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Real-time use of a CFD modelling system in the framework of "Toxic 2014" a major civilian security exercise at a complex urban site in Paris

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Introduction and context of the exercise (1/2)

- Explosions and toxic releases may originate from industrial accidents or malicious releases. Due to their potentially dramatic consequences, a great attention is paid to the prevention, provision, and managing of the "CBRN-E threats".

- In the last years, modelling and simulation have experienced considerable improvements. This is not only good and important for the scientist and engineer, but also an opportunity to change the status of the predictive computations performed in emergency preparedness and response to make them an effective support in the decision-making process.

- While built environments with a complex topography and varying meteorological conditions are definitely the places where CBRN-E events may arise, advanced modelling is now able to produce 2D / 3D detailed and realistic results directly useable by the civilian security in a very limited amount of time even for a very large urban domain (see Oldrini et al.).

- This presentation documents a major civilian security exercise called "Toxic 2014" hold in "La Defense" district near Paris and implying the fictitious release of a toxic chemical.

Introduction and context of the exercise (2/2)

- Since 2012, the CEA has launched a research work about the adequacy of the modelling and decision-support tools with the actual needs of the emergency players.

- In this framework, the CEA was associated to the organization of "Toxic 2014" exercise held on 22 May 2014 to test the safety procedures plan of "La Defense" business district.

- The partners were the Paris Fire Brigade, the public body in charge of "La Defense" security, and the "Prefecture" which is the local public authority in France.

- The involvement of CEA in the exercise included contributions to both:
  - The preliminary elaboration of the noxious release scenario, and;
  - The exercise itself by providing atmospheric dispersion modelling and expertise.

- Details are now given about the simulations produced for preparedness and response.

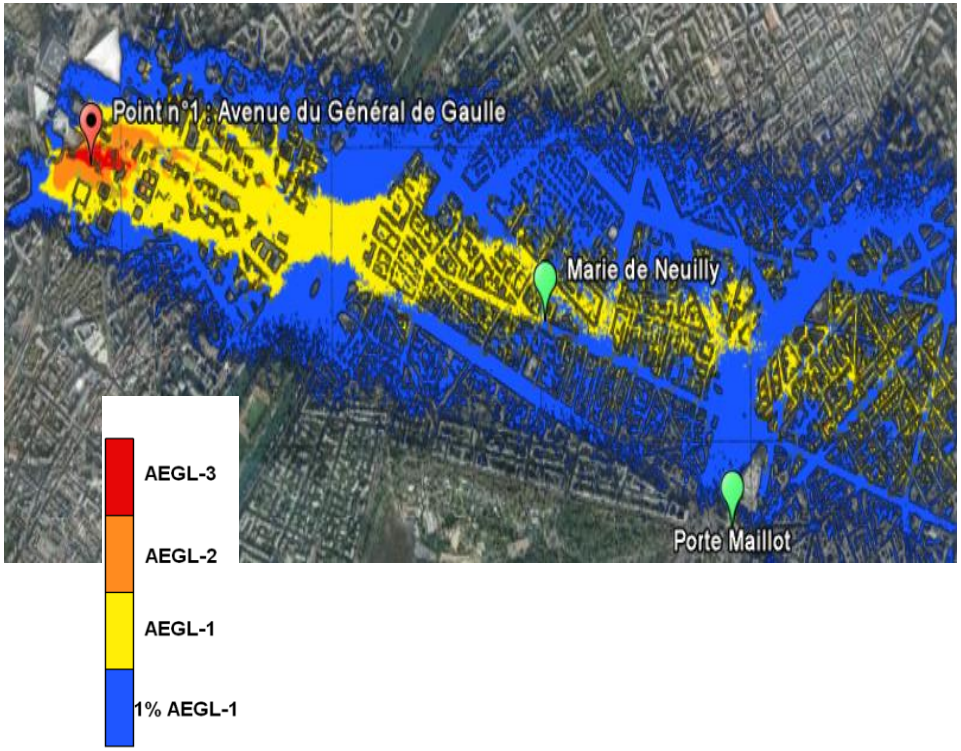
The design and scenario of "Toxic 2014"(1/3)

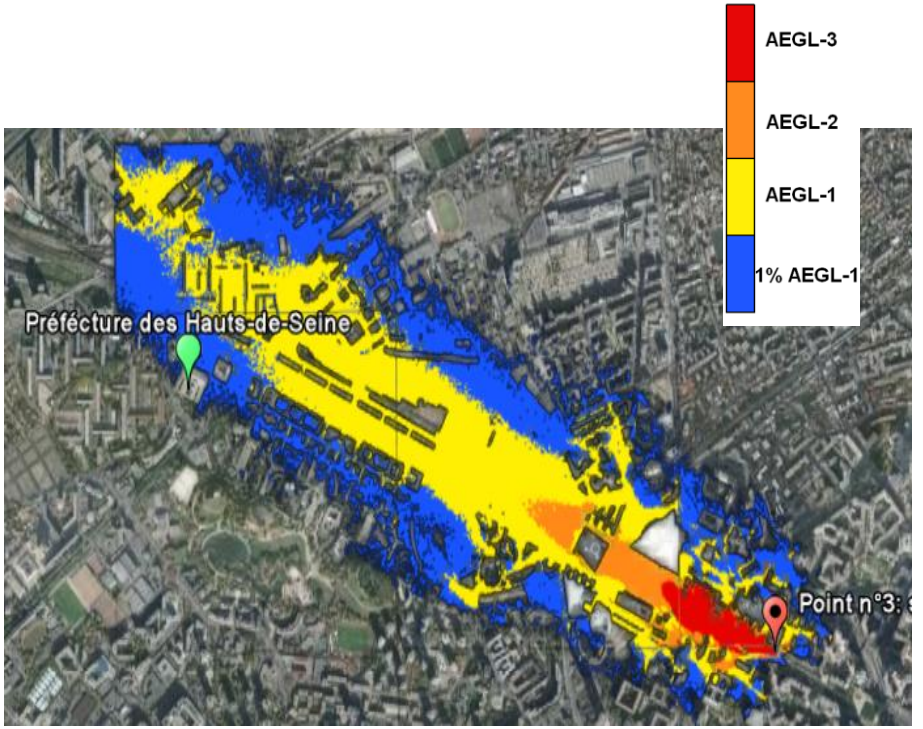
- Proposal for scenarios – In September 2013, the CEA was asked by the Prefecture to develop scenarios of a hazardous dispersion fulfilling a number of requests:
  - Releases should be those of chemicals ("dirty bomb" exercise the year before);
  - Met' conditions should be chosen in order to affect a large part of "La Defense";
  - Danger zones should be quite large to simulate a serious event and to train the Fire Brigade first-responders and the Prefecture command centre.

- Final choice of the exercise scenario – In December 2013, the CEA presented the modelling results of various fictitious releases and potential consequences on the population to the players of the future exercise (Prefecture, municipalities, fire-fighters, health service, police, public transport operators...). This was a basis to decide the scenario of the exercise.

The design and scenario of "Toxic 2014"(2/3)

Panel of possible scenarios corresponding to either accidents or attacks with different weather conditions, locations of the release, and toxic chemicals…





Distribution of a toxic chemical released in "La Defense" district (for two fictive release locations)

The danger zones have warm colours and were determined using the AEGLs of the US-EPA

The design and scenario of "Toxic 2014"(3/3)

- The chosen hypothetical event was a "hazmat" transport accident – a breach in a tanker-vehicle containing liquefied ammonia – located on the western part of "La Defense" district
- The final realistic scenario was featured by CEA obeying the following requests:
  - Respect the protocols and intervention times of the fire-fighters;
  - Make the Prefecture command center work in anticipation by considering a change in the wind direction before the end of the release, thus a variation of the affected areas that could be predicted during the exercise.
- Final inputs for "Toxic 2014" – Presented to the exercise teams in March 2014.

Meteorological conditions	Wind blowing first from northwest then from southwest
Source term	~10 tons of ammonia with 15% instantaneously released and 85% evaporating in 45 min
Mock-up of the district	Includes the topography, the explicit description of the buildings at 1 m resolution and a rugosity length for the small elements (bus shelters, booths…) not described in the obstacles files

The timeline of the "Toxic 2014" exercise (1/2)

	Phase 0 – Beginning of the exercise at 1:00 pm
1:15 pm	Alert of the Prefecture to a tanker-vehicle accident at "La Defense"
1:25 pm	Activation of the crisis command centre and the security procedures plan
1:30 pm	Information of the CEA by the Fire Brigade (place of the event and gross estimate of the source term) and start of a real-time simulation of the dispersion event
1:50 pm	Dispersion results taking account of the buildings obtained in about 20 minutes and sent to Fire Brigade operational center (in Paris) and Prefecture command centre
2:00 pm	CEA expert requested to join the crisis command centre
	Phase 1 – First decisions taken
	Population sheltering or evacuation discussed by the Fire Brigade, the medical emergency team, and the Prefecture using the map views of the dispersion pattern displayed on the computers terminals
2:03 pm	Recommendation by the Fire Brigade to confine rather than evacuate the skyscrapers Decision taken by the Prefecture to confine the whole district as a precaution
2:23 pm	From the CEA video, the release was over and the plume diluted with concentrations below any adverse effects on the human health. The map of the toxic load was used to delimitate the health consequences zones. While the most severe effects were limited to "La Defense" esplanade, numerous people might have detected the abnormal presence of the ammonia in many localities at the north of the district due to a low olfaction threshold

The timeline of the "Toxic 2014" exercise (2/2)

	Phase 2 – Intermediate update of the situation
2:39 pm	Arrival of the Prefecture cabinet director. The Fire Brigade indicated with a map the presence of the rescue teams on the spot and the measures taken to confine the population. The CEA presented the simulation of the plume dispersion on a video and the assessment of the health consequences (from the beginning of the release). The Fire Brigade explained that the risk did not evolve anymore and that a confirmation was expected from the field
From 2:48 pm	The medical emergency team updated the number of casualties and the hospitals taking care of them. It also stressed the saturation problem which could happen if people smelling the ammonia headed to the hospitals. The measures taken in the municipalities at the north of La Defense were further examined. It was noticed that buildings aeration could be advised as the plume had left the sector. Moreover, measurements in the field indicated that the concentration levels were very low consistently with the modelling
	Phase 3 – Final update of the situation
4:00 pm	Arrival of the Prefect at the command center. The event nature and the population protection measures were enlightened as the progressive annulment of the confinement measures. To supplement the Fire Brigade and health emergency service reviews, the CEA was requested to present the ammonia dispersion simulation and the consequences assessment
4:30 pm	Full termination of the security measures all over "La Defense" district

Numerical simulations in "Toxic 2014"(1/3)

- Dispersion simulations – They were performed with Parallel-Micro-SWIFT-SPRAY (PMSS)
  - Developed since 2008 by ARIA Technologies, MOKILI, the CEA and ARIANET
  - PMSS is nested by WRF meso-scale weather forecast operated routinely by CEA
  - PMSS solves the 3D local urban flow and dispersion at a resolution from 1 to 5 meters

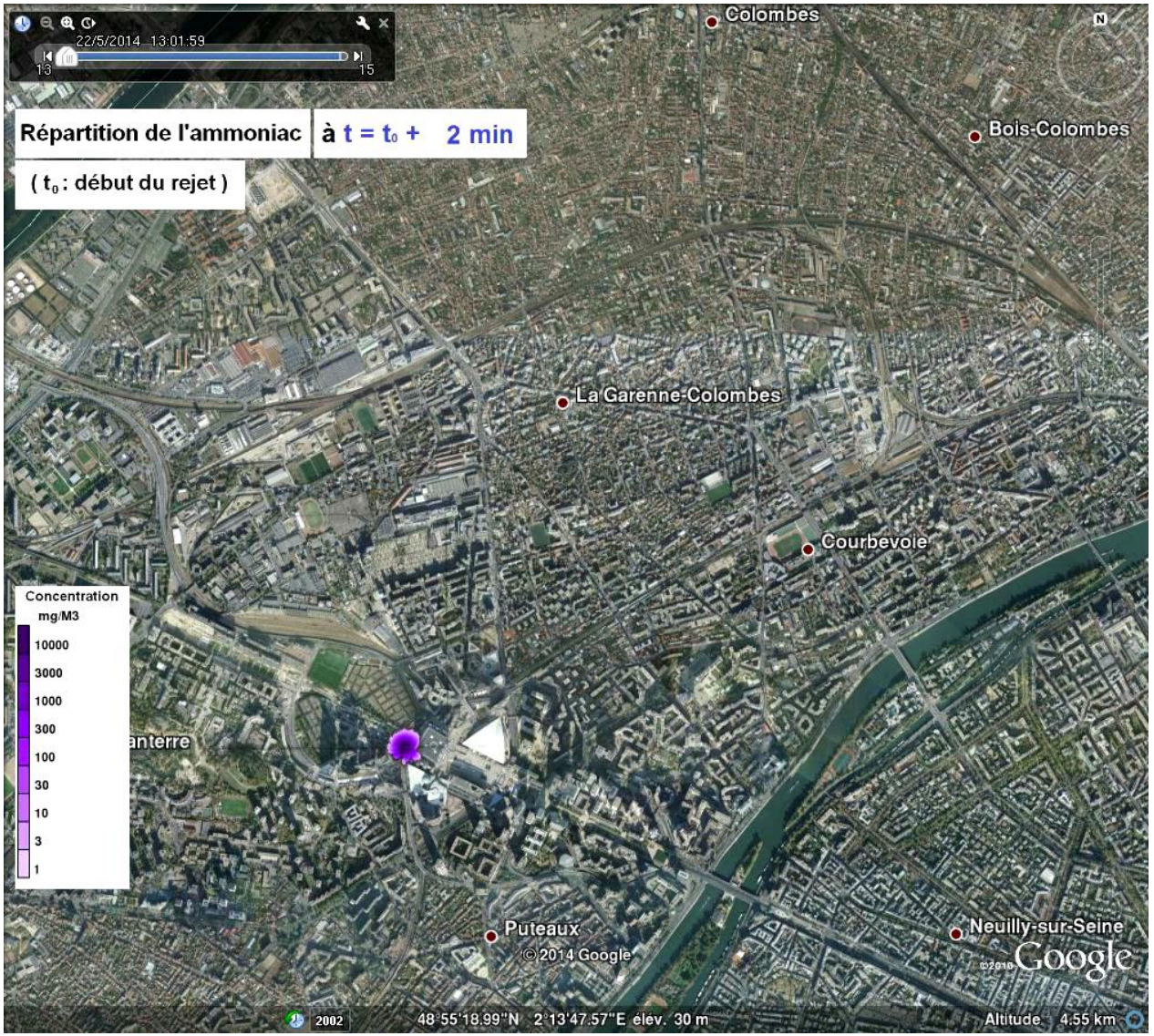
- In this case, PMSS simulations were carried out on a domain with dimensions 4.2 km x 6.3 km
  - Large domain sub-divided in 24 tiles of maximum 351 x 351 points
  - Horizontal mesh size of 3 meters and vertical mesh of 37 levels from ground to 800 m
  - P-SWIFT run on 25 processors and P-SPRAY on a maximum number of 64 processors
  - All the simulations were carried out in less than 15 minutes

- Assessment of the toxic loads – Health consequences were evaluated using the reference toxicological values applicable in France in case of accidental acute exposure by inhalation

- Ammonia olfactory perception – This is a concentration between 3.5 and 35 $mg.m^{-3}$ depending on the individuals (not resulting in any health effect and not associated with time duration)

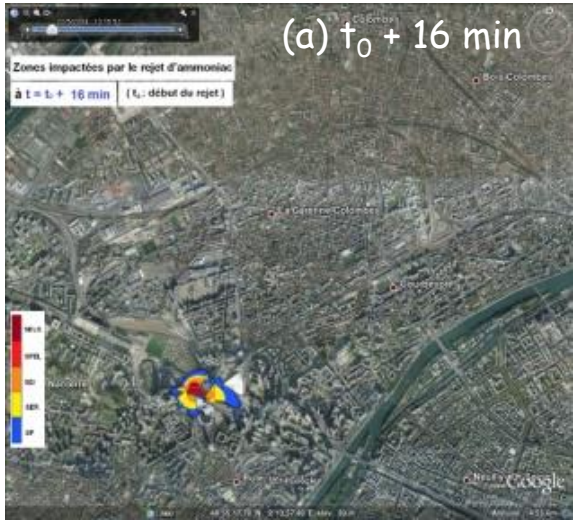
Numerical simulations in "Toxic 2014"(2/3)

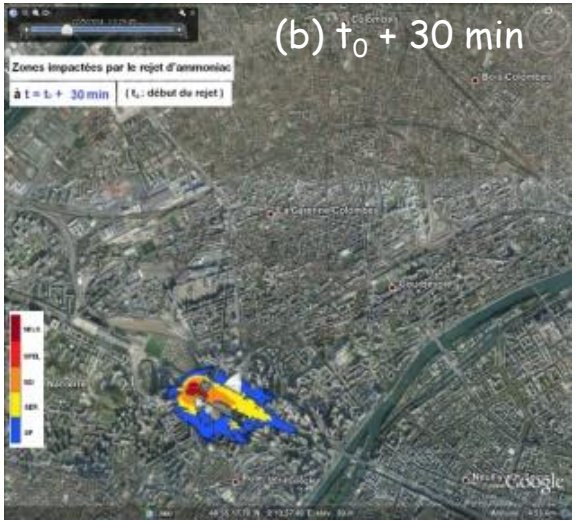
Ammonia volumetric concentration distribution (in $mg.m^{-3}$)

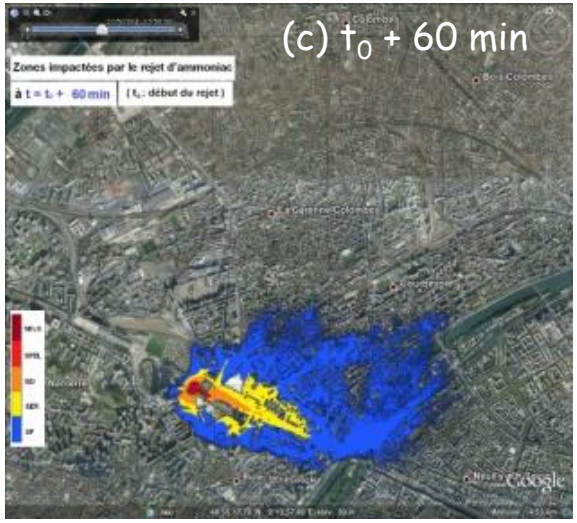


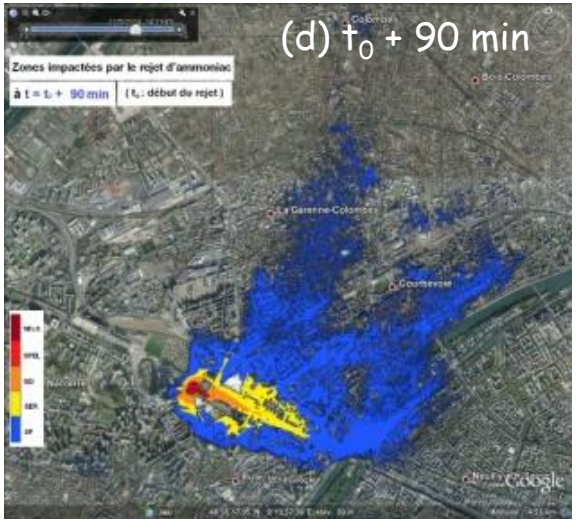
Numerical simulations in "Toxic 2014"(3/3)

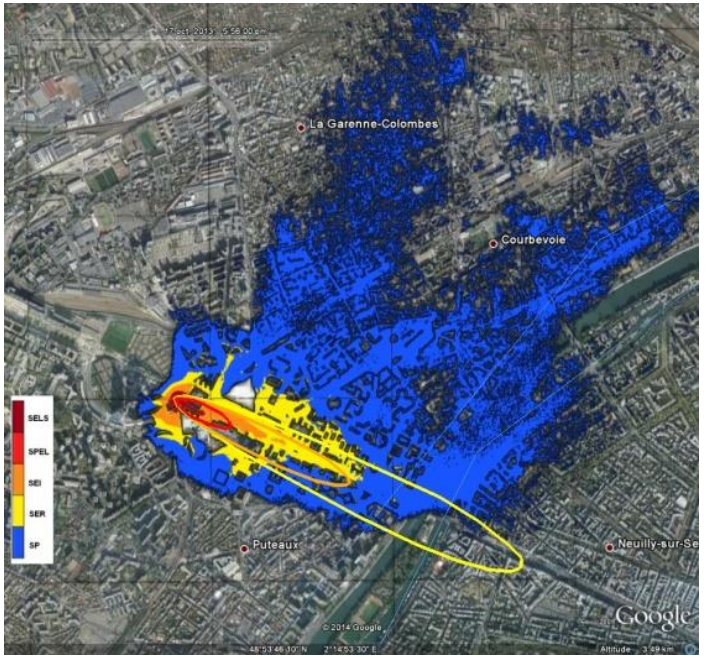
Danger zones and olfactory perception area











Comparison of the danger zones predicted by PMSS and ALOHA (smooth ellipses)

Conclusion – Lessons learnt from "Toxic 2014"

- Modelling activities in the preparation of the exercise had two main benefits:

  1 – Full CBRN risk analysis of events targeting "La Defense" with a better apprehension of the human and organizational impact (to our knowledge, a "premiere" for a business district)

  2 – Development of a technically more precise than the usual practices, realistic and relevant scenario which allowed the services to work in-depth the time sequence of the exercise

- Modelling expertise in the course of the exercise had also two major interests:

  1 – Effective use of the modelling by the population protection services to identify the dispersion processes, adapt the first actions of the rescue teams and anticipate the event follow-up

  2 – Use of the static and dynamic presentation of the results all along the exercise for communication purpose and to help in sharing a collective view during the situation updates

- The exercise revealed two essential benefits in providing real-time modelling expertise:

  1 – Simulation is relevant to enhance a common understanding of the 4D chemical distribution, thus helps in making decisions and taking adapted measures for the population protection

  2 – Simulation may be used to facilitate the communication to the authorities and all players, thus helps in generating a shared representation and an optimal coordination of the centre

- Finally, it was a good opportunity to work collaboratively with practitioners and make the CEA computational tools better fit the needs and missions of the civilian security organization

Questions?

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