Potential Use of Transport and Dispersion Model Output to Supplement ATP-45 Hazard Prediction Templates

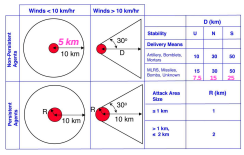
Nathan Platt and Leo Jones
Institute for Defense Analyses, Alexandria, VA 22311, USA

Introduction

Allied Tactical Publication-45(C) is the current US and NATO command doctrine for Nuclear, Chemical and Biological (NBC) events. ATP-45 is designed to warn military populations of NBC hazard by providing area warning templates based on NBC messages. ATP-45 is designed to produce a single 2-hour hazard area template that accounts for wind speed fluctuations, but it does not take into account: a) time intervals of less than 2 hours and b) spatial and temporal variations in the wind field that could result in the incorrect orientation of the triangle template. Additionally, an abrupt discontinuity in the template from a circle to a triangle occurs as the wind speed passes through 10 km/hr. This abrupt change is unrealistic and can result in a significant under- or over-prediction of the hazard area. CT-Analyst, developed by the Naval Research Laboratory (NRL), is designed to provide near instantaneous hazard predictions resulting from large-scale chemical releases within a city. The CT-Analyst methodology is based on interpolation of pre-computed hazard area nomografsTM. These nomografs are created by using a computational fluid dynamics (CFD) code (FAST3D-CT also developed and maintained by NRL) to produce highly-resolved urban transport and dispersion predictions.

Our efforts have focused on comparisons of CT-Analyst hazard area predictions with the corresponding ATP-45 templates.

ATP-45 Template and its Modification to be Compatible with CT-Analyst Large Area Nomograf



- ATP-45 Template designed to estimate hazard area 2 hours after release
- CT-Analyst cloud evolution is limited to 1-hour
- Need to modify ATP-45 template to accommodate 1-hour hazard area
- CT-Analyst nomografs are based on an instantaneous 1 ton release of GB which could be "equated" to a missile attack for ATP-45 purposes

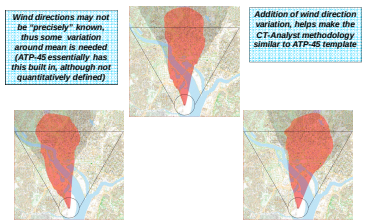
We modify ATP-45 template by
- *For wind speed > 10 km /hr reduce downwind distance in half*
- *For wind speed < 10 km/hr reduce "circle diameter" in half*

Figure above is reprinted from reference 4.

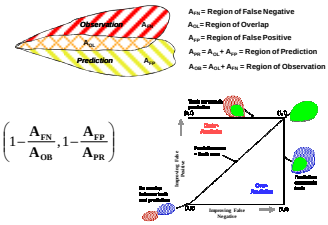
Notional Concept for CT-Analyst/ATP-45 Comparison for 12 km/hr wind from the South (± 10°)

Wind directions may not be "precisely" known, thus some variation around mean is needed (ATP-45 essentially has this built in, although not quantitatively defined)

Addition of wind direction variation, helps make the CT-Analyst methodology similar to ATP-45 template



User-Oriented Two-Dimensional MOE

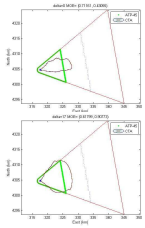


A_{FN} = Region of False Negative
A_{OL} = Region of Overlap
A_{FP} = Region of False Positive
$A_{PR} = A_{OL} + A_{FP}$ = Region of Prediction
$A_{OB} = A_{OL} + A_{FN}$ = Region of Observation

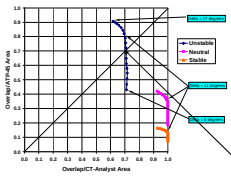
$$\left(1-\frac{A_{FN}}{A_{OB}}, 1-\frac{A_{FP}}{A_{PR}}\right)$$

Typical Areas, Wind Speed = 13 km/hr

- Two plots on the right depict visual comparisons of
  - Single CT-Analyst 1-hour plume footprint for wind speed of 13 km/hr and wind direction of 260°
  - Union of CT-Analyst 1-hour plume footprints for wind speed of 13 km/hr and wind directions of 260-17 and 260+17
    - In 1° increment
    - CT-Analyst hazard area extends beyond sides of ATP-45 "Neutral" and "Stable" triangles
  - Maximum angle difference from main wind speed (260°) used to construct ATP-45 and initial CT-Analyst will be called Δ
    - Here Δ = 17°

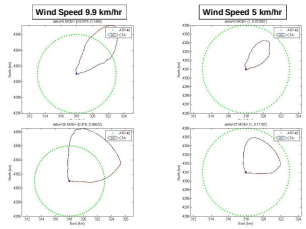


Typical MOE Results



- 2D-MOE plots
  - As a function of Δ
- Both "Neutral" and "Stable" ATP-45 "triangles" initially completely envelop CT-Analyst hazard area
  - CT-Analyst area is significantly smaller than "Neutral" and "Stable" ATP-45 triangles area
- At Δ = 11°, CT-Analyst hazard area extends beyond sides of ATP-45 "Neutral" and "Stable" triangles
- CT-Analyst hazard area extends beyond "Unstable" ATP-45 triangle
  - For Δ = 7°, ATP-45 and CT-Analyst produce areas that are approximately equal to each other

Wind Speed < 10 km/hr



For Wind Speed > 10 km/hr

- The extent of the CT-Analyst hazard area lies beyond the Unstable ATP-45 triangle and becomes significant as the wind speed increases.
- Neutral and Stable ATP-45 triangles envelop the single wind CT-Analyst hazard areas with the CT-Analyst hazard area being significantly smaller than the ATP 45 areas.
- At certain ±Δ wind sweep angles, the union CT-Analyst hazard area extends beyond the sides of ATP-45 triangles.
  - The calculated ±Δ wind direction angle when the union CT-Analyst hazard area extends just beyond the sides of ATP-45 triangles for wind speeds greater than 10 km/hr are 11, 9, 12, 10, 17, 18, and 10 degrees for the seven selected locations with a mean angle of 12 degrees and median angle of 11 degrees. Because of the turbulent and unpredictable behaviour of the atmosphere, these potential bounds on wind direction values are within realistic "error" bounds for measured wind, especially when using a representative single steady wind value to cover spatio-temporal evolution of the wind field over the evolution of the hazard area (e.g., 1-hour time interval used for the evolution of CT-Analyst hazard area).

For Wind Speed < 10 km/hr

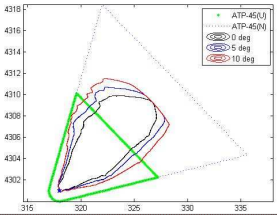
- For some range of wind speeds above 5 km/hr, the CT-Analyst hazard area extends beyond the ATP-45 circle with the portion of the area that lies outside of ATP-45 circle becoming significant as the wind speed approaches the threshold wind speed of 10 km/hr.
- Below some critical wind speed, the CT-Analyst hazard area lies completely within the ATP-45 circle.
- Both single wind direction and a union CT-Analyst predicted areas are significantly smaller than the ATP-45 hazard area.

Conclusions

We conclude that the proper use of CT-Analyst or other T&D models to produce real-time hazard area warnings:

- Does not have an arbitrary discontinuity in the hazard area at any wind speed (e.g., 10 km/hr) threshold.
  - Could produce time-dependent hazard areas in less than 2-hour time intervals.
  - Consistently handles the risk
  - Can incorporate additional information (e.g., complex, space and time dependent meteorology) if that information is available and could be utilized by the T&D model.

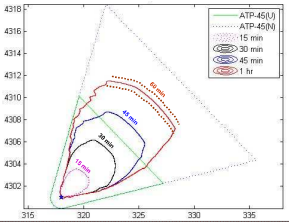
Notional Real-Time Use of CT-Analyst for Hazard Area Prediction at Fixed Time but Varied Wind Sweep Angle



- Wind speed is 15 km/hr
- Mean wind direction is 225°
  - Used for ATP-45 triangle positioning
- "Union" CT-Analyst hazard area is calculated in 1° increments for wind directions 225°±5° and 225°±10°

Wind direction fluctuations of ±5° and ±10 km/hr are purely notional
Actual values need further analysis and concurrence within CBD community
Because of limited spatial domain used in CT-Analyst nomograf, ATP-45 downwind extent is reduced in half

Notional Real-Time Use of CT-Analyst for Hazard Area Prediction at Fixed Wind Sweep Angle but Varied Time



- Wind speed is 15 km/hr
- Mean wind direction is 225°
  - Used for ATP-45 triangle positioning
- "Union" CT-Analyst hazard area is calculated in 1° increments for wind directions 225°±10°
- Potentially, one could vary wind speed by ±1 km/hr to account for errors in wind speed measurements
  - Will result in two additional contours per time interval of interest
    - Notionally denoted by brown dashed line on the leading edge of the hazard area in the picture

Time interval of 15 minutes, wind direction and speed fluctuations of ±10° and ±1 km/hr are purely notional
Actual values need further analysis and concurrence within CBD community
Because of limited spatial domain used in CT-Analyst nomograf, ATP-45 downwind extent is reduced in half

References

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2. Boris, J.P., Fulton, J., Obenschain, K., Patnaik, G. And T.R. Young, 2004, *CT-ANALYST, Fast and Accurate CBR Emergency Assesement*, Proceedings: SPIE Defense and Simulation Symposium, SPIE Paper 5416-01, Orlando, FL, 10-16 April 2004.
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Caveats

We do not advocate that ATP-45 2-hour hazard area templates could or should be extended to include 1-hour hazard area templates. In fact, it would have been preferable to perform this study with high-resolution urban nomografs covering 2 hour hazard area evolution. Nevertheless, we believe that similar conclusions would have been reached.

Both wind direction fluctuation of ±5 and ±10 degrees and time intervals of 15 minutes, wind fluctuations of ±10 degrees, and wind speed variations of ±1 km used in the construction of the figures above are notional and are not being specifically advocated. If these suggestions on the use of a T&D model to supplement ATP-45 hazard area templates are to be contemplated, then the actual values to be used require further analyses and concurrence within the Chemical and Biological Defense community.

Acknowledgments

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Contact Information

Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, VA 22311
USA

Nathan Platt: nplatt@ida.org
Leo Jones: ljones@ida.org