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EMERGENCIES – A MODELING AND DECISION-SUPPORT PROJECT FOR THE GREAT PARIS IN CASE OF AN ACCIDENTAL OR MALICIOUS CBRN-E DISPERSION

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Abstract: EMERGENCIES aims to demonstrate the feasibility of real time tracking of toxic atmospheric releases, be they accidental or intentional, in a large city and its buildings through numerical simulation. Our modelling domain covers Greater Paris, and extends to the airports of Orly and Roissy Charles de Gaulle. This geographic area is under the authority of la Brigade des Sapeurs-Pompiers de Paris (BSPP), the Paris Fire Brigade. The domain forms a giant square measuring 40 km by 40 km, and consists in a 3D grid with a horizontal resolution of 3 meters. It features sub-grids with a resolution of 1 meter, describing the interior and vicinity of public-access buildings. EMERGENCIES is a world première in very high resolution atmospheric simulations and was tested for the first time in Greater Paris. This model can be transposed to every metropolis in the world.

Key words: *CBRN-E dispersion, PMSS, Code_SATURNE, high performance computing, very large domain, parallel modeling, nested simulations.*

INTRODUCTION

PMSS (Parallel-Micro-SWIFT-SPRAY), (Oldrini et al., 2011) allows modelling of atmospheric transport and dispersion on large areas, like the whole city of Paris, at high metric resolution. PMSS consists of SWIFT (Oldrini et al., 2014, Moussafir et al., 2004), a 3D wind field model, and SPRAY (Tinarelli et al., 2013), a Lagrangian particle dispersion model. Parallelization allows PMSS to model large areas compatible in size with responsibility areas of emergency response units.

Project EMERGENCIES was a modelling exercise of the transport and dispersion of fictitious CBRN-E releases on a gigantic area. The project was done to demonstrate the capacity of modelling as a support tool for crisis management. Domain chosen for the exercise is the Great Paris area. This domain is the responsibility area of Paris Fire Brigade. The size of modelling domain is 40 by 40km with a resolution of 3m. Calculations were performed on CCRT (*Centre de Calcul Recherche et Technologie*), CEA intensive cluster, using from 1,000 to 30,000 computational cores. Project EMERGENCIES was labelled “Grand Challenge” by the CEA.

Modelling was realized considering three hypothetical CBRN-E releases near, or inside, public buildings in Paris centre area: a museum, a train station and an administrative building. Three nested domains were defined around these buildings, modelling both the inside and the outside at 1m resolution. The 40 by 40km grid has a 3m resolution and is split in 1,088 sub domains, computed in parallel. Meteorology is computed on a 24h basis.

Visualization of simulations was also a challenge, due to the generated volume of data. Tools were developed to handle large quantity of data and allow a smooth visualization through web browser using online geographical information system. These tools allow operational exploration of data in a time compatible with crisis management.

SCENARIO OF THE FICTITIOUS ATMOSPHERIC RELEASES

The case chosen to demonstrate our purpose is a hypothetical scenario of accidental or intentional toxic atmospheric release of NRBC-E substances, in the vicinity or within the confines of a rail station, a museum, or a major public administration.

The first emission occurs at 10 o'clock within the museum, and propagates outside of the building. The second emission occurs one our later in the courtyard of the administration building and propagate inside and around the building. The third and last emission, at noon, is located in front of the train station and propagates inside and around the building. All releases are 10mn long.

Meteorology and turbulence are computed starting from WRF meso-scale forecasts operated routinely at CEA over France. The domain is 40 by 40km and meshed at a resolution of 3m, consisting of roughly 12 500 x 13 300 nodes. Vertically, it extends up to 1000m using 39 grid points. The domain contains more than 6 billion nodes. It is divided in 1088 tiles, computed in parallel. Each tile has a size of 401 x 401 x 39 nodes.

The domain contains 1.15 millions buildings. Its size is 1Go.

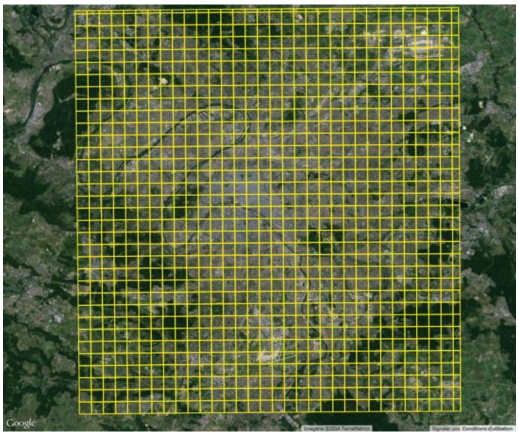

Figure 1. View of the 1088 computing tiles over the 40 by 40km domain

Three very-high-resolution nests are defined around the buildings of interests. The meshes have a resolution of 1m and count 2.6, 4.6 and 5.6 million nodes. They describe both the inside and outside of buildings.

Massively parallel clusters simulate:

- Turbulent airflows in and around public-access buildings at ultra high resolution (1 meter). Simulations over Greater Paris are produced at high resolution (3 meters) and feature explicit modelling for all buildings.
- Toxic dispersion at the same scales, transfers between the interior and the exterior of public-access buildings, and plume tracking at a larger distance through the street network.

PHYSICAL AND NUMERICAL MODELLING

EMERGENCIES enables coupling of the following models:

- PMSS (Parallel-Micro-SWIFT-SPRAY, see Oldrini et al., 2011), which was jointly developed by ARIA Technologies, MOKILI, ARIAnet and the French Atomic and alternative Energies Commission (CEA). This model incorporates the PSWIFT simplified wind and atmospheric turbulence model, and PSPRAY, a Lagrangien Particle Dispersion Model.
- Code_SATURNE (Archambeaul et al., 2004) developed by Electricité de France Research and Development, another Computational Fluid Dynamics model that enables flow computations of public-access building interiors.

PMSS is used on the 40x40km domain, while Code_SATURNE is handling the three very-high-resolution nests. SPRAY is used both on the gigantic domain and the three nests, using the nested capability (Nibart et al., 2011). 40 000 particles are emitted every 5 seconds, leading to a global emission of 14.4 million particles.

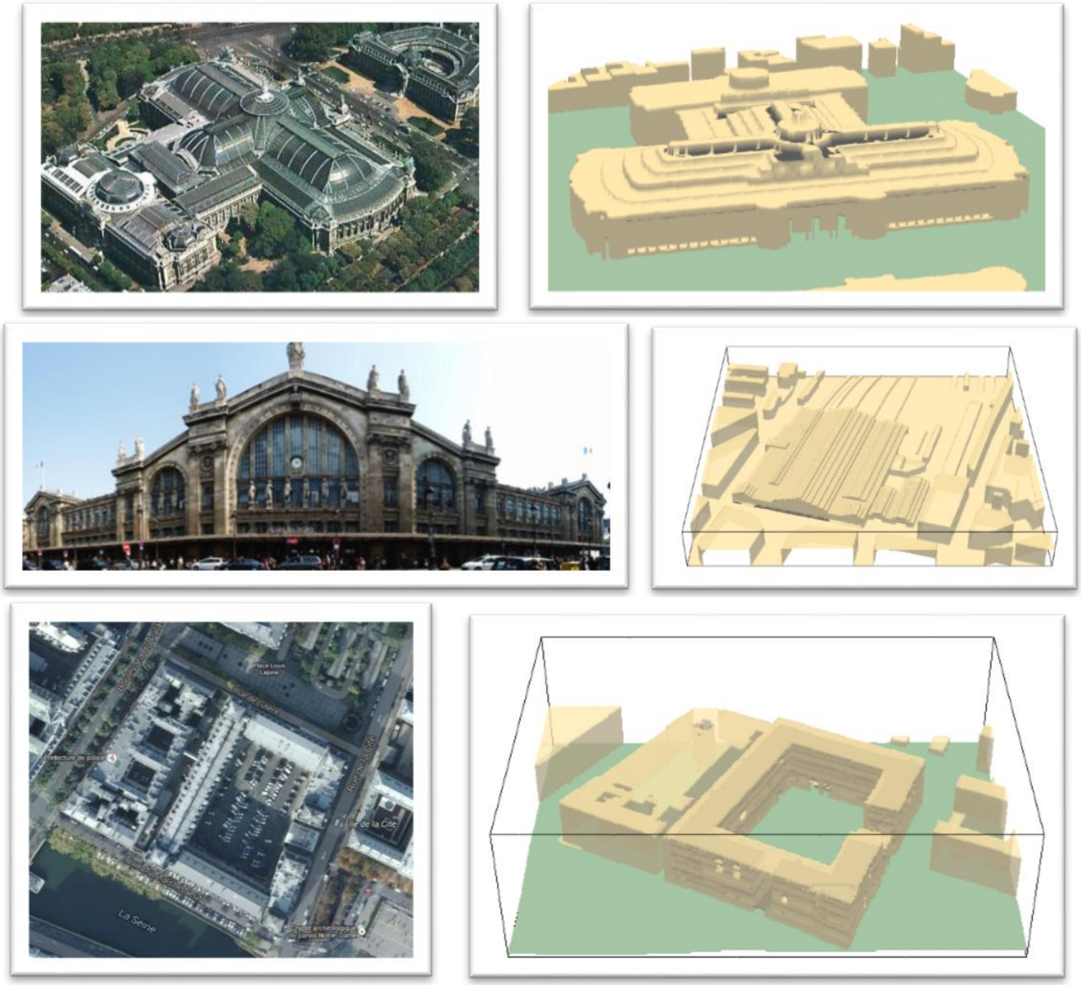

Figure 2. Picture of the building next to the release point, and their 3D numerical models (right side)

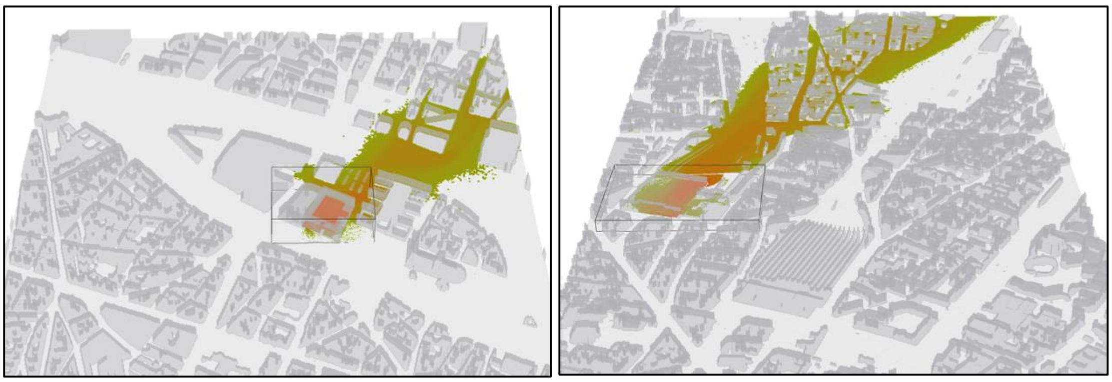

Figure 3. Close view of ground concentration in the vicinity of the administrative building and the train station, 20mn after the release

PERFORMANCE

3D simulation of local-scale air flow, hour by hour and over an entire day, is obtained through mesoscale weather forecasts, kindly provided by the CEA (WRF model).

EMERGENCIES produces local forecasts for the following day:

- Two hours are required for greater Paris, covering a gigantic domain measuring 40 km by 40 km, which is divided into 1 088 tiles using 2177 cores,
- Two additional hours, using 5000 cores, are required to produce sub-grids encompassing indoor and outdoor domain around public-access buildings, measuring 300 meters by 300 meters.

Dispersion simulations for the urban domain and public-access buildings are obtained in one and a half hours and produce a five-hour simulation, using 500 cores.

Figure 4. Close-up 3D view of the plume remaining trapped by topography and buildings near the *Buttes Chaumont* park on the left side of the picture

The 3D viewing of this huge volume of data (about 100 terabytes) requires a massively parallel reader and a software library, kindly provided by AmpliSIM. This allows almost instantaneous viewing of simulations through the major Geographic Information Systems (GIS).

Tests have been realised using from 1 000 (the minimum) up to 25 000 cores.

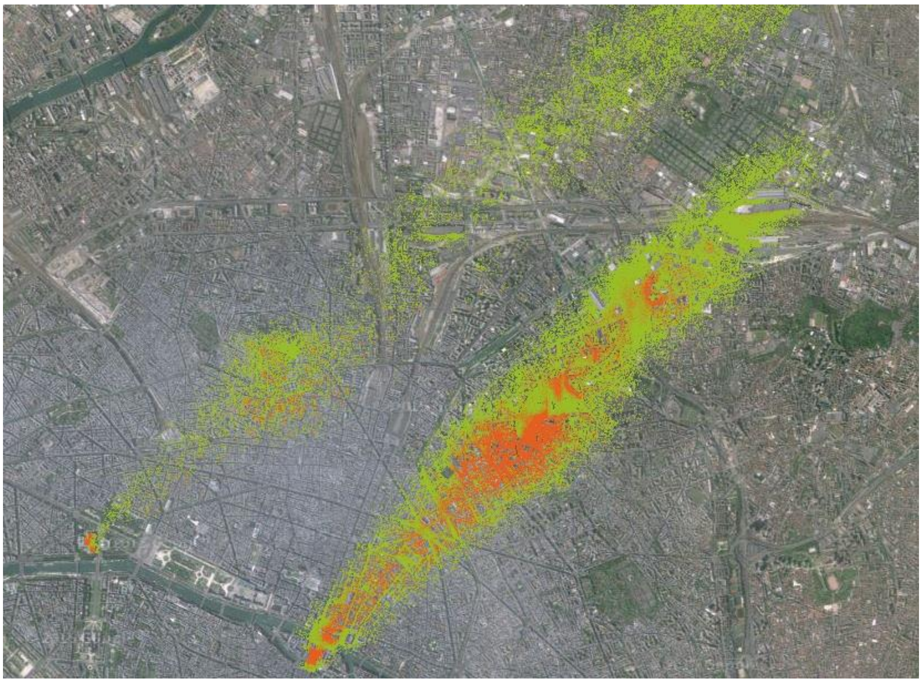

Figure 5. Web geographical information system view of the plumes 1h50mn after the first release

CONCLUSION

EMERGENCIES project demonstrated the feasibility of high-end simulations integrating:

- Meteorological forecasts at metric resolution on a very large 40 by 40km domain encompassing Paris and the neighboring districts,
- Coupling of simulations between the very large domain and several nested domains describing the interior of chosen public-access buildings,
- Visualisation of the huge amount of data.

Atmospheric hazard have been simulated in and around the public-access buildings, including the transport and dispersion inside the gigantic urban domain. Nested domain and parallel computing made it possible to:

- Handle the propagation inside out or outside in of the selected buildings, the release point being inside or outside,
- Follow the propagation up to several tenths of kilometers downwind, with a very fine resolution, and thus permitting to see the entrapment of airborne contaminant in street canyons and the influence of the topography even very far from the source.

EMERGENCIES is a collaborative work between small and medium businesses (MOKILI, CAIRN and ARIA) and a large research institute (CEA). It was awarded the Great Challenge Label for exceptional value. Through this recognition, EMERGENCIES gained access to the resources of the CEA Research and Technology Computing Centre.

EMERGENCIES would not have been possible without the calculation resources, and the support of the CCRT team at the CEA.

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