6.3 AN INTEGRATED APPROACH TO DEFINING REALTIME UPWIND THREAT ZONES

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1. INTRODUCTION

One aspect of a site and building protection system for airborne hazards, is the development of threat zone displays for hazard awareness. A threat zone indicates the geographical area in which an atmospheric release of toxic material, if it were to occur, would impact a given target (*eg*. building or site) during a specified time frame.

This is a modification of the general concept of a hazard area. A hazard area is a region that is at risk from some potential or actual event. Examples include the warning and watch areas issued by the NWS, and hazard areas that are a result of a toxic spill or release. The difference is that a hazard area encloses all points affected by the hazard, while a threat zone encloses those points that affect the target. If the release from a point does not impact the target it is not part of the threat zone, though it may have its own hazard area.

The threat zone is an important tool for homeland security operations in that it provides heightened awareness for personnel, and allows for targeted monitoring by mobile sensors and stand-off detectors. In the event a release does occur, the threat zone also indicates the estimated time before the plume arrives.

2. DETERMINATION OF THE THREAT ZONE

The threat zone is determined using a Monte Carlo technique (Metropolis and Ulam, 1949) of multiple continuous releases at potential release sites. The plume from each release is tracked to determine if it intercepted the target of interest and what the travel time was. The travel times are then mapped at their respective release location. This mapping constitutes the threat zone area which is contoured by estimated arrival times for releases occurring within the threat zone.

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Potentially a very large number of releases are required to define the threat zone. Many release sites can be eliminated based on their location relative to the target, those downwind for example. Determining which release locations are downwind is a non-trivial process due to the time-varying nature of the wind. To select release locations based on local meteorology we use a receptor-modeling influence function technique (Uliasz, 1994; Uliasz *et al*., 1996), which is similar to back trajectory analysis (Stohl, 1998) but also accounts for turbulent diffusion.

The influence function is obtained by running a transport and dispersion model backward in time with a release at the receptor (target site). SCIPUFF (Sykes *et al.*, 1993; Sykes and Henn, 1995) is used for both the forward and backward transport and dispersion models. SCIPUFF is a Lagrangian puff dispersion model that uses a second-order turbulence closure scheme to relate the dispersion rates to measurable velocity statistics. SCIPUFF is capable of simulating the release of a wide variety of gaseous, aerosol, or particulate chemical or biological contaminants. In our study, a passive tracer, SF_6, was used.

3. ATMOSPHERIC MODELING SYSTEMS

The threat zone determination is one component of a larger building and site protection system. In addition to the threat zone computation there are hazardous atmospheric release prediction, source determination, and source location capabilities.

Key to the successful operation of this system is the variety of predictive models and variational assimilation systems operating at scales from regional down to building scale that are used to provide the required meteorological inputs to the transport and dispersion models. The atmospheric fields required by the transport and dispersion models include winds, temperature, boundary layer height and sensible heat flux. The atmospheric modeling systems include the Real-Time Four-Dimensional Data Assimilation system (RTFDDA), the Variational Doppler Radar

Assimilation System (VDRAS), and the Variational Lidar Assimilation System (VLAS). Loose interaction between the models is achieved through the passing of initial and boundary conditions. A short overview of each modeling system follows.

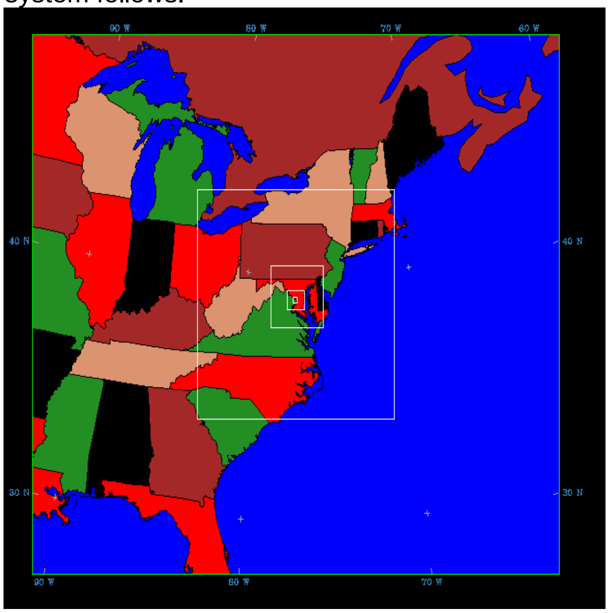

Figure 1 Nested domains of the RT-FDDA system.

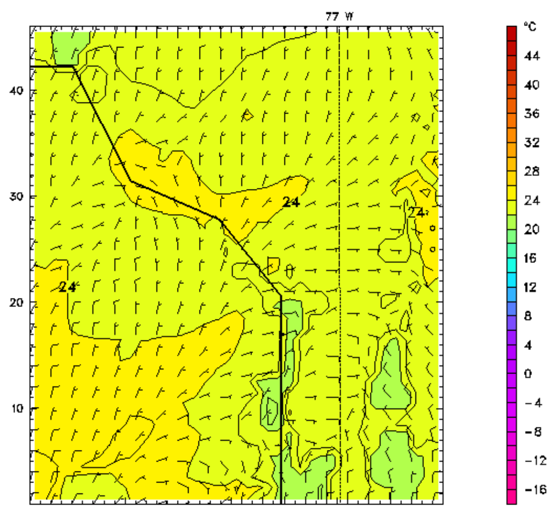

Figure 2 Finest RT-FDDA domain illustrating fine-scale flow (every fourth wind barb is shown)..

3.1.RT-FDDA

The RT-FDDA is an assimilation and modeling system for producing high-resolution analyses and forecasts. The modeling component is based upon the MM5 core (Dudhia, 1993; Grell *et al.*, 1994). The assimilation scheme is a 4-dimensional observation nudging approach that can ingest standard, and special, surface and upper air observations including satellite-derived winds and profiler and ACARS data. There is also the capability to ingest the derived wind fields from the VDRAS and VLAS systems. RT-FDDA forecasts may be used as first guess fields for VDRAS and VLAS.

A nested configuration was used (Figure 1) to produce forecasts of up to 36 hours in length on a 3-hour cycle at a range of scales from regional down to metropolitan. The finest domain (Figure 2) is sufficient to cover a metropolitan area at 500 m resolution, and able to resolve a variety of thermal and orographic flows.

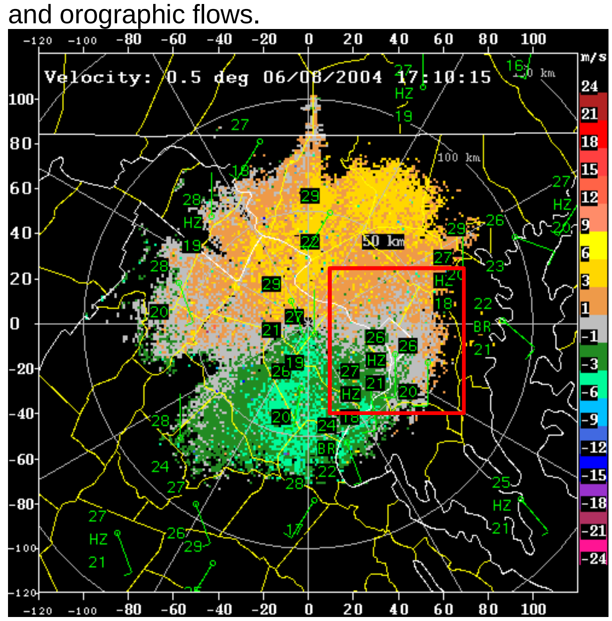

Figure 3 Sterling, VA radial Doppler winds for 1710 UTC 08 June 2004, the red box indicated the VDRAS analysis region. Range rings are spaced every 50 km.

3.2.VDRAS

Sun and Crook (1997, 2001) describe the VDRAS concept in detail. In brief the system uses a simplified Boussinesq model along with the corresponding adjoint to fit the model to the observations through the minimization of a cost function based upon the difference between the model solution and the 4-dimensional observations. The observations ingested by VDRAS include radar reflectivity and Doppler winds, along with other *in situ* measurements.

Figure 3 shows the observed radial wind field from the Sterling, VA WSR-88D radar at 1710 UTC 08 June 2004. The Doppler winds indicate an overall Southerly flow that is confirmed by the overlain station wind barbs.

A VDRAS analysis requires a minimum of 2 radar volume scales, and generally about 40 iterations of the forward and adjoint model are required to minimize the cost function. In addition to the analysis, a short-term forecast, typically 30 minutes, can also be produced. Common grid configurations are 1 km horizontal grid separation, 375m vertical grid separation, and a domain area of 10^4 km^2. Execution time for the system on current dual-processor PC hardware is about 10 minutes.

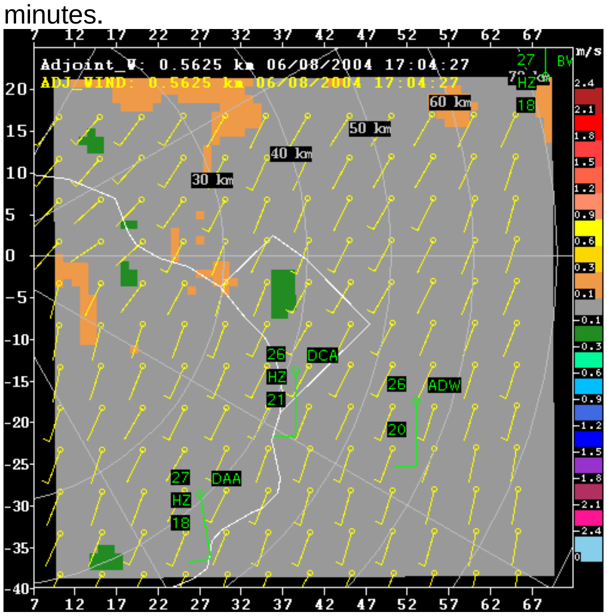

Figure 4 VDRAS lowest level, 375 m, analysis valid at 1704 UTC 08 June 2004, every fifth grid point in shown by the yellow barbs. Observations are indicated by the green barbs.

In Figure 4 the lowest level, 375 m, winds from a VDRAS analysis are shown. The retrieved winds winds are mostly out of the south-southwest, while the observed, 10 m, winds are of a more southerly nature. It is noted that much of the directional difference may be due to lack of collocation in height between the analyzed and observed winds.

3.3.VLAS

The VLAS system is very similar to VDRAS, with minor changes to incorporate the resolution and scan characteristics of Doppler lidars. Typical configurations are 100 m horizontal grid separation, 50 m vertical grid separation, and a domain area of 10^2 km^2. Execution times are similar to VDRAS with minor variations depending on scan strategy and data volume. An example of a VLAS wind retrieval showing a south-southwesterly flow is shown in Figure 5.

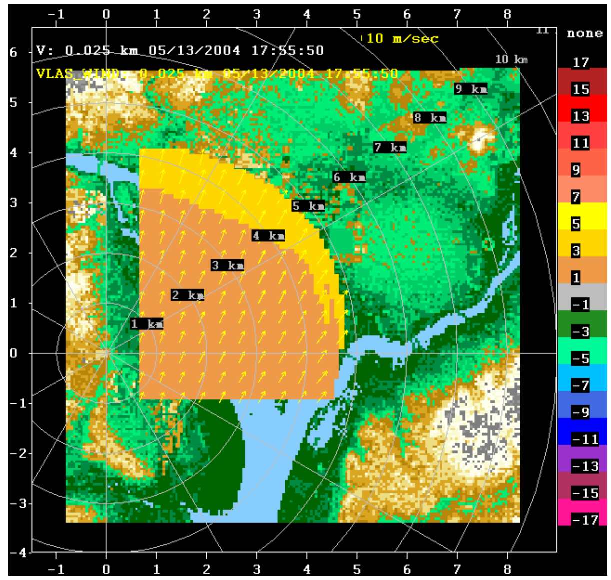

Figure 5 VLAS analysis valid at 1756 UTC 13 May 2004. Every fifth wind vector is shown overlain with wind magnitude.

3.4.Blended Wind Field

The wind forecast and analysis systems produce fields at a variety of scales over several different spatial domains and at different temporal frequencies and periods. In order to drive the transport and diffusion model these fields are blended to minimize any discontinuities at domain boundaries which may adversely impact the plume predictions.

4. SAMPLE THREAT ZONE

Schematically, the threat zone determination consists of the following steps. A network of virtual samplers are set up in the SCIPUFF modeling domain (Figure 6). A uniform density of virtual samplers is shown, but there is an option to vary virtual sampler density with distance from the target in order to maximize resolution close in to the target. Also shown in Figure 6 is the influence function for a backward in time dispersion run. A one-hour continuous receptor release was simulated over the site and the virtual samplers indicated by red crosses are those that may impact the target.

Each virtual sensor which detected non-zero concentration in the receptor run is used as a release location for a one-hour forward SCIPUFF

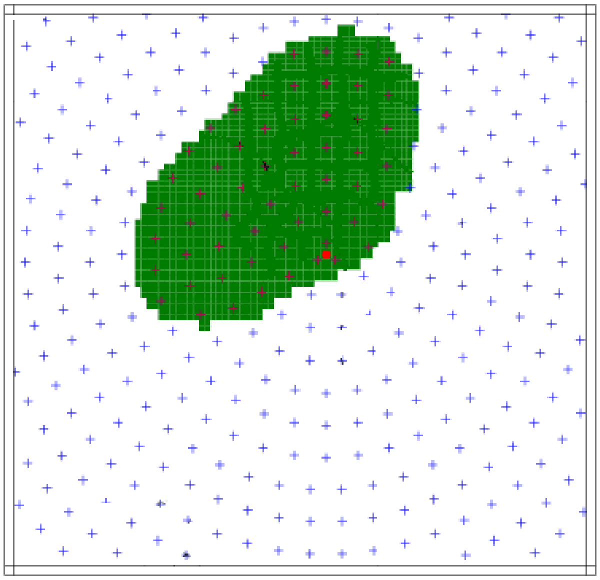

Figure 6 Influence function for a one-hour release from the receptor site (red circle). Virtual sampler network is indicated by the crosses.

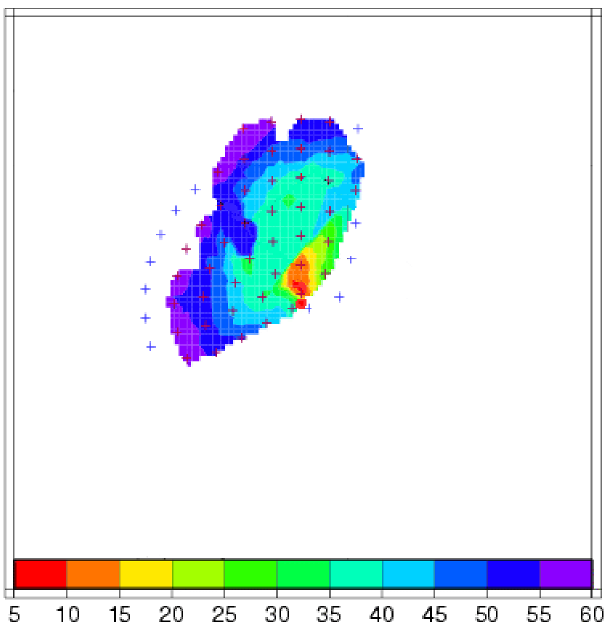

Figure 7 One-hour threat zone for the receptor site (red circle), contour interval is in minutes. Crosses are release points from the influence function and those in red had plumes reach the site.

run, both to confirm that a release from that location would impact the target and to determine the plume arrival time. Arrival times are spatially mapped to produce the threat zone shown in Figure 7. A large amount of variability is evident due to the varied path that the plume from each release point takes and the spatial-temporal variation in the wind over the simulation period.

5. SUMMARY

An algorithm to calculate the threat zone, using RT-FDDA, VDRAS, and VLAS winds, for a building or site was developed as part of a total airborne-hazard protection system. The system is flexible in its application in that it can be readily transferred to various locations as long as high-resolution winds are available.

6. REFERENCES

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