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METEOROLOGICAL FORECAST AND DISPERSION OF NOXIOUS AGENTS IN THE URBAN ENVIRONMENT

APPLICATION OF A MODELLING CHAIN IN REAL-TIME TO A FICTITIOUS EVENT IN PARIS CITY

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Introduction – Motivation & Modelling system

- AT&D modelling may be of great help for rescue teams and public authorities:
  - For preparedness before a crisis implying the release of hazardous materials
  - Also in the course of a real emergency (what we are going to try to demonstrate!)
- Advanced 4D simulations of the air flow and dispersion provide the decision makers with a precise and realistic view on the event in terms of CBRN distribution and health effects
- CEA and Paris Fire Brigade (BSPP) have done a "dirty bomb" exercise on 20th June 2012
  - Radionuclides dispersion and impact assessment in real-time at CEA premises
  - Transmission of the results to the BSPP Operations Survey Centre (CSO)
- Operational chain of models elaborated by CEA comprising:
  - The meso-scale CEA weather forecast system MEDICIS based on WRF
  - The micro-scale Parallel-Micro-SWIFT-SPRAY (PMSS) suite developed by ARIA Technologies, ARIANET, MOKILI, and CEA (Armand *et al.*, 2011)

Armand, P., C. Duchenne, O. Oldrini, C. Olry, J. Moussafir, and A. Albergel. Simulation with PMSS of the wind field and potential dispersion in the streets of Paris. *15th Annual George Mason University Conference on Atmospheric Transport and Dispersion Modeling, GMU 2011*, July 12-14, 2011, Fairfax (VA) USA

Exercise scenario & Computations method

- Scenario of a FALSE "dirty bomb" explosion chosen in agreement with the Fire Brigade

1) *Attack supposed to happen in Paris 8th district, a strategic area encompassing USA, UK, and Israel Embassies, Ministry of Home Affairs, the French President residence…*
2) *Bomb inside a van parked in front of post office in La Boétie street near Miromesnil metro*
3) *20th June 2012 – 11 am, moderate explosion, but strong enough to disperse an aerosol*
4) *Less than 2 min release, producing a cylindrical plume of 10 m diameter, rising up to 20 m (initial approximate geometry to take account of the explosion blast effect)*
5) *Later on, it is found that the release is radioactive and the radionuclide identified as ^{60}Co*

- Principle of the computations

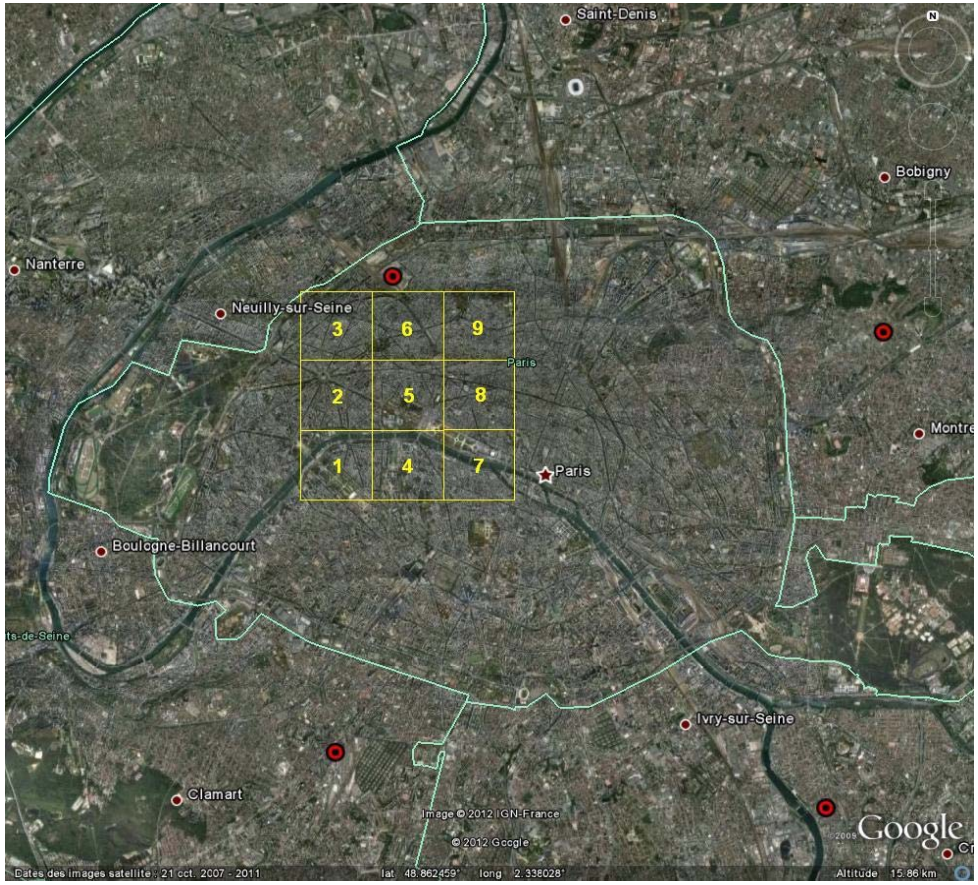
1) *Air flow forecast inside all Paris streets was available before and during the exercise…*
2) *… While atmospheric dispersion computations were launched at the time of the exercise*
3) *Then, post-processing to produce maps of the radionuclide distribution and consequences*

Weather forecast & Dispersion calculations

- Calculation domain and geographical data
  - Domain covering all Paris meshed horizontally at 3 m resolution – As this domain cannot be handled by a single core, it is divided in “tiles” distributed to multi-processors running in parallel
  - Vertical grid had 27 nodes from the ground to 1,000 m
  - Dispersion simulation on the same horizontal grid with a vertical meshing up to 180 m
  - Topographical data are issued by the French Geographical Institute IGN BD ALTI®
  - 3D buildings description comes from IGN BD TOPO®
- A chain of prediction models is operated routinely by CEA, providing automatically and refreshing every 6 hrs the meteorological forecast at 3 m resolution in all streets of Paris
  - MEDICIS meso-scale forecast runs WRF at 5 km over France and 1.6 km over some regions (Paris area, South-East of France…)
  - The micro-scale air fluxes are continuously computed by down-scaling MEDICIS hourly results
- Dispersion computations
  - 800,000 numerical particles were simulated (a high number giving very precise concentrations)
  - Calculation carried out on a 16-core machine (a quite powerful, but not exceptional machine!)

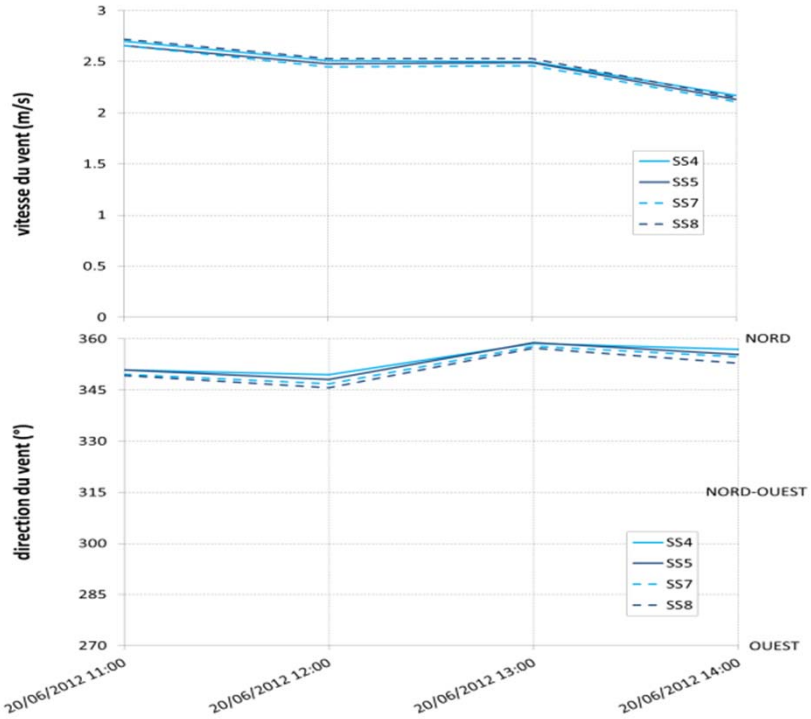
Meso-scale meteorological forecast (WRF)

View of 9 tiles of the total simulation domain
(each tile: 451 x 451 nodes; 1,350 x 1,350 m)



The red dots are meso-model grid nodes where wind, temperature and humidity vertical profiles are extracted for the urban mass-consistent flow diagnostic

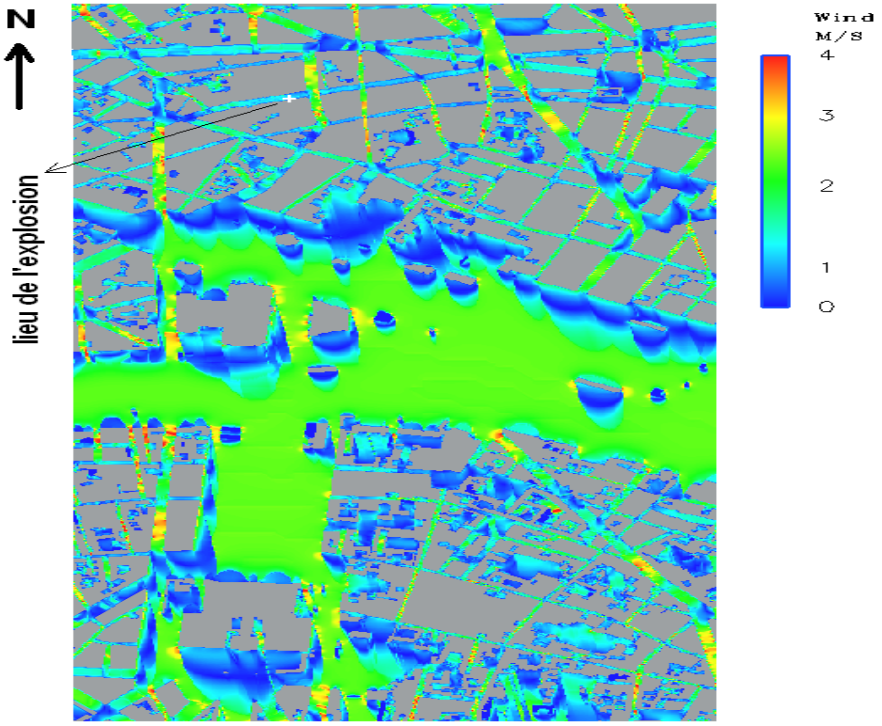
Time profiles on 20th June 2012 (11 am to 2 pm)
of the wind modulus (in $m.s^{-1}$) and direction (in °)



Meso-scale results near the ground at the red dots on the left figure, i.e. without buildings influence. At a sufficiently high altitude over the town, weather conditions are quite unchanging with a 2.5 $m.s^{-1}$ North wind varying less than 15°, and no precipitation in the period

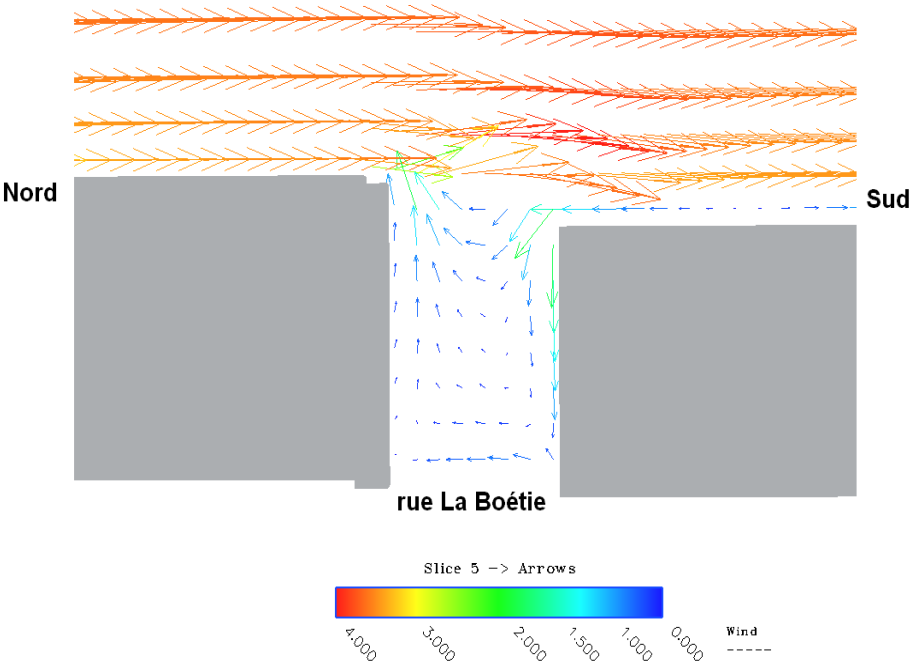
Micro-scale air flow results (PSWIFT)

Wind velocity (in m.s^{-1}) on 20th June 2012 (11 pm)
in a part of the domain including the release location



In the "free from buildings" areas, the velocity is a bit less than 3 m.s^{-1}, consistent with the meso-scale prediction. On the contrary, in the "influenced by the buildings" areas, wind velocity is weaker, around 1 m.s^{-1}, except in the N-S streets where the velocity can reach more than 4 m.s^{-1}

Cross section of the wind field
in *La Boétie* street on 20th June 2012 (11 pm)

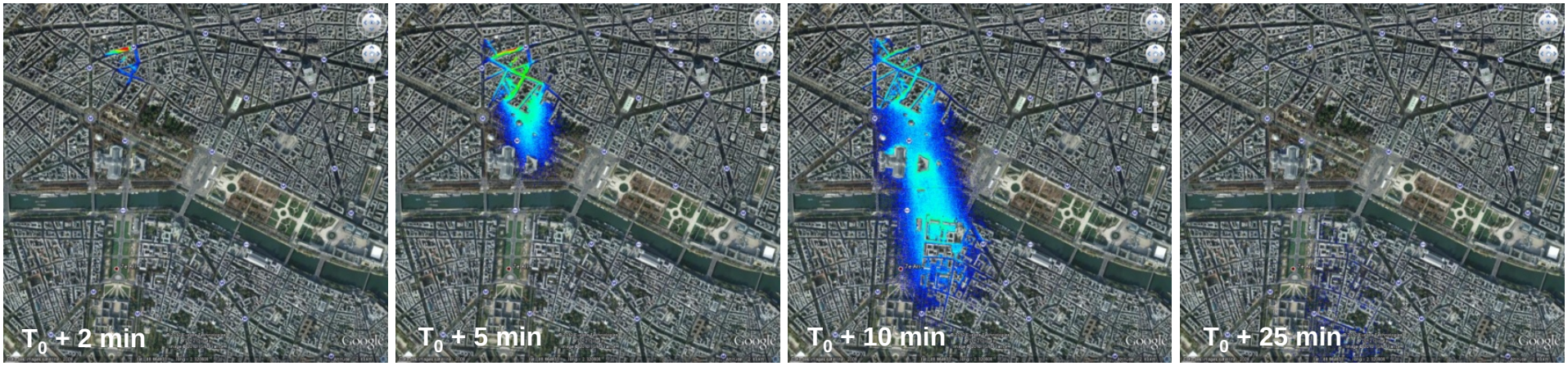


This zoom shows the flow complexity inside the streets, especially for streets perpendicular to the wind axis where the air flux near the ground is opposed to the wind N-S main direction due to a vortex forming induced by the flow above the roof level (spiral motion of the air in these W-E streets)

Threat agent dispersion results (PSPRAY)

1) At the FICTITIOUS news that a bomb had blown up in Paris, very few information was available for modelling, except the news of a moderate explosion in a critical Paris area
2) It was not obvious that the bomb was accompanied by radioactive materials which were not identified!
3) As a R event could not be excluded, it was decided to do a unit release dispersion calculation (1 TBq)

Concentration field AGL (height of one to two buildings floors) 2, 5, 10, and 25 min after the explosion



At the time of the bomb attack, the wind blew N to S.

The plume reached the corner of Matignon avenue and Saint-Honoré street, 200 m from the release point, at 11:02, the Petit Palais (exhibition place) (800 m) at 11:05, and Invalides boulevard (2 km) at 11:10.

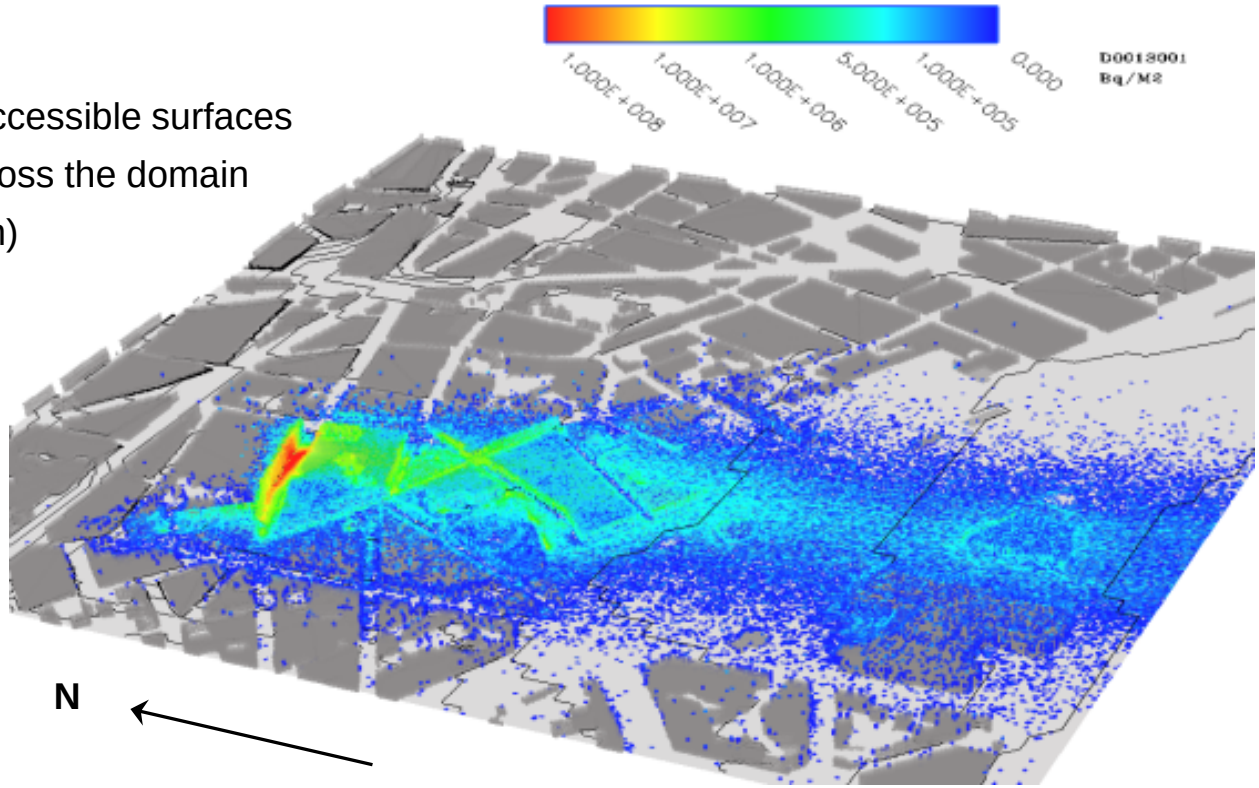
At 11:15, as a part of the plume already left the domain, a significant amount of radioactive materials was still trapped in La Boétie street, and the plume spread 3 km downwind and 1 km crosswind!

Threat agent deposition results (PSPRAY)

Finally, the plume came out of the domain quite entirely at 11:30.

It did not mean that there was no more radioactivity as it was transported on aerosol particles depositing on all accessible surfaces!

Radioactive deposition on all accessible surfaces after the plume finished to cross the domain (after 11:30 am)



In the exercise, we did not evaluate infiltration inside the buildings although PSPRAY can do it.

Obviously, it is the most important where deposition on façades is the highest!

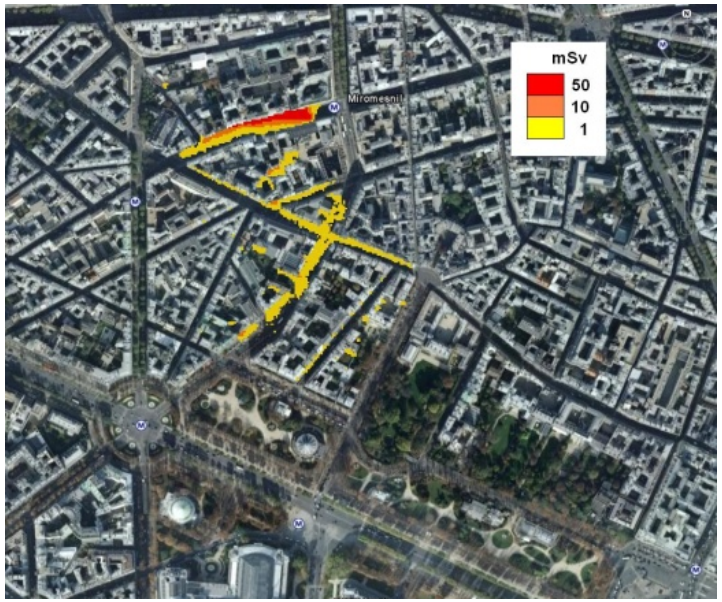
Health impact assessment (inhalation)

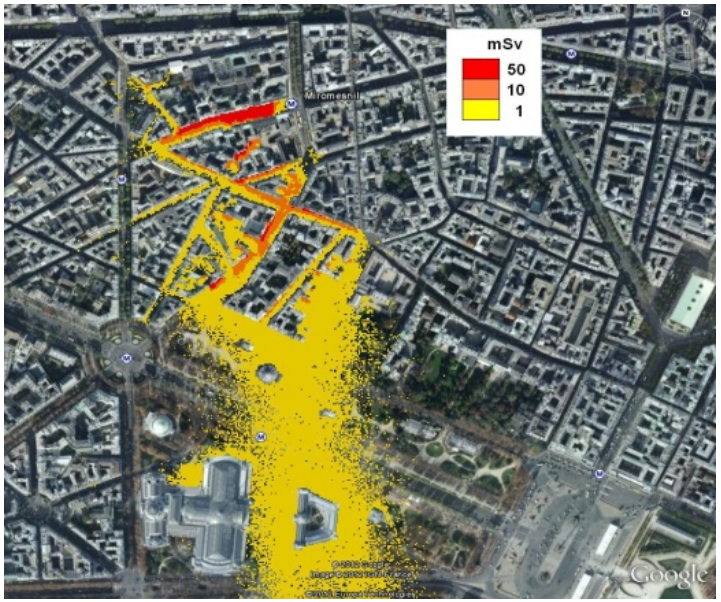
1) In case of a radiological emergency, it is crucial to estimate the population and first responders exposure
2) Short-term impact assessment considers inhalation and irradiation (cloud shine and ground shine)
3) Counter-measures depend on the exposure: sheltering (evacuation) if TEDE exceeds 10 mSv (50 mSv)
4) Otherwise, regulation requires a 1 mSv per year limit of the population exposure to nuclear activities

In the exercise, doses were computed by post-processing PSPRAY results and using ^{60}Co dose coefficients

N.B. SPRAYSHINE post-processor could have been used for a more precise assessment of the irradiation

Dose by inhalation after the plume has gone through the area for a ^{60}Co release of 1 TBq (left) vs. 10 TBq (right)



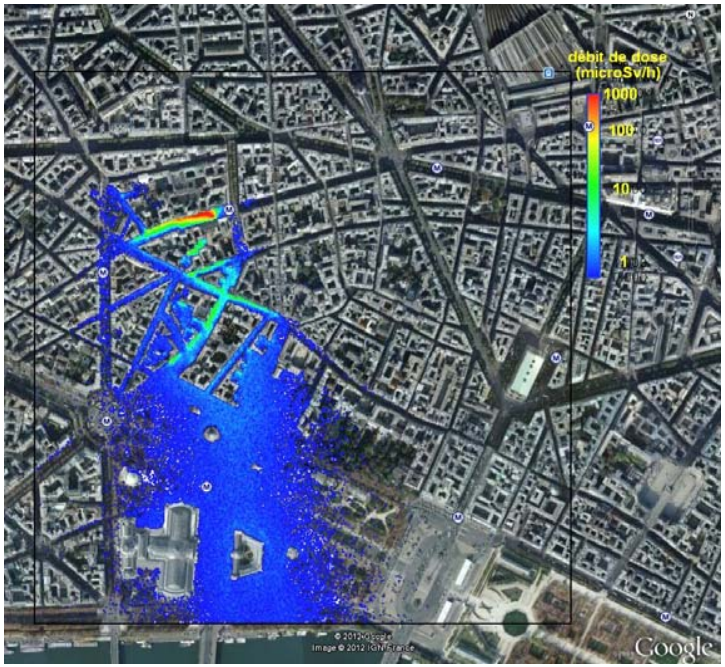


At the beginning of a crisis, the released quantity of hazardous materials is not known or not precisely.
It is better identified when information gradually comes from the premises.
Here, we did not need any new dispersion computation, but just had to re-estimate dose with modified ST (e.g.10 TBq)!

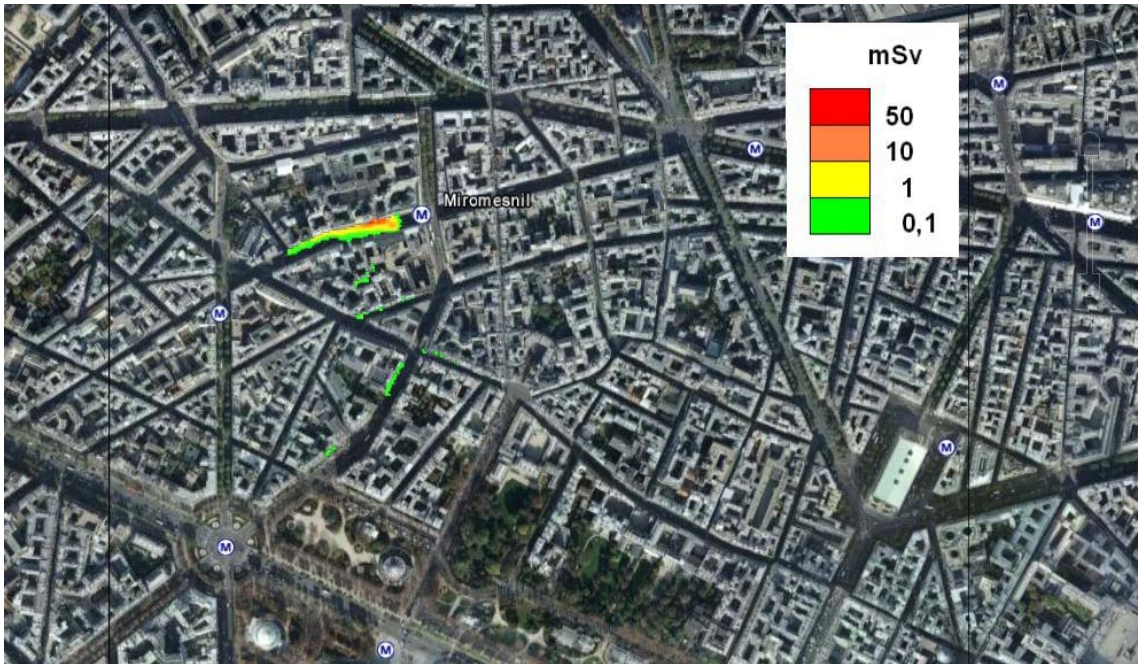
Health impact assessment (irradiation)

1) The external exposure due to cloud and ground shine was also computed during the exercise
2) Immersion in the plume leads to doses much less than those by inhalation
3) Ground shine depends on the presence over the contaminated areas!

Dose RATE by ground shine
for a ^{60}Co release of 1 TBq



Dose by ground shine integrated from 11 am to 5 pm
for a ^{60}Co release of 1 TBq



With a 6-hour exposure for the rescue teams, ground shine from 11 am to 5 pm is much less than inhalation. However, even if ground shine goes beyond 1 mSv only in *La Boétie* street, some places exhibit a dose higher than 0.1 mSv showing that a longer exposure duration would imply the exceeding of 1 mSv threshold value

Conclusion – Exercise summary & Sequence

- Exercise on 20th June 2012, 11 am to 12:25 pm, simultaneously at the Operations Survey Centre (CSO) of Paris Fire Brigade (BSPP) and at CEA DAM Île-de-France where computations were operated and images presenting the results produced
- Files transmitted by e-mail to the CSO (24 / 7 vigil) which in turn sent the information to Command Post Vehicle (VPC) equipped with a large screen unfolded during exercise

N.B. In a real emergency handling, VPC would be fully implied and near the event location

Time	Event
11:00 am	Phone call from BSPP to CEA in order to warn about an explosion (possibly, a “dirty bomb”) Dispersion computation launched on a 16-core machine (3.16 GHz) with PSPRAY model
11:15 am	Dispersion results obtained in 15 minutes (using 800,000 numerical particles)
11:30 am	Dispersion results post-processed to provide geo-referenced images of the 2D concentration Results formatted to be directly used in the GIS of the BSPP and forwarded to CSO
	Decision to wait 25 minutes more before sending exposure results! In real life, this time lapse would be used to raise doubts about radiological nature of the event and identify radionuclides
11:55 am	Geo-referenced images of the exposure sent to BSPP
12:00 pm	Source term was re-evaluated and updated exposure computation transmitted to BSPP…
12:25 pm	End of the exercise

Conclusion – Comments & lessons learned

- CEA micro-scale weather forecast system is operational and provides every six hours the air flux prediction in all or any part of the streets of Paris
- Dispersion computation can be launched given at the minimum location of the release, later specifying the nature, quantity and history of the release
- Dispersion results are post-processed to visualize the concentration field and determine the doses in formats fully consistent with the GIS of the BSPP

  N.B. More automation of this final part of the modelling system in progress
- During the exercise, sending e-mails to BSPP was done manually; automation and dedicated e-mail boxes will help to forward results even quicker
- In real life, performances would be a bit decreased as it could be harder to decide first ST

Finally, the exercise demonstrated:

- *The operational capability to assess the dispersion and consequences of noxious releases with advanced 4D models in a time consistent with crisis management*
- *The interest of Civil Security services to be provided in real-time with precise and practical impact assessment results visualized in GIS to help decision making*

Questions?

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