A Unified Modeling Approach in CBRN Detection Systems Deployment and System Analysis

Paul E. Bieringer[1], Scott Longmore[2], George Bieberbach[1],
Luna M. Rodriguez[3], Jeff Copeland[4], John Hannan[5], and Aaron J. Piña[1]

[1]Aeris LLC, [2]CIRA, [3]STAR, [4]WeatherFlow, [5]DTRA

BACKGROUND AND OBJECTIVES

There are a variety of CBRN analysis applications that require the use of a comprehensive specification of the weather conditions combined with an analysis that uses detailed modeling and simulation. The combination of these two elements can make it difficult to achieve the desired level of fidelity in a logistically feasible way. Furthermore, many applications involve several phenomenological processes making it necessary to couple models into a unified analysis methodology that can resolve the interactions between the phenomena. An example of this type of complex application is the optimal placement of surface-based samplers, within an urban environment, to optimally detect and characterize emissions emanating from a building of interest. The impact of the building on the material transport from the indoors in conjunction with the non-intuitive dispersion patterns associated with the wind flow around the buildings and through the urban canyons make site selection difficult. In this presentation we illustrate an approach designed to make it logistically feasible to conduct a complex dispersion modeling assessment that utilizes meteorological conditions that are representative of the full range of climatological conditions. The approach is illustrated in the context of a methodology for identifying the optimum locations for air quality and CB agent detection monitoring equipment deployed in an urban locale. This application requires a high fidelity solution that is obtained by utilizing a building-aware urban wind-flow, and a coupled atmospheric transport and dispersion (AT&D) building-aware dispersion model that incorporates wind-loading pressures into the interior contaminant flow, as well as, exfiltration and exterior dispersion estimates. The modeling results are then used to determine the locations of where to deploy surface based airborne chemical sampling equipment within the central commercial district (12 city block area) of Boulder Colorado, USA. (Bieringer et al 2013).

METHODOLOGY

1. Utilized hourly historical weather observations (1981 - 2013) from the Rocky Mountain Metropolitan Airport (BJC) combined with a gridded (40km) hourly three-dimensional weather reanalysis of all standard meteorological variables (1985 - 2005) to represent the full range of representative meteorological conditions. (Figure 1)

2. Reduced the full climatological record (183,960 records) into a subset of characteristic meteorological patterns (200 patterns) and associated frequencies of occurrence, utilizing a multi-dimensional feature extraction and classification technique known as the Self Organizing Map (SOM) (Kohonen, 1990). (Figure 2)

3. Downscaled and diagnosed the urban area building-aware wind flow and pressure perturbation fields, over downtown Boulder, CO, for each characteristic meteorological pattern, utilizing the Quick Urban Industrial Complex (QUIC) Dispersion Modeling System (LANL, 2007). (Figure 3)

4. Calculated the impact of the weather conditions on the building and the corresponding impact on the interior contaminant transport and exfiltration to the outdoors, utilizing the CONTAM multi-zone interior dispersion model (Walton and Dols, 2008). (Figure 4)

5. Simulated exterior atmospheric transport and dispersion of the building exfiltrated material for each downscaled meteorological pattern, utilizing QUIC. (Figure 5)

6. The combination of predicted downwind concentrations/dosages for each meteorological pattern with their associated frequency of occurrence were used to generate Probability of Detection/Exceedance spatial maps for a variety of prescribed thresholds. (Figure 6)

RESULTS

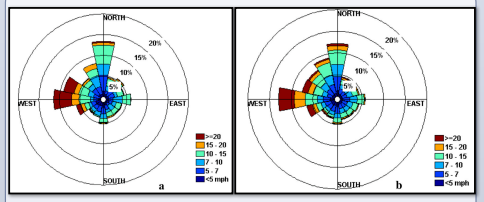


Figure 1. Wind roses derived from observations from the Rocky Mountain Metropolitan Airport (a), and from the SOM technique (b).

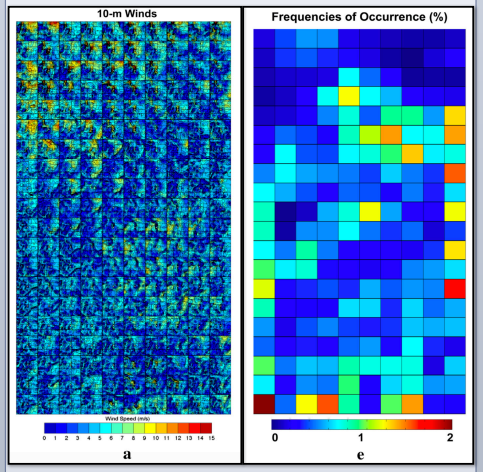


Figure 2. The 10x20 SOM for 10-m wind speed (a) and the frequency at which each node is present in the climatological record (b).

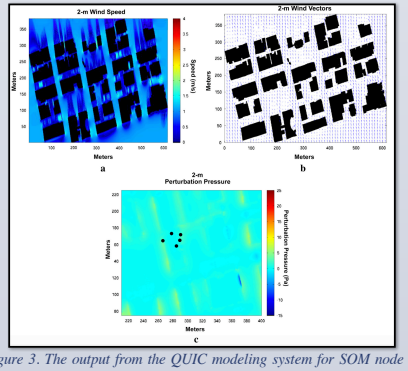
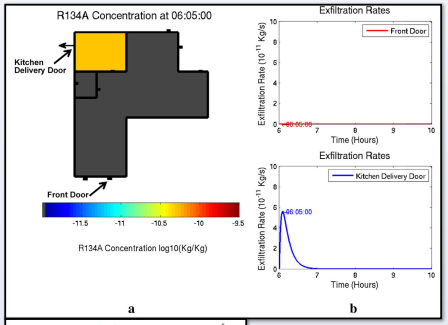


Figure 3. The output from the QUIC modeling system for SOM node 190 for wind speed (a), wind direction vectors (b), and perturbation pressure (c). The dots on figure c correspond with infiltration/exfiltration points that correspond with the configuration of the CONTAM interior dispersion model.

RESULTS (cont'd)



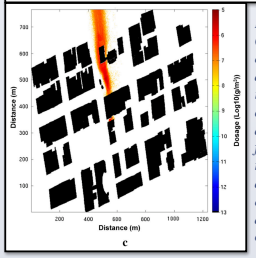
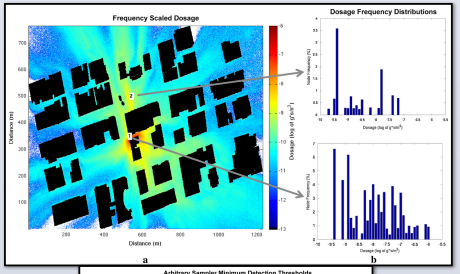


Figure 4. The output from the CONTAM interior and QUIC exterior "building-aware" dispersion models. The images depict the interior contaminant concentration and direction of material flow (a), the exfiltration rates through the front and kitchen delivery doors (b), and the exterior contaminant dispersion (c) for the weather conditions from node 190.



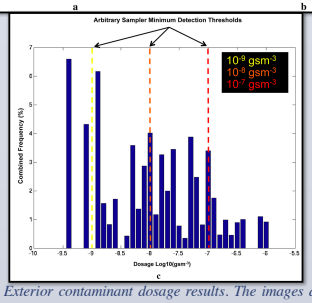


Figure 5. Exterior contaminant dosage results. The images depict the 1 hour integrated dosage scaled by the SOM frequency (a), the distribution of dosage frequency across all 200 nodes for two locations (b), and an example of the setting dosage thresholds to estimate the probability of exceeding a given dosage threshold (c).

RESULTS (cont'd)

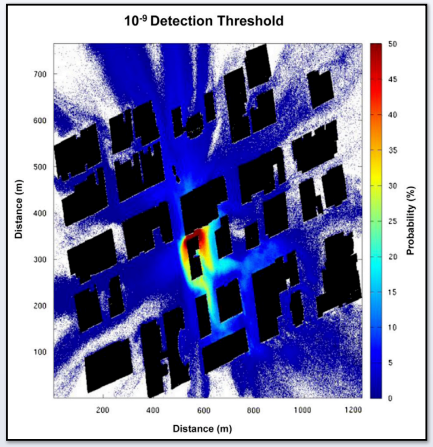


Figure 6. Probability of detection (POD) map. The image depicts the 1-hour integrated dosage POD for a dosage exceeding 1x10⁻⁹ gs m⁻³.

CONCLUSIONS

For this effort, we leveraged weather pattern recognition techniques to address the limitation of running a series of computationally expensive dispersion solutions. We identified where to place sensing/sampling resources by producing probability of detection maps for a given sampler detection threshold and sampling period. The methodology is flexible and can be tuned to allow the detailed characterization of Probability of Detection (POD) for a given sampler detection threshold and sampling period (e.g. sampling duration, season, time of day). An example of this methodology was presented for a single facility in an urban location surrounded by numerous multi-story buildings.

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CONTACT

Aeris LLC
1314 Main Street, Suite 101
Louisville, CO 80027
http://www.aerisllc.com
Paul E. Bieringer: paulb@aerisllc.com

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