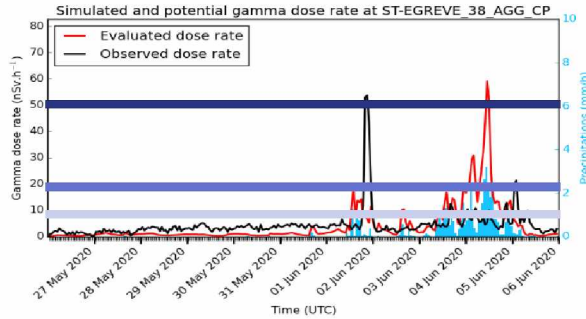


Air concentration maps(Bq/m3)

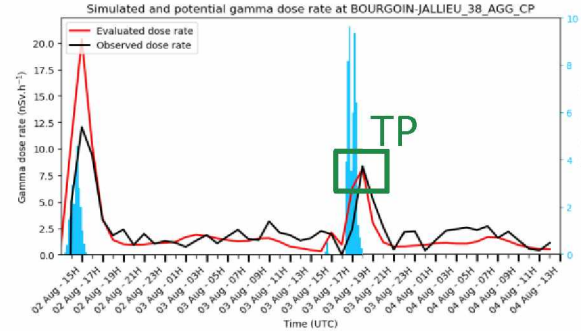


Methods: Model to measurement comparison

3 thresholds: 10, 20 and 50 nSv/h

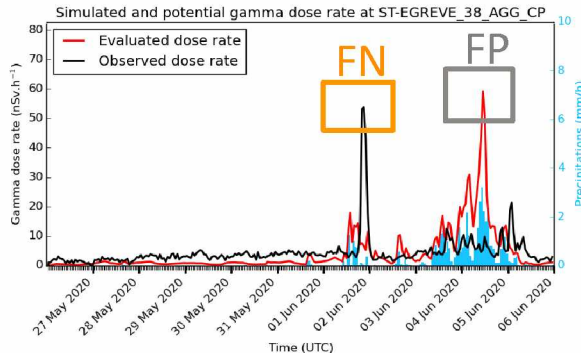
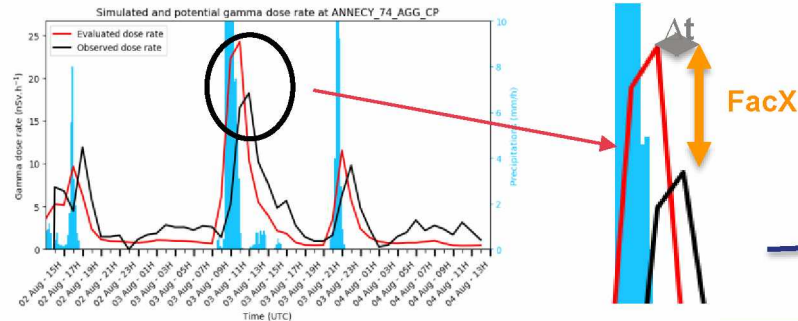


3 classes of events:



TP: Simulated well observed

2 criteria : observed and simulated peaks within Δt in time and **FacX** in amplitude from each other



- FN: Observed not simulated
- FP: Simulated not observed

Methods: Metrics

Peak-to-peak

- **Recall** = $\frac{TP}{TP+FN}$ tendency to miss events
- **Precision** = $\frac{TP}{TP+FP}$ tendency to produce false alarms
- **F1_score** = $2/(recall^{-1} + precision^{-1})$ global accuracy

Time series

- **1st Wasserstein distance:** minimal cost of transforming one distribution to another: lower \rightarrow higher similarity
- **Fac 2:** % $\frac{ddd_{obs}}{2} \leq sim_ddd \leq 2obs_ddd$
- **Pearson correlation coefficient:** from -1 (total anti-correlation) to 1 (total correlation)

Methods: case study

Comparison over a period of 6 months with more than 15 000 peaks > 10 nSv/h

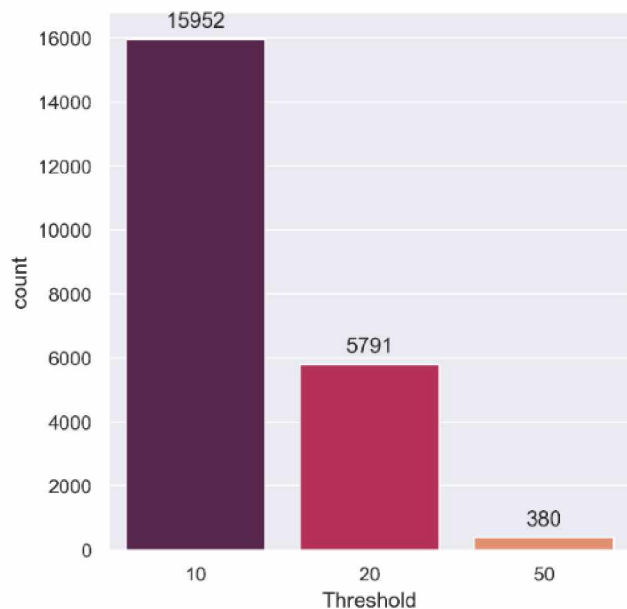


Fig.1: Total number of peaks by threshold

Two types of precipitation data:

- predictions from Météo-France Arpege Model: $\Delta t=1h$ and $\Delta x=\Delta y=0.1^\circ \approx 10km$
- radar observations : $\Delta t=5$ minutes and $\Delta x=\Delta y=1km$ historical and more precise. Used for reanalysis.

Two exhalation flux configurations:

- Constant in time : BERAD¹ (France) + Karstens² (rest of Europe)
- Varying by month: Karstens²(all of Europe)

1: Bureau d'étude et d'expertise du radon – IRSN – based on Ielsch et al. 2017 <http://dx.doi.org/10.1016/j.jenvrad.2016.05.022>

2: Karstens, U., Schwingshackl, C., Schmithüsen, D., and Levin, I.: A process-based ²²²radon flux map for Europe and its comparison to long-term observations, Atmos. Chem. Phys., 15, 12845–12865, <https://doi.org/10.5194/acp-15-12845-2015>, 2015

Results: three primary statistical evaluations

1

Using radar observations instead of rain predictions yields better results → **subsequent evaluations are carried out using radar data**

rain predictions

Threshold (nSv/h)	F1_score (%)
10	50
20	40
50	20

1

<

radar observations

F1_score (%)
63
57
31



3

Poor results for peaks above 50 nSv/h

2

Recall is higher than precision: failures tend to be false positives more than false negatives

Threshold (nSv/h)	Recall (%)
10	69
20	79
50	61

2

>

Precision (%)
58
45
21



Setting: Fac2, $\Delta t=3h$, combined BERAD+Karstens source term

Results: statistical evaluation

- The improvement from increasing the time tolerance from 3h to 6h is marginal compared to that obtained considering Fac5 instead of Fac2 between the observed and simulated peaks.

failures are due to simulated values being far apart from observations in amplitude rather than in time

- This is confirmed by the distribution of bias between observed and simulated peaks: 0.75 quantile < 0

a consistent tendency to overestimate peaks

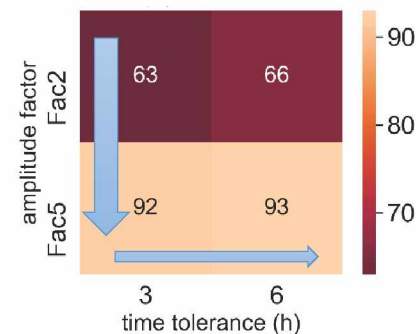


Fig.2: Evolution of F1_score at threshold 10 nSv/h

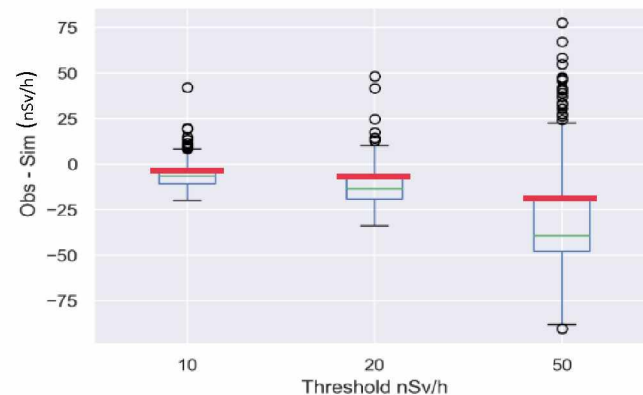


Fig.3: Distribution of bias between observed and simulated peaks

Results: statistical evaluation

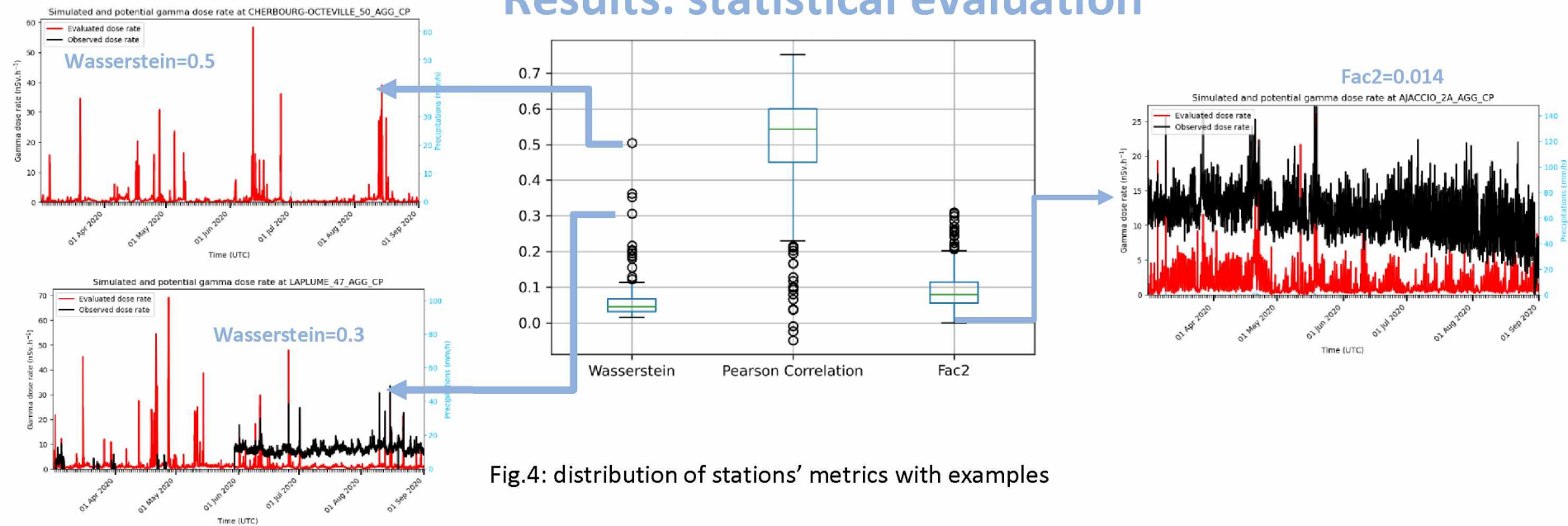


Fig.4: distribution of stations' metrics with examples

- Wasserstein distance exceptionally high for stations with anomalous observations (missing data, technical malfunction, etc.).
- Good correlation with some exceptions.
- Low Fac2: bias between observations and simulations is mainly due to the inefficient extraction of the background radiation from the observations.

Results: effect of exhalation flux on peaks

From a **BERAD+Karstens** combination to a **Karstens** exhalation flux:

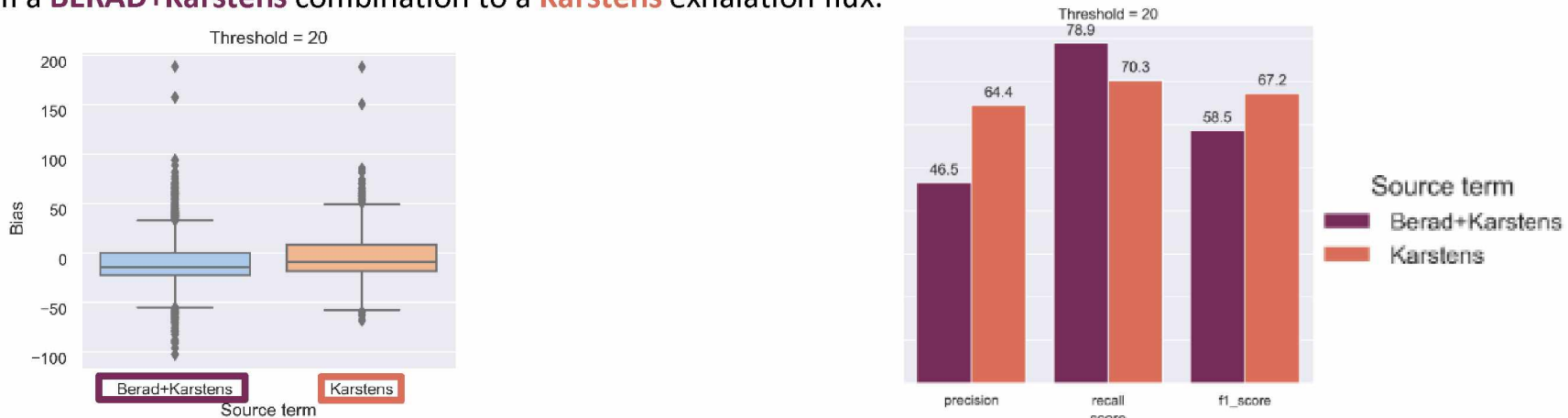


Fig.5: Effect of source term on the distribution of bias (left) and metrics (right) by threshold

BERAD+Karstens has a negative bias in mean

- -> its gamma dose rate peaks have higher magnitude
- -> lead to a greater number of false positives

Karstens has a better precision (less false positives), worse recall (more false negatives) but globally better accuracy (higher f1_score).



The choice of an exhalation flux should be guided by which aspect is more critical: missing true events or producing false alarms

Effect of station environment

Weak correlations between a station's metrics and characteristics of its immediate 1km environment: soil occupancy¹, type² and geological age³

1: CORINE Land Cover
2: INRAE
3: BRGM geol. map at 1/1 000 000

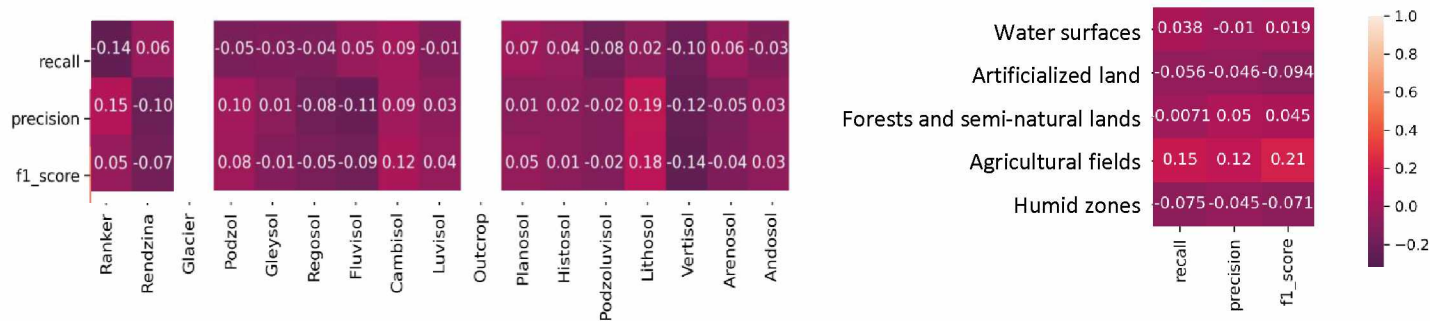


Fig.6: Pearson correlation coefficient between a station metrics and type of soil (left) and soil occupancy (right)

Same conclusion from Anova tests: p-value > $\alpha = 0.05$ significance level.



The model's metrics are unaffected by the measurement station immediate environment.

Conclusions

- We presented a model capable of successfully simulating around 60% of observed gamma dose rate peaks within a Fac2 in amplitude and 3h time tolerance.
- This performance is sensitive to the used exhalation flux and precipitations accuracy, but not to the soil characteristics around the measurement station
- Our simulated gamma dose rate peaks are often higher than observed ones, which makes the model prone to produce false positives more than false negatives

Outlook

- Many optimization paths: exhalation flux, wet deposition schemes...etc.
- Evaluation on the capacity to predict Radon air concentration
- Validation over a longer period of 2 years