CERES™ CBRN – A unified modelling and decision support system to assess the dispersal and health impact of hazardous releases in urban or open-field environments

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SUMMARY – WHAT IS CERES™ CBRN?

- An innovative development by CEA (French Atomic and alternative Energies Commission) and research partners of the French CNRS
- A computational platform devoted to hazmat atmospheric dispersion modelling and impact assessment gathering:
  (1) Source term models
  (2) Flexible dispersion approaches (from Gaussian puff to advanced 4D flow and dispersion computations)
  (3) Population and first responders health consequences modules adapted to R-N, C or B noxious agents
- A multi-threat and multi-risk operational system committed by design to the response in case of emergency (max. 15 minutes), thus addressing both emergent and more usual issues of CBRN accidental or malevolent releases for the Civilian Security

This poster presents new advances in CERES and illustrates the results of realistic applications obtained in a few minutes on a standard multi-core laptop rendering CERES a promising decision support tool for crisis preparation and handling.

FOUR MAIN FEATURES OF CERES™ CBRN MODELLING SYSTEM

1 – CERES platform can cope with situations as various as regular emissions from industrial facilities in routine operations, moderate or serious accidents affecting industrial (nuclear or non nuclear) plants or occurring during hazmat transports, and even, malicious activities resulting in toxic releases.

2 – CERES can handle all categories of threat agents like radionuclides, chemicals or biological agents. It means that it is not only a computational tool, but it includes large data bases with the main characteristics of the hazardous gases or particles potentially released in the atmosphere.

3 – CERES has been conceived as a flexible platform grouping modules dedicated sequentially to source term description and modelling, meteorological data processing, atmospheric dispersion simulation at the local or regional scale, and environmental or health impact evaluation.

4 – CERES simulations can be performed repeatedly using, at each step, the whole available information. The results are spread through a tried and tested ergonomic graphical user interface and can be visualized in CERES own Geographic Information System or exported in formats adapted to other GIS.

CHEMISTRY AND TRANSPORT MODELLING IN CERES™ CBRN (CEA / UBP-LAMP)

- ✓ ***Most decision support systems simply ignore the interaction, if any, of the atmospheric background chemistry with the released species which may lead to overestimate the consequences if the chemicals disappear in the air, or underestimate them if the products of the reactions have a worst health impact.***
- ✓ ***To better assess the concentrations in the air, the Gaussian puff dispersion model MITHRA and M2C2 or KPP-SAPRC-99 chemical modules can now be used together in CERES. Consistently with crisis handling, the coupling method has been chosen to keep moderate computation times.***

Validation cases demonstrate that chemical reactivity may notably influence the dispersion in a number of scenarios!

E.g. Release of 100 kg gaseous ammoniac at 12 am during 30 min. (an unpolluted, called "remote", chemical background is applied)

Figure 1 shows that if dispersion is not corrected by the chemical reactivity, NH3 max. concentration value of 0.1 mg.m^{-3} is observed well beyond 5 km. When chemical reactivity is taken into account, NH_3 max. atmospheric concentration significantly decreases, and, at 5 km, NH_3 maximum concentration is less than 0.1 mg.m^{-3}. This result is expected as NH_3 undergoes photolysis and oxidation by hydroxyl radical OH, both reaching a maximum at noon.

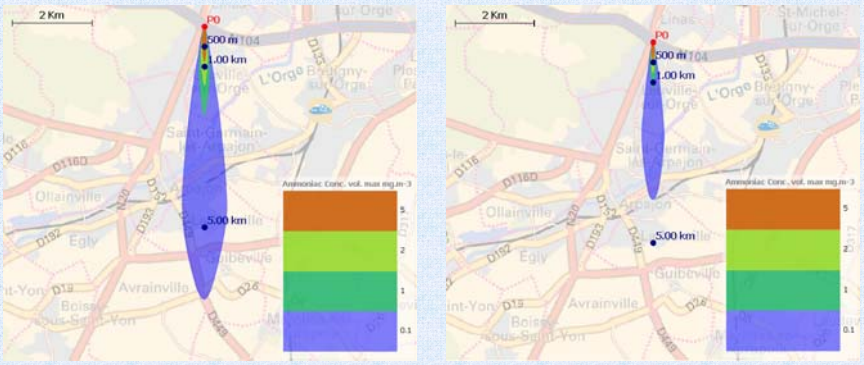

Fig. 1. NH_3 max. concentration (in mg.m^{-3}) without (left) and with (right) chemical reactivity.

N.B. M2C2 results from the coupling of a multiphase explicit chemistry model for gases and aqueous phase (Deguillaume et al., 2005) and a cloud microphysics two-moment model (Chaumerliac et al., 1990). KPP pre-processor (Sandu and Sander, 2006) developed for 3D CTM such as WRF-CHEM is based on the SAPRC-99 chemical mechanisms.

URBAN SIMPLIFIED DISPERSION MODELLING IN CERES™ CBRN (CEA / ECL-LMFA)

- ✓ ***CERES platform now integrates SIRANERISK, a dispersion solver specifically adapted to the urban environment, combining a Gaussian puff model above the street level and the resolution of a transport equation inside the streets network taking account of the species transfers between the two air layers.***
- ✓ ***SIRANERISK validation has been performed by the satisfactory comparison of the model results (mean arrival time and longitudinal spread of the plume) with wind tunnel measurements for continuous and short releases on a rough surface and inside an idealized urban canopy (ECL campaign for CEA).***

Figure 2 illustrates an example of CERES application to a fictitious malevolent release in Lyons (France). In this case study, a "dirty bomb" blows up near the major railway and underground "*La Part Dieu*" station, resulting in the prompt release of a radioactive aerosol. As clearly visible in the figure, the dispersion pattern of the particles is strongly influenced by the channelling in the streets canyons. Then, the exposure by inhalation and irradiation and the Total Effective Dose Equivalent are evaluated using CERES radiological impact module. The simulated period of 50 minutes is calculated is only 10 minutes.

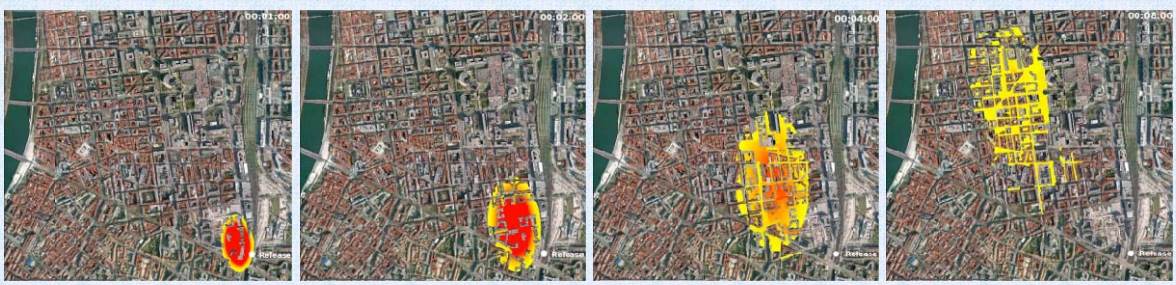

Fig. 2. Instantaneous activity concentration 1, 2, 4, and 8 minutes after a fictitious explosion in "*La Part-Dieu*" railway station in Lyons.

Urban dispersion modelling in CERES provides far more realistic results than Gaussian model with slightly increased computation times!

Chaumerliac, N., E. Richard, and R. Rosset, 1990: Meso-scale modelling of acidity production in orographic clouds and rain. Atmos. Environ. Vol. 24 A, pp. 1573-1584.
Deguillaume, L., M. Leriche, and N. Chaumerliac, 2005: Impact of radical versus non-radical pathway in the Fenton chemistry on the iron redox cycle in clouds. *Chemosphere*, 60-5, pp. 718-724.
Lamaison, G., L. Soulhac, and P. Armand, P, 2011: Presentation of SIRANERISK-2.0 – Examples of application. Harmo'14, Kos Island, Greece, 2-6 October 2011.
Sandu, A., and R. Sander, 2006: Technical Note – Simulating chemical systems in Fortran 90 and Matlab with the kinetic preprocessor KPP-2.1. *Atmos. Chem. and Phys*. Vol. 6, pp. 187-195.

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