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Emergencies planning and response: Coupling an exposure model with different atmospheric dispersion models

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HIGHLIGHTS

- The D-F and D-M coupled systems are a very interesting tool for risk analysis.
- D-F is an excellent tool in the planning stage of emergencies and disasters.
- D-M is appropriate to provide efficient real time responses to emergencies.

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ABSTRACT

Information on spatial and time dependent concentration patterns of hazardous substances, as well as on the potential effects on population, is necessary to assist in chemical emergency planning and response. To that end, some models predict transport and dispersion of hazardous substances, and others estimate potential effects upon exposed population. Taken together, both groups constitute a powerful tool to estimate vulnerable regions and to evaluate environmental impact upon affected populations.

The development of methodologies and models with direct application to the context in which we live allows us to draft a more clear representation of the risk scenario and, hence, to obtain the adequate tools for an optimal response. By means of the recently developed DDC (Damage Differential Coupling) exposure model, it was possible to optimize, from both the qualitative and the quantitative points of view, the estimation of the population affected by a toxic cloud, because the DDC model has a very good capacity to couple with different atmospheric dispersion models able to provide data over time. In this way, DDC analyzes the different concentration profiles (output from the transport model) associating them with some reference concentration to identify risk zones.

In this work we present a disaster scenario in Chicago (USA), by coupling DDC with two transport models of different complexity, showing the close relationship between a representative result and the run time of the models. In the same way, it becomes evident that knowing the time evolution of the toxic cloud and of the affected regions significantly improves the probability of taking the correct decisions on planning and response facing the emergency.

1. Introduction

The adverse health effects of an accidental release of hazardous substances into the atmosphere are motive of concern in very populated urban areas, due to the size of the potentially affected population and to the complexity of the scenario. Simulation models of chemical incidents constitute an important tool both for a real time emergency response and for planning it in several contexts. The appropriate model to be employed in an emergency will depend on the level of detail required and on the execution time available; both characteristics are closely related (Warner et al., 2008; Hanna et al., 2009).

Nevertheless, many exposure models for chemical incidents currently applied have serious constraints when authorities try to use them in actual situations. Firstly, they do not take into account

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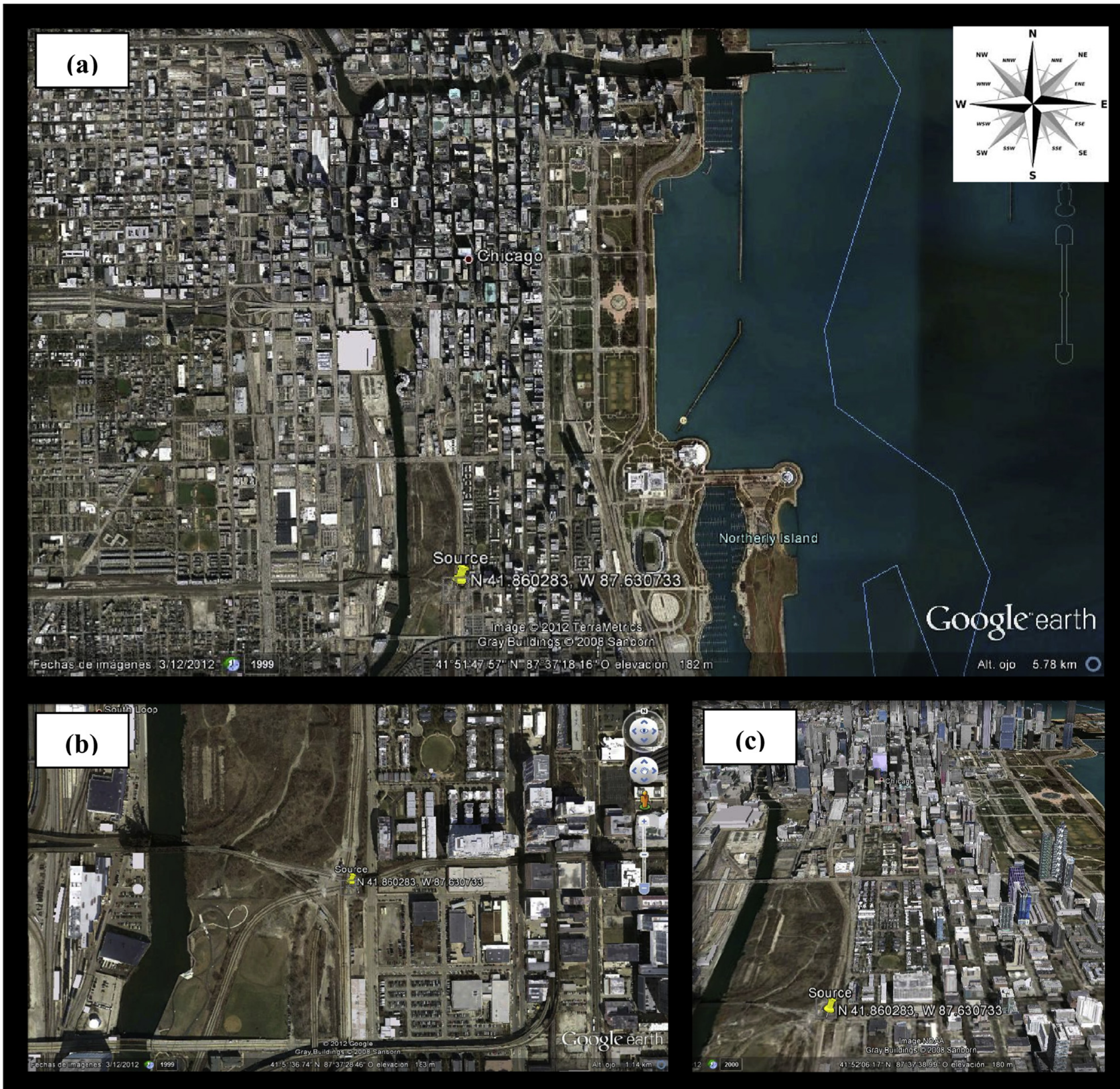

Fig. 1. Aerial view of study area. In (a) a wide view of the emission source and its environment is observed. In the same picture the Chicago River can be seen to the left of the source, and also the tall buildings to the North. In (b) the railway junction and the plain open terrain around the source are visualized. (c) shows an angled view of the scenario, with a densely built (characterized by tall buildings) adjoining the open area around the source. Source: Google maps, 2011.

time as a variable: they only describe the expected final state, although time is a conditioning factor on emergencies responses. Moreover, the adverse health effects calculated by most current models are overestimated according to conservative decisions, and often their severity is not quantified (Reynolds, 1992; Ruiz Boada et al., 2003; Acquesta et al., 2011; Sanchez and Acquesta, 2011).

Taking into account the above-mentioned constraints, we have recently implemented the exposure DDC (Damage Differential Coupling) model, which computes the time evolution of the exposure to concentrations, permitting therefore a continuous monitoring. The method estimates maximum and minimum levels (hereinafter referred to as maximum damage and minimum damage, respectively) of adverse health effects caused by the exposure to a toxic cloud, using a recursive algorithm for that purpose (Sanchez, 2012; Sanchez et al., 2010, 2011; 2012a,b). DDC is applicable to acute exposures: therefore it employs the toxicological indices of acute exposure (AEGLs, ERPGs and TEELs), incorporating the exposure characteristics described in the technical reports that justify these values (Craig et al., 2000; ERPG and WEEL, 2007; US EPA, 2012). As described in Sanchez et al.

Table 1
AEGLs for chlorine, corresponding to the 2012 update of the U.S. EPA July 2006 final statement.

Index	Exposure time (minutes)				
	10	30	60	240	480
AEGL-1 (mg m^3)	1.5	1.5	1.5	1.5	1.5
AEGL-2 (mg m^3)	8.3	8.3	5.9	3	2.1
AEGL-3 (mg m^3)	147.7	82.7	59.1	29.5	21
AEGL-1 (ppm)	0.5	0.5	0.5	0.5	0.5
AEGL-2 (ppm)	2.8	2.8	2	1	0.71
AEGL-3 (ppm)	50	28	20	10	7.1