INTEGRATION OF EARTH OBSERVATION, AEROSOL AND PEOPLE EVACUATION MODELLING FOR PREPAREDNESS AND EMERGENCY RESPONSE

F. Ferrucci [1,2], L.R. Filippidis [3], B. Hirn [2], S. Marsella [4], M. Marzoli [4], F. Punzo [5], S. Schiano Lo Moriello [6], A. Weeraswamy [3]

1) University of Calabria, Rende (Cosenza), Italy
2) Intelligence for Environment and Security - IES Consulting, Rome, Italy
3) University of Greenwich, London, United Kingdom
4) Italian Ministry of Interior - National Firemen Corps, Italy
5) Aerospace Laboratory for Innovative components - ALI, Naples, Italy
6) Euro.Soft, Naples, Italy

ABSTRACT

Keywords: Emergency Planning, Evacuation Planning, Fires, Satellite Remote Sensing, Telecommunications.

According to recent statistics on natural disaster (https://www.unisdr.org/we/inform/disaster-statistics, e.g.), the frequency of occurrence of fire disasters, possibly climate-driven, is growing on a global basis. Growth is accompanied by decrease of the number of large fires per year, and increase of average individual surfaces burnt in severe wildfires. Such geographically expanding impact scenarios (2016 Great Smoky Mountains, USA; 2017 Portugal and Northern Spain, fed by the remnant of hurricane Ophelia; 2018 California and Greece, e.g.) lead to increasingly complex emergencies by involving massive heterogeneous fuels - from human settlements and various types of infrastructure - during days or even weeks, in changing meteorological and propagation conditions. Scenario triggering and fire development can be further complicated by involving man-made hazard components as, for instance, hazardous materials (HazMats) stored or transported in large quantities by road or rail.

In such conditions, standard emergency planning proves inadequate as generic information does not allow responders distributing the available resources, selecting unavailable resources that are actually needed, and prioritizing the interventions in space and time. As for complex emergencies themselves, we shall note that (i) most plans are not drawn for multi-component emergencies; (ii) they are seldom, or never tested against a real emergency of severe magnitude; (iii) they usually lack in quantitative and geographical thresholds for monitored physical and chemical parameters, and (iv) always lack in assessments of the time needed to escape the active threat and reach a safe place, while (v) safe places themselves are subjected to change, and may require redefinition in the course of the event. As it is not always possible to identify a safe place before emergencies, emergency plans usually select several possible candidate safe places: however, only the emergency dynamics will say if they are appropriate and/or still safe, knowing that – in case of sheltering needed – the safest shelter could well be out of the area covered by the emergency plan.

Besides of RT/NRT quantitative estimates of active fire’s parameters and aerosol propagation, the above elements (iv) and (v) deserve top priority in the response scenario IF settlements are involved with their inhabitants. Accounting for the expected, significant heterogeneity in age, health status and knowledgeability of involved people, in lack of instant data on people’s location and physical characteristics, the search of best escape paths and straightforward simulation of evacuation fluxes is best run for preparedness or in forensic investigations rather than as a response tool (e.g., in Veeraswamy et al., 2016).

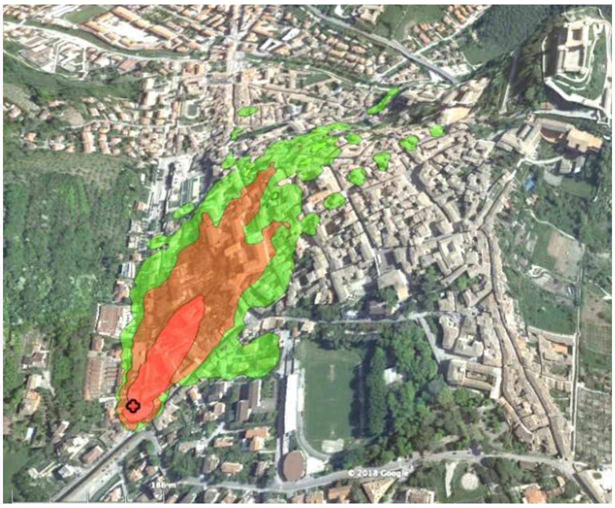

Figure 1
Pre-computing of aerosol concentrations for a LPG accident at the outskirts of the town of Spoleto, Italy, in the meteorological conditions of July 19, 2018. Simulated concentrations – shown 30min after outburst - are used in input to 32 simulations of evacuation on a known population sample by age, health, floor lived. The red cross is the centre of the hot-spot centroid. Color coding: Red=AEGL-3/ Lethal Concentration Low level; Brown=AEGL-2 level; Green=AEGL-3 level). AEGL stays for Acute Exposure Guideline Level by the US EPA

In combination with ground-based facilities (where and until when they are available), airborne and spaceborne Earth Observation, and satellite borne telecommunications and navigation are known to allow better coping with this non-exhaustive list of drawbacks, although with some restrictions. A good example of this in the domain of fires, relates to detection and quantitative estimate of ongoing fires as, for instance, satellite borne thermal hot-spots that are distributed – with some product difference – by all major meteorological satellite operators. Pixel, or quarter-pixel hot-spots are useful for early fire detection and propagation forecast if (a) their repeat rate is high enough – minutes – to cope with the extinguishers' need and (b) include quantitative estimates of the fire radiative power (FRP), aimed at (c) characterizing the emitted aerosols' content. However, refresh rates of minutes are appropriate for geostationary payloads only, which may have relatively poor detection thresholds (over several tens of Megawatts) because of multispectral pixel footprints of several square kilometres. As smaller fires will be detected by other – local – means, that will not give any FRP estimate but might provide information on the type of fuel, a solution is that of integrating the hot-spot detection system in/with the Fire Brigades' or Forest Guards' Operation Rooms for Real-Time (RT) or Near-RealTime (NRT) support to field operations, and forecast of the behaviour of smokes and aerosols, along with their potential toxic concentrations.

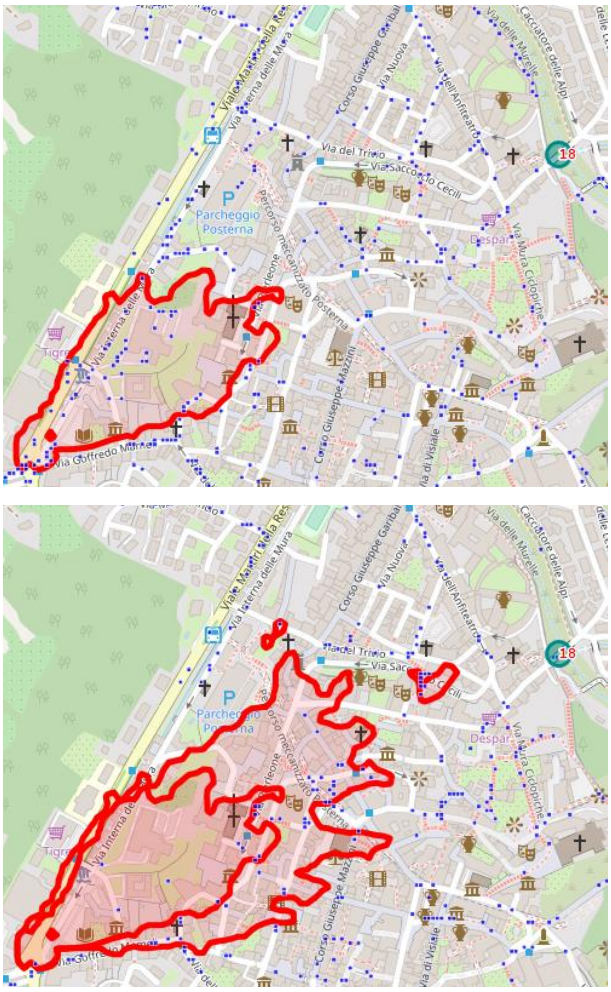

Figure 2
Forward modelling of the people evacuation dynamics following the LPG accident in Fig.1, computed at T_0+15min (top) and T_0+30min (bottom). Involved individuals are represented by blue dots. The threat, corresponds to the AEGL-2 level

Although appropriate for RT/NRT operations and best run in unsupervised mode to minimise operational time gaps, large sets of pre-computed aerosols based on available land cover information and statistically significant FRPs can/should be run for both preparedness and response fine-tuning.

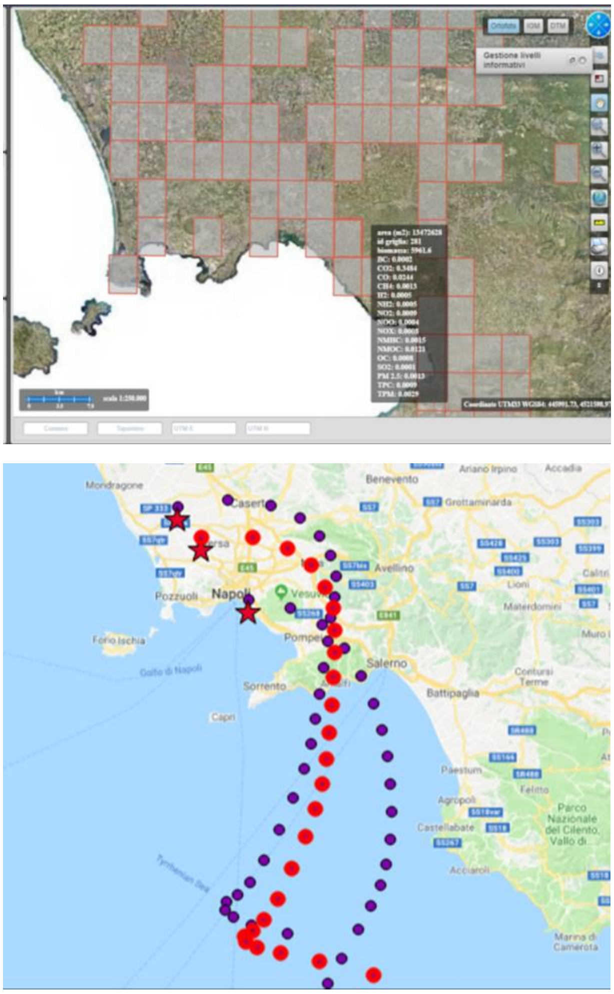

Figure 3
Top: footprints of 15 km^2 MSG SEVIRI's pixels on Naples, used to detect, locate and compute FRP on 5-min thermal hotspots Bottom: pre-computed of smoke trajectories from theoretical fire hotspots (red stars) based on 84-hour meteorological forecast. Both tools are developed/incorporated in the European Space Agency's ARTES-IAP project TALED, 2017-2018.

The actions in support to Planning and Preparedness described here are in the focus of project IN-PREP (2017-2020, contract no. 74062 by the REA - Research Executive Agency of the European Commission), whereas the system for EO/TLC/NAVSAT information support to emergency response was developed in the framework of demonstration project TALED (2017-2018, contract ARTES-IAP no. 4000119336/16/UK/ND by the Business Applications Unit of the European Space Agency).

TALED integrates the spaceborne tools described above (Figs. 3 and 4) with ground-based tools for ground communications between the DOS (director of fire extinguishing operations) and individual extinguishers located on the fire line, to improve the security of workforce and the efficiency of crew management.

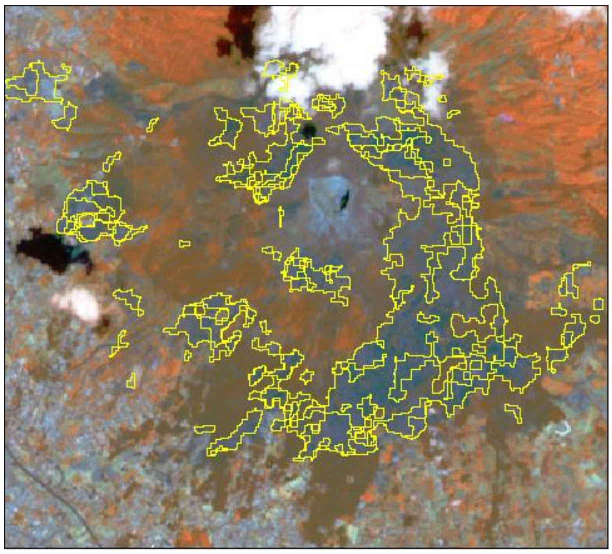

Figure 4
Unsupervised burn scar map of the major, July 2017 fires on Mt. Vesuvius, Naples, Italy. Data by Copernicus Sentinel-2A/-2B. Code MyME2, European patent no. 01642087/2006

As simulations return a theoretically infinite number of scenarios that can be updated instantly by use of actual observed data, traditional, one-scenario emergency plans appear to provide outdated support to the most difficult decisions to be taken, as the extent of the evacuation or "shelter-in-place" instructions to be issued to minimise people's exposure in the course of whatever fire. Demonstrations show that the comprehensive procedures illustrated here, either pre-computed or real-time computed, are based on proved physical models and computational tools robust enough to apply equally at forest and urban scale, as to vegetal and industrial fires.

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