RÉPUBLIQUE FRANÇAISE

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maîtriser le risque
pour un développement durable

UNMANNED AERIAL AIR QUALITY MEASUREMENTS:

THE POTENTIAL FOR INDUSTRIAL FIRE PLUMES CHARACTERIZATION WITH ONBOARD LOW-COST SENSOR MEASUREMENTS.

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"Characterization of the air environment in the vicinity of the source" / "Environments and impacts on the living »

Context

Increasing evolution of accidentology in France (Source BARPI, 2020)

- significant contribution from SEVESO sites
- half of the occurrences: **Fires**

The Lubrizol fire in 2013 and the Lubrizol and NL Logistics fire in 2019 highlighted:

- Increasingly numerous and diversified risks;
- immediate and serious consequences for employees, local residents, property and the environment.

To characterize the impact of such events, there is a need for tools and methods that provide rapid responses, allowing reliable data collection.

Rouen, September 26, 2019
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Existing tools :

- Obligation for operators to have appropriate capacities for the immediate follow-up phase.
- The RIPA laboratory network for the post-accident phase.
- Different tools for modeling accident situations depending on the phase considered.

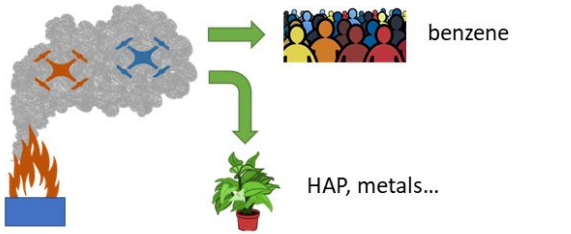
Persistent needs:

- Difficulties in knowing the composition of the smoke.
- Difficulties in providing reliable data to atmospheric modeling tools.

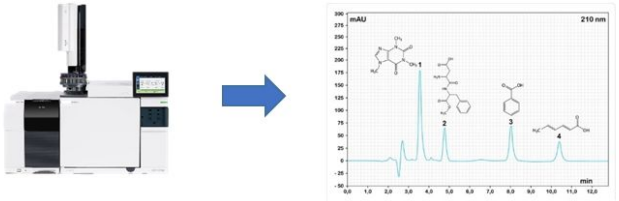
What technological responses can drones provide in accident situations? For atmospheric modeling?

The potential of UAVs

Chemical characterization of the plumes

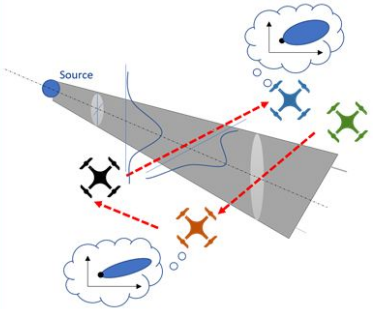


- ***In-situ* sampling of pollutants for off-line characterization**



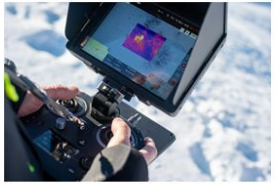
- **Monitoring the evolution of species**

Help with modeling



- **Concentration maps, temporal follow-up…**
- Determination of **gradients of parameters** describing the plumes (temperature, concentration…)
- **Comparative data** of the physical characteristics of the plumes (heights, widths…)
- **Physical characterization of pollutants** (morphology of soot…)

Remote decision tool



- **Security of operational staff**
- **Access to areas inaccessible by an operator**
- **Synergies between professions**

DESIHR

Use of a fleet of autonomous drones capable of adapting their flight plans according to the information acquired by each of them in order to fulfill two missions.

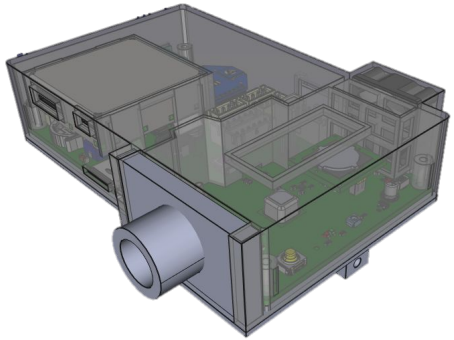
Mission 1

- to **position themselves in the axis of dispersion** of the plume at increasing distances
- **take samples which are quickly analyzed** on the ground for gases and analyzed in the laboratory for soot

Mission 2

- **acquire from outside the plume video images of it,** simultaneously and from different angles
- **transmitting the acquisitions live** from the field to a location several kilometers away (crisis cell)
- **to determine various parameters useful for the modeling of the plume by image processing**

Real-time measurements



Selection of tracers and environmental parameters acquired

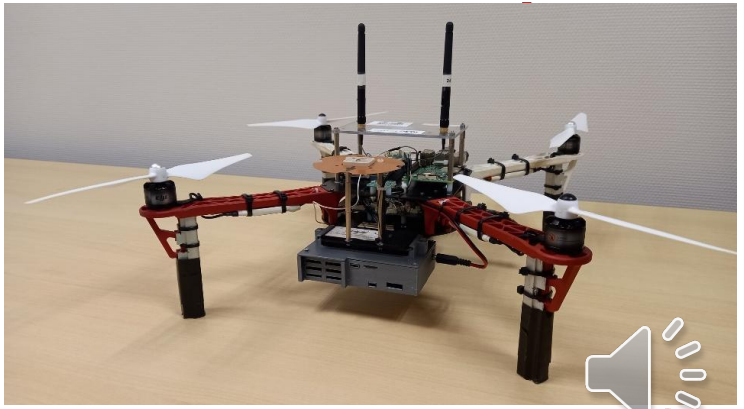
- gaseous pollutants: **CO_2** et **CO**
- particulate pollutants: **particles < 40 µm**
- additional parameters: temperature, humidity, pressure

Selection of candidate sensors based on

- **prior knowledge** of metrological performance
- **modelling requirements**
- mechanical and energy constraints

Sensor qualification

- Framework for the evaluation of the metrological performance of on-board microsensors
  - **No normative framework currently** exists for air quality micro sensors
  - Under construction at **CEN/WG42 level** **but in fixed situation**
- Reflections on the performance criteria required for AQ measurements on UAVs
  - What influence of mobility on the measurement?
  - What use of a spatial and temporal AQ measurement database?



Real-time measurements

AiR'QUALITY SENSOR

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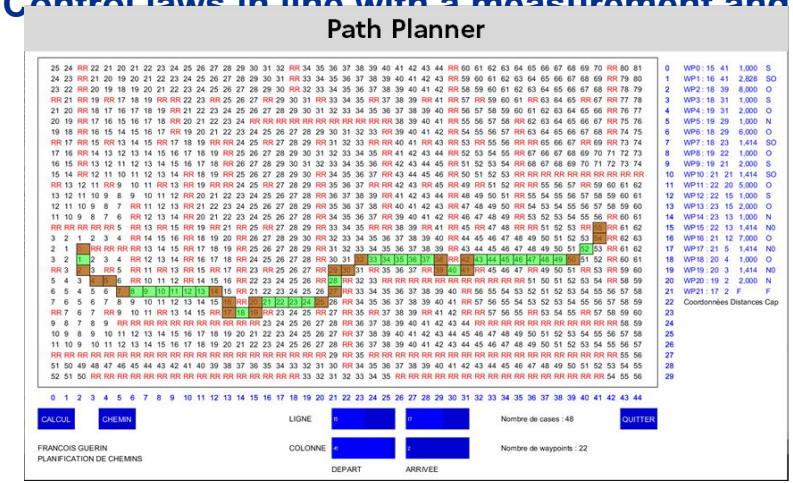
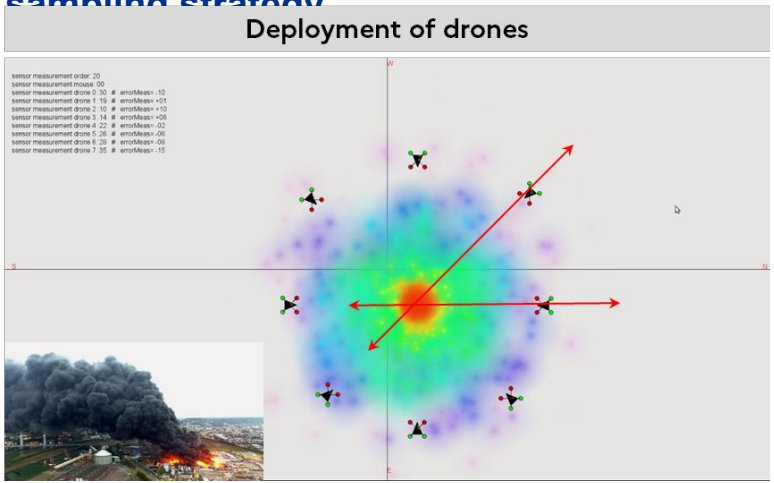
Autonomous drones

Able to navigate in complex industrial environments

- Trajectory optimization problem
- Obstacle avoidance problem

Control laws in line with a measurement and sampling strategy





Real-life tests

LauguiConcept - Valuable partner for field experiments

- Fire safety, emergency and first aid, crisis management and professional risks.
- Located in an industrial zone
- Provision of 2 fire simulators
  - Simulator for (semi-)confined fires, pallet combustion
  - mb yo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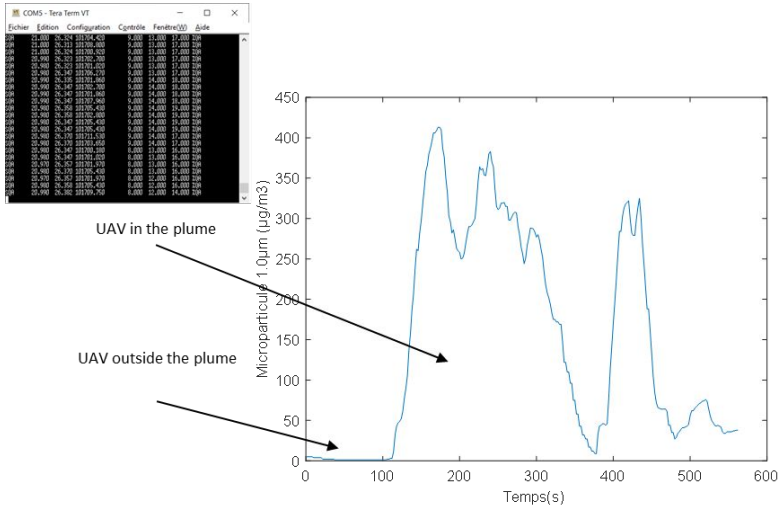
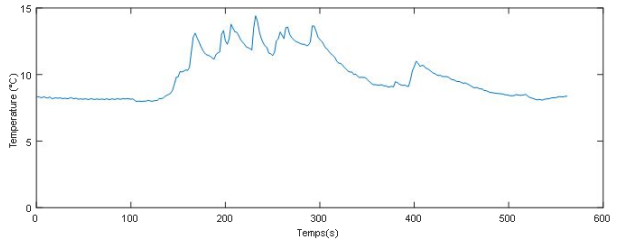
Online results

Real-time data display & processing

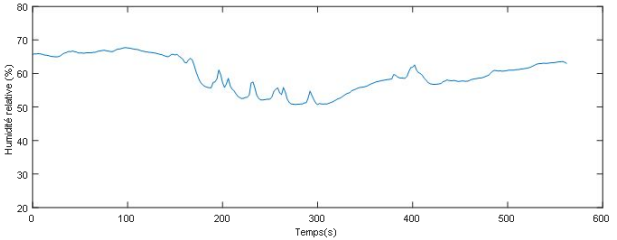
- Environmental parameters for drone safety and contextualization of the measurement
- Remote monitoring of fire pollutants



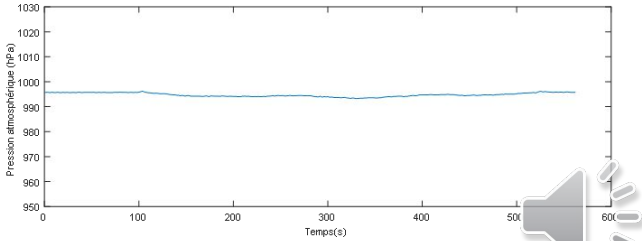
Temperature (°C)



Humidity (%)



Pressure (hPa)



Offline results

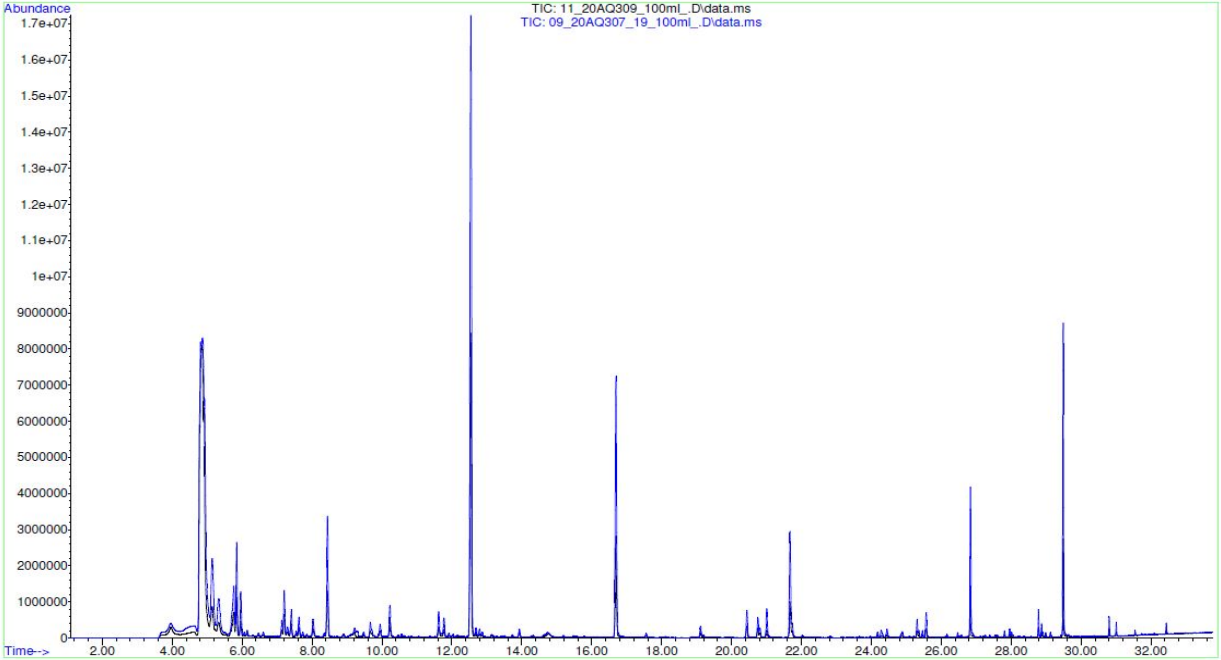
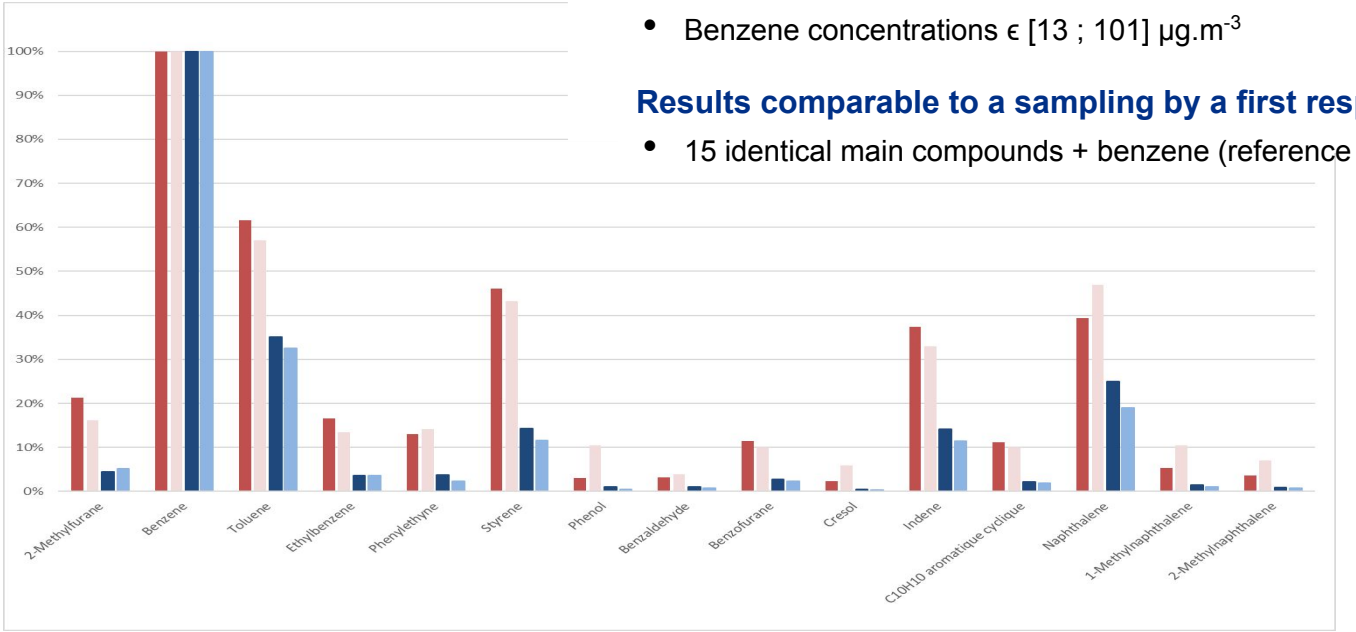


Illustration of the UAV-based gas sampling system

Illustration of the particle sampling device

Offline results



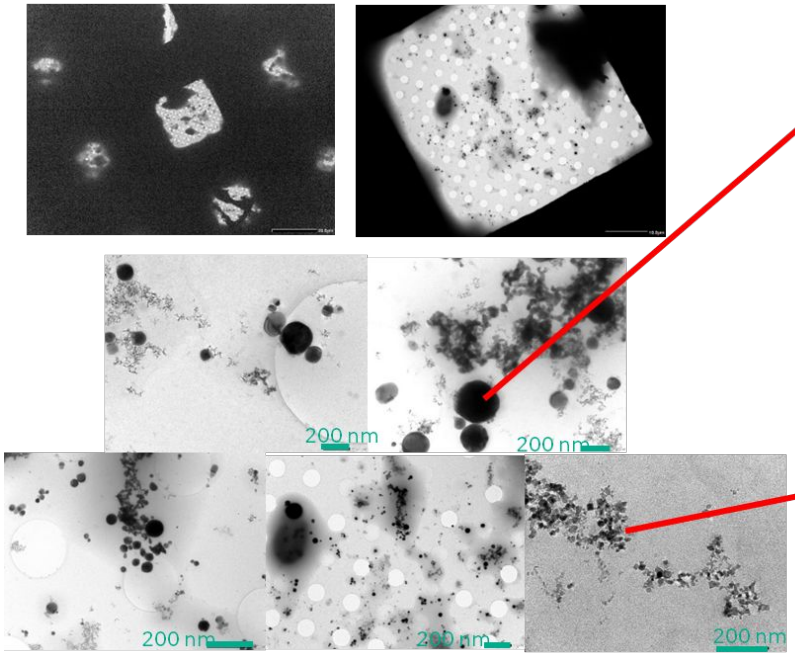
Replication results for a stable pollution source

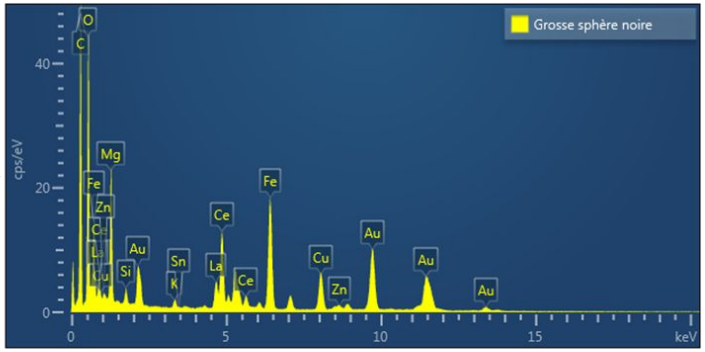
- Benzene concentrations ϵ [13 ; 101] µg.m^{-3}

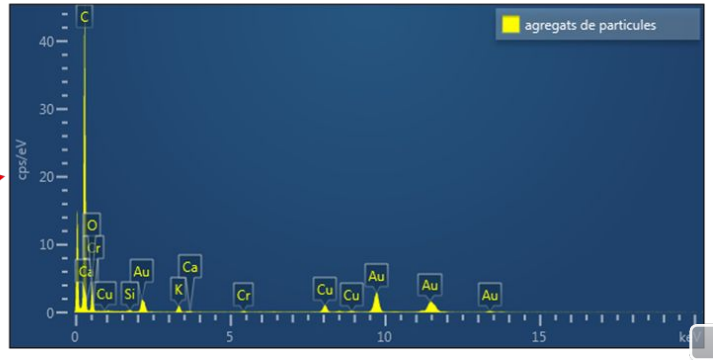
Results comparable to a sampling by a first responder

- 15 identical main compounds + benzene (reference in semi-quantification)

Offline results







Conclusion

Holistic approach to the problem of plume characterization by drone swarm

- Taking into account the **needs of atmospheric modeling during accidental crises**
- Implementation of a measurement strategy in adequation with the observed phenomena
- Deployment of an operational fleet of drones

A customized measurement chain

- Based on fire plume tracers
- Qualification of QA microsensors addressed (especially influence of mobility on the measurement)

Use of a fleet of about 10 drones for sampling (delayed analysis) and real-time measurements

Autonomous navigation of UAVs considered in formation or in swarms within the framework of a decentralized approach

- **Obstacle and avoidance management**
- **Innovative drone deployment** algorithms **based on air quality measurement data**

Preliminary tests that have provided rather encouraging results