TERRIFFIC

ACCELERATED CBRNE RESPONSE

DIRECT AND INVERSE MODELLING OF ATMOSPHERIC DISPERSION AND GAMMA RADIATION IN THE CONTEXT OF CRISIS MANAGEMENT OF ACCIDENTAL OR DELIBERATE RADIOACTIVE RELEASES: THE TERRIFFIC PROJECT

[a]Chi Vuong NGUYEN, [a]Lionel SOULHAC, [a]Guillevic LAMAISON and [a]Perrine CHARVOLIN

[a] Univ Lyon, Ecole Centrale de Lyon, CNRS, Univ Claude Bernard Lyon 1, INSA Lyon, LMFA, UMR5509, 69130, Ecully, France

18th June 2021 – 20th HARMO conference, Tartu, Estonia

OUTLINE

- **The TERRIFFIC project**
- Direct model
- Inverse model
- Application on real field
- Conclusion

THE TERRIFFIC PROJECT

OBJECTIVES

- CBRNe event issues:
  - Stop threat
  - Save victims
  - Manage *crime* scene
- The TERRIFFIC system aims to:
  - Provide first responders faster information
  - Enable better management of the control zone

Example of intervention with the TERRIFFIC system in case of CBRNe event

TERRIFFIC ACCELERATED CBRNE RESPONSE

ÉCOLE CENTRALE LYON

THE TERRIFFIC PROJECT

PARTNERS

ARTTIC
INTERNATIONAL MANAGEMENT SERVICES

arktis
RADIATION DETECTORS

TL & ASSOCIES

BRUHN NEWTECH
LIFE SAVING SOFTWARE SOLUTIONS

list
cea tech

nexter
SYSTEMS

ISEM INSTITUTE
INTERNATIONAL SECURITY AND EMERGENCY MANAGEMENT INSTITUTE

ÉCOLE CENTRALE LYON

aeraccess®
airborne engineering research

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY
LIST

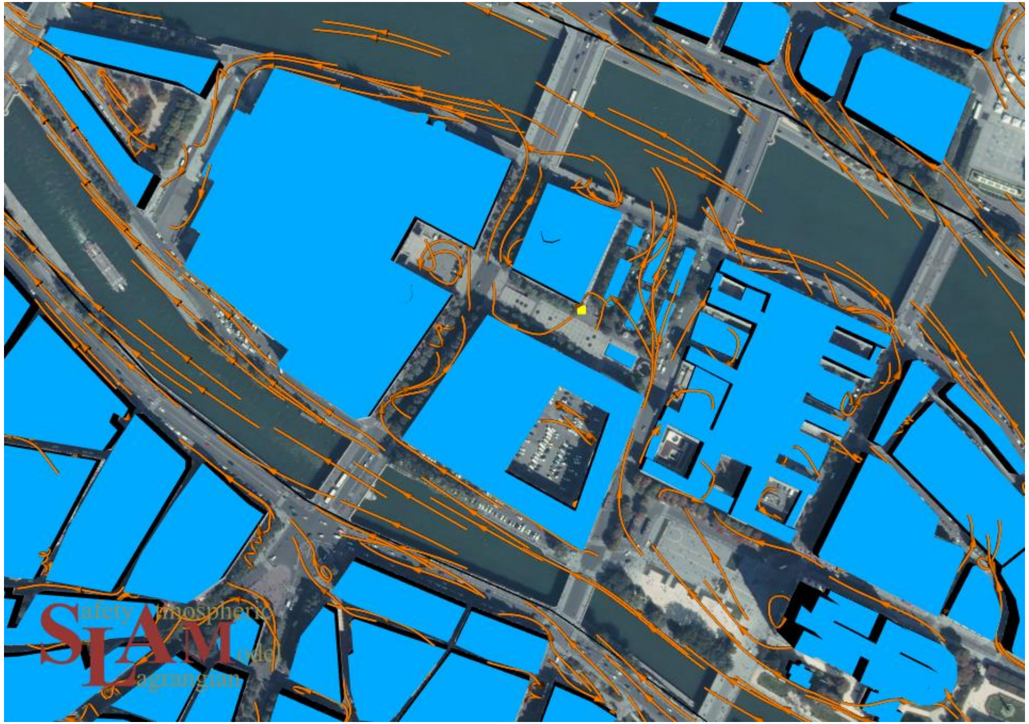
OUTLINE

- The TERRIFFIC project
- **Direct model**
- Inverse model
- Application on real field
- Conclusion

DIRECT MODEL

SAFETY LAGRANGIAN ATMOSPHERIC MODEL (SLAM)

- Stochastic particle dispersion model coupled with a wind field database
- Wind field database:
  - Constructed with CFD simulations
  - 18 wind directions
  - 7 stability conditions
- Reconstruction of a specific meteorological condition by an interpolation of the database

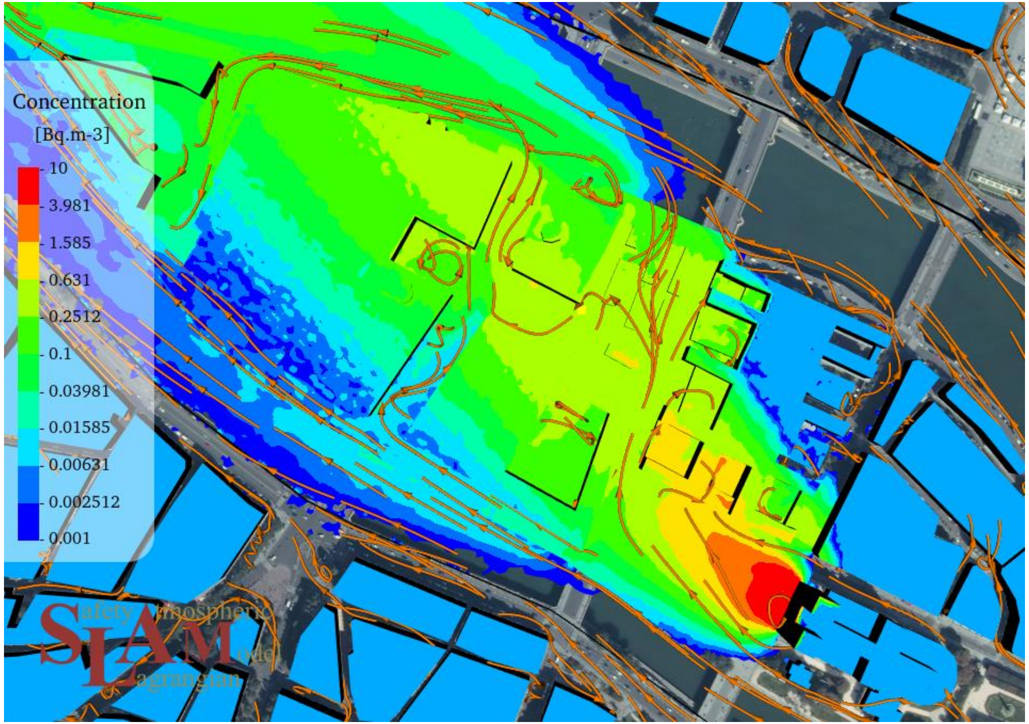


Example of wind field

DIRECT MODEL

SAFETY LAGRANGIAN ATMOSPHERIC MODEL (SLAM)

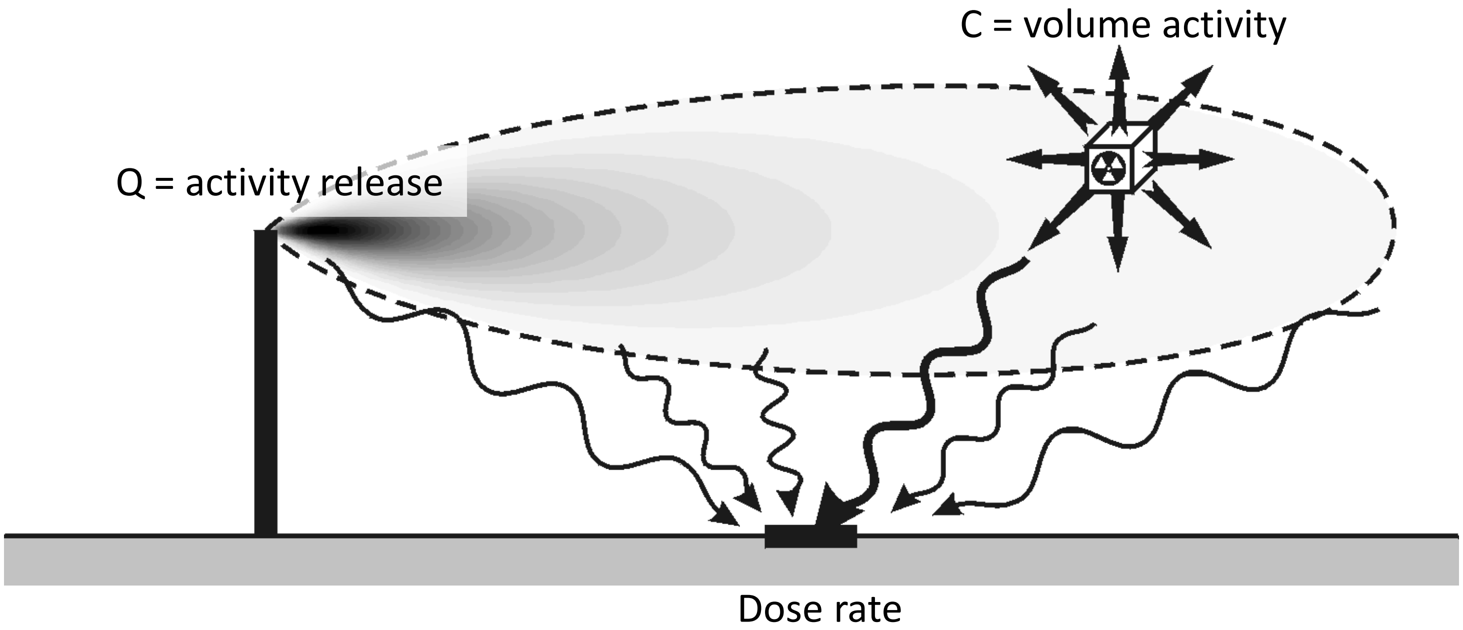
- Stochastic particle dispersion model coupled with a wind field database
- Wind field database:
  - Constructed with CFD simulations
  - 18 wind directions
  - 7 stability conditions
- Reconstruction of a specific meteorological condition by an interpolation of the database



Example of concentration field (on the *ground*)

DIRECT MODEL

MODEL FOR ATMOSPHERIC RADIATION INDOOR & IN ENVIRONMENT (MARIE)



DIRECT MODEL

MODEL FOR ATMOSPHERIC RADIATION INDOOR & IN ENVIRONMENT (MARIE)

- Estimate of the dose rate D [Sv.s^{-1}] induced by several sources emitting gamma ray with energy E [eV]:

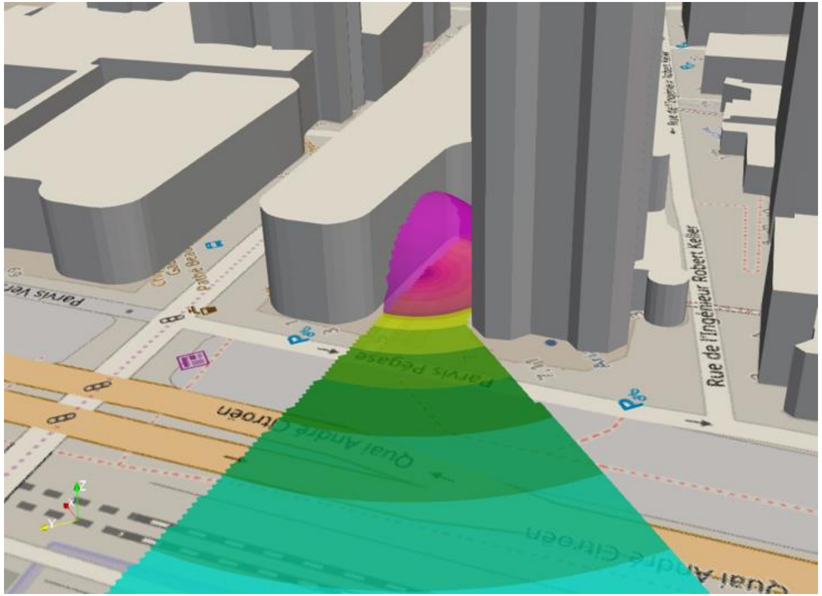
$$D(E) = \alpha(E) \sum_{source\ i} \frac{B(E, \mu r_i)\exp(-\mu r_i)}{4\pi r_i^2} I Q_i$$

with:

  - r_i [m]: distance to the source i
  - $B(E, \mu r)$ []: build-up factor
  - $I(E)$ [] : branch ratio of the gamma ray with the energy E
  - Q_i [Bq] : activity of the source i
  - $\alpha(E)$ [Sv.m^2]: dose rate coefficient by fluence rate

- The *total* dose rate is calculated by summing the contributions of all the gamma rays emitted by the sources

- *Shadow effect* taken into account

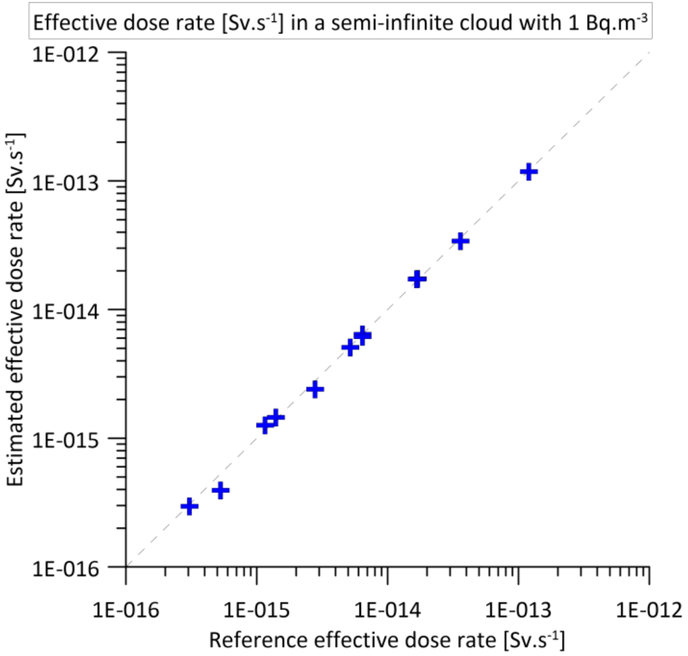


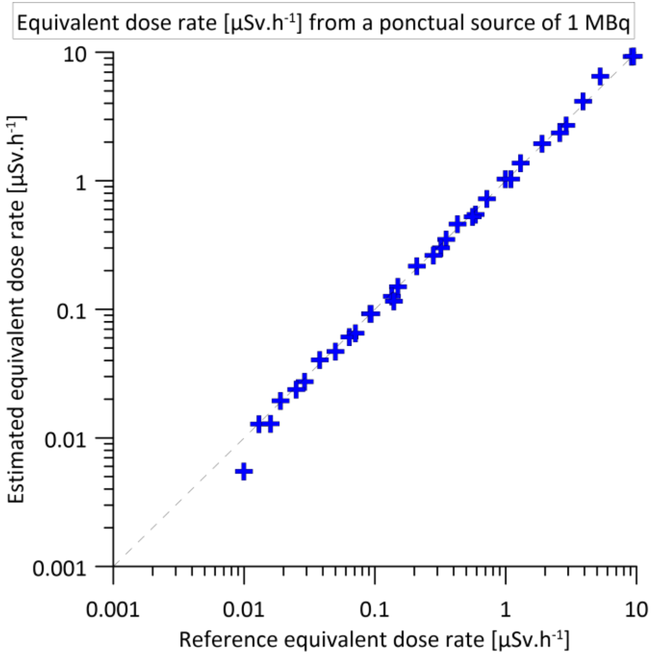
Example of dose rate field

DIRECT MODEL

MODEL FOR ATMOSPHERIC RADIATION INDOOR & IN ENVIRONMENT (MARIE)

- Dose rates estimated with MARIE are in agreement with reference values provided by Dewji et al. (2018) and IRSN data sheets



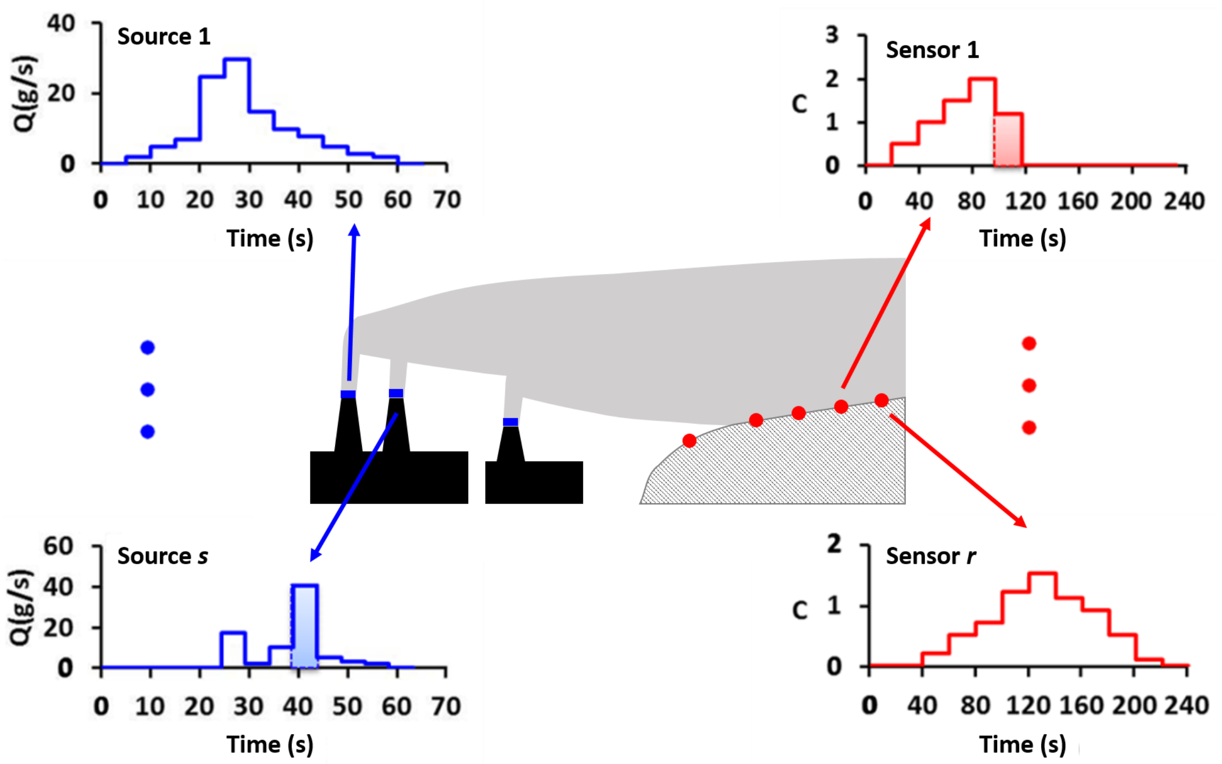


OUTLINE

- The TERRIFFIC project
- Direct model
- **Inverse model**
- Application on real field
- Conclusion

INVERSE MODEL

PROBLEM STATEMENT



INVERSE MODEL

REWIND

- ReWind estimates the source rates assuming a linear relation with the fluence/dose rates:

$$\begin{pmatrix} ATC_{11} & \cdots & ATC_{1n} \\ \vdots & \ddots & \vdots \\ ATC_{m1} & \dots & ATC_{mn} \end{pmatrix} \begin{pmatrix} Q_1 \\ \vdots \\ Q_n \end{pmatrix} = \begin{pmatrix} C_1 \\ \vdots \\ C_m \end{pmatrix}$$

with:

- C_m: measured fluence/dose rate relative to the m^{th} observation
- Q_n: release rate of the n^{th} *source*
- ATC_{mn}: Atmospheric Transfer Coefficient from the n^{th} *source* to the m^{th} observation

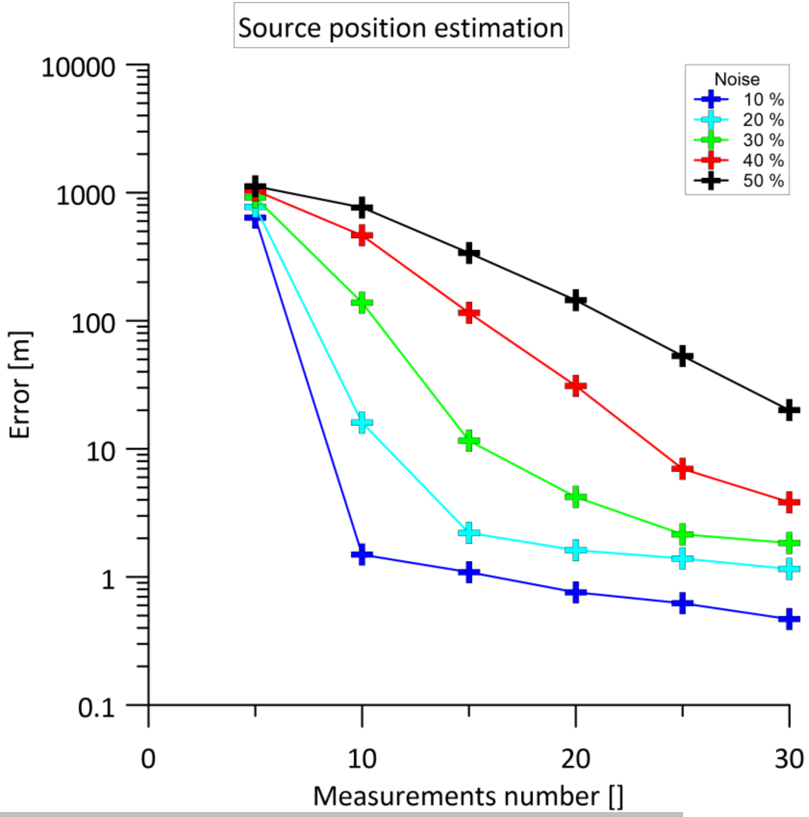
- An iterative algorithm is applied to test different sources locations and nuclide types. The most probable characteristics (location, rate, nuclide type) are those which minimize discrepancies between modelled and measured radiations.

INVERSE MODEL

SOURCE LOCATION: SENSITIVITY STUDY

- Parameters studied:
  - Number of measurements
  - Measurement uncertainty

- Setup:
  - Point source
  - Synthetic measurements constructed with MARIE
  - Distance sensors-source constant (100 m)
  - Gaussian measurement noise
  - 10 000 tests per number of measurements
  - Error averaged over the 10 000 tests



OUTLINE

- The TERRIFFIC project
- Direct model
- Inverse model
- **Application on real field**
- Conclusion

APPLICATION ON REAL FIELD

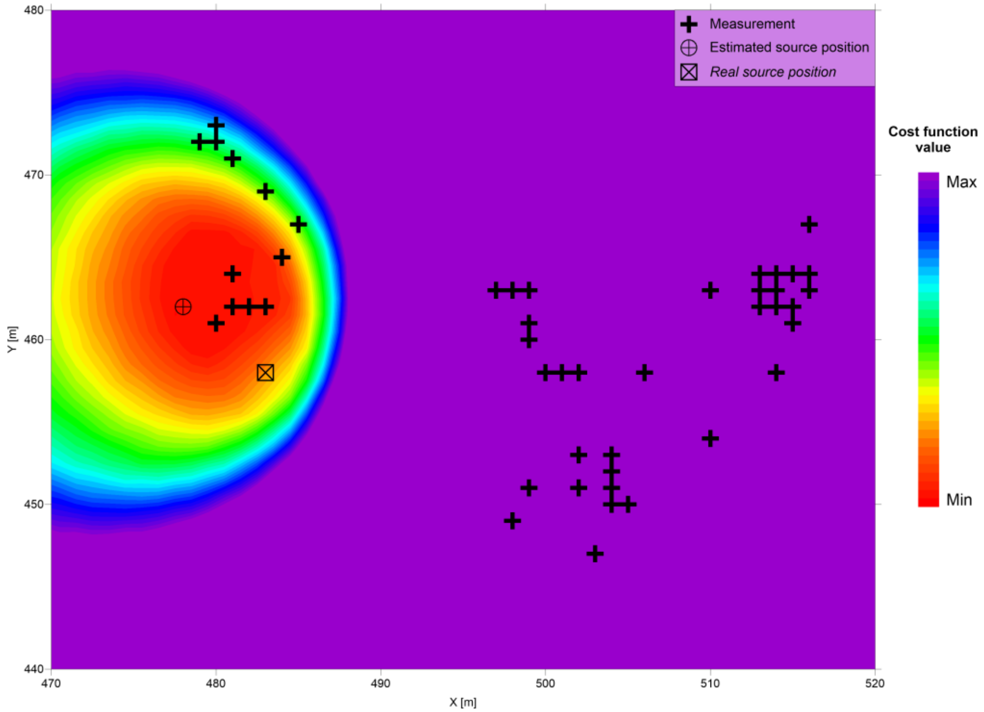
MEASUREMENT CAMPAIGN

- Real solid radioactive source (Cs137 and Co60, about 300 MBq)
- Deployement of a drone and a robot
- Measurements carried out with SiPR and Gamma Camera sensors

APPLICATION ON REAL FIELD

CHARACTERIZATION OF THE SOURCE

- Inversion with real field data
- Source location error is about 10 m with about 100 observations
- The accuracy differs depending on the GPS used, leading to errors in the inverse modelling



Cost function field and source position estimated

OUTLINE

- The TERRIFFIC project
- Direct model
- Inverse model
- Application on real field
- **Conclusion**

CONCLUSION

- An inverse modelling chain, composed of SLAM, MARIE, and ReWind has been developed for the TERRIFFIC system
- Estimates provided by MARIE are in agreement with reference values
- ReWind:
    - Lower are the measurement errors, the better is the source position estimate
    - The higher is the number of measurements, the lower is the error on the source position
- Application of the inverse modelling chain on real field data shows encouraging results

ACKNOWLEDGMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement n° 786729

The views expressed in this presentation reflect the views of the authors. The European Commission is not liable for its content and the use that may be made of the information contained herein.

THANK YOU.

ANY QUESTIONS?

www.terriffic.eu

TERRIFFIC
ACCELERATED CBRNE RESPONSE