A Framework for Developing Synthetic Chemical and Biological Agent Release Data Sets

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Chemical and Biological (CB) Defense Systems Test and Evaluation (T&E)

- **Technology gap**
  - **Insufficient field data for T&E**
  - **Economic and logistic limitations for chemical biological defense T&E**

- **One solution**
  - **Physically realistic virtual environments and synthetic observations**

Best Solution Will be Derived from the use of Both Observations and Virtual Environment Data

Virtual Testing Methodology
(Observation System Simulation Experiment)

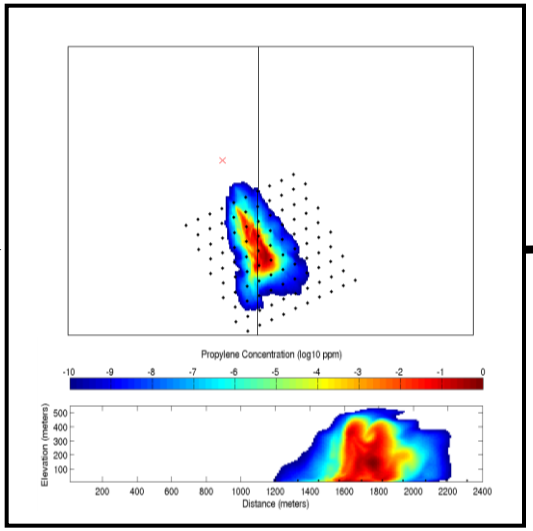
Generation of Synthetic Environment

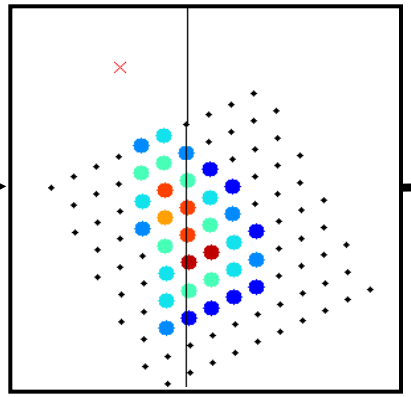
Simulated Sensor Measurements

Applications That Utilize Observations

Atmospheric Models

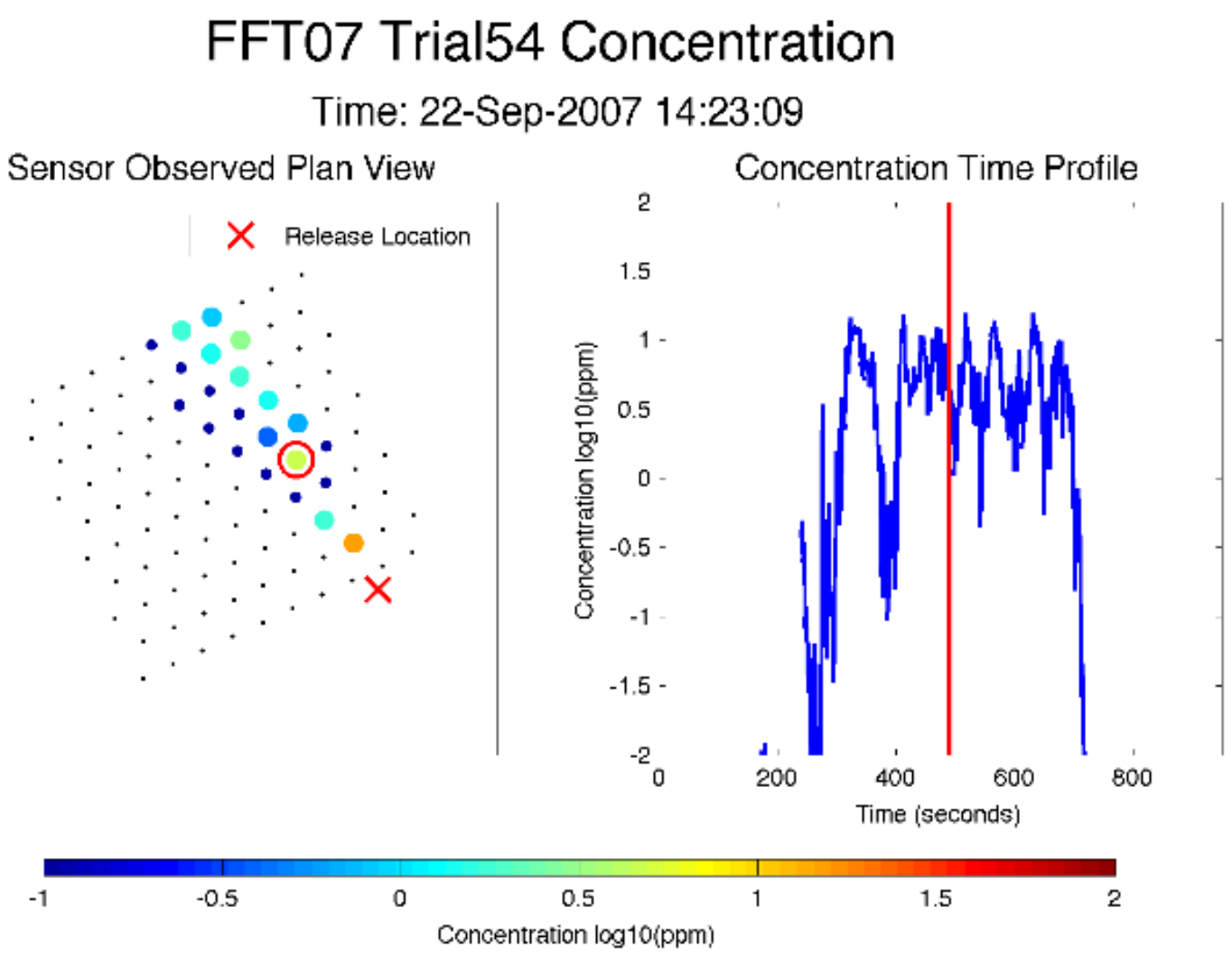
Transport and Dispersion Models





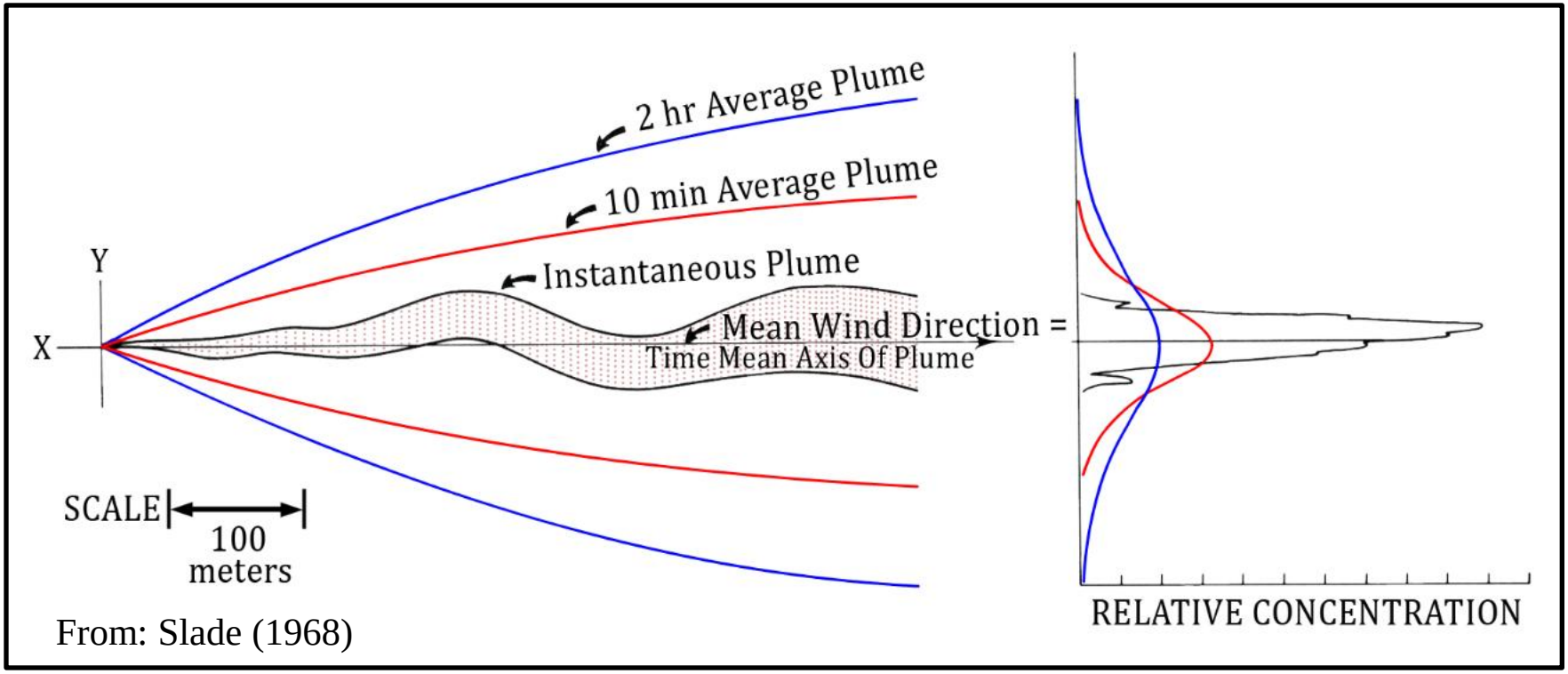
Models and Analysis Systems

Real Sensor Data Characteristics



Near-Field Dispersion Modeling

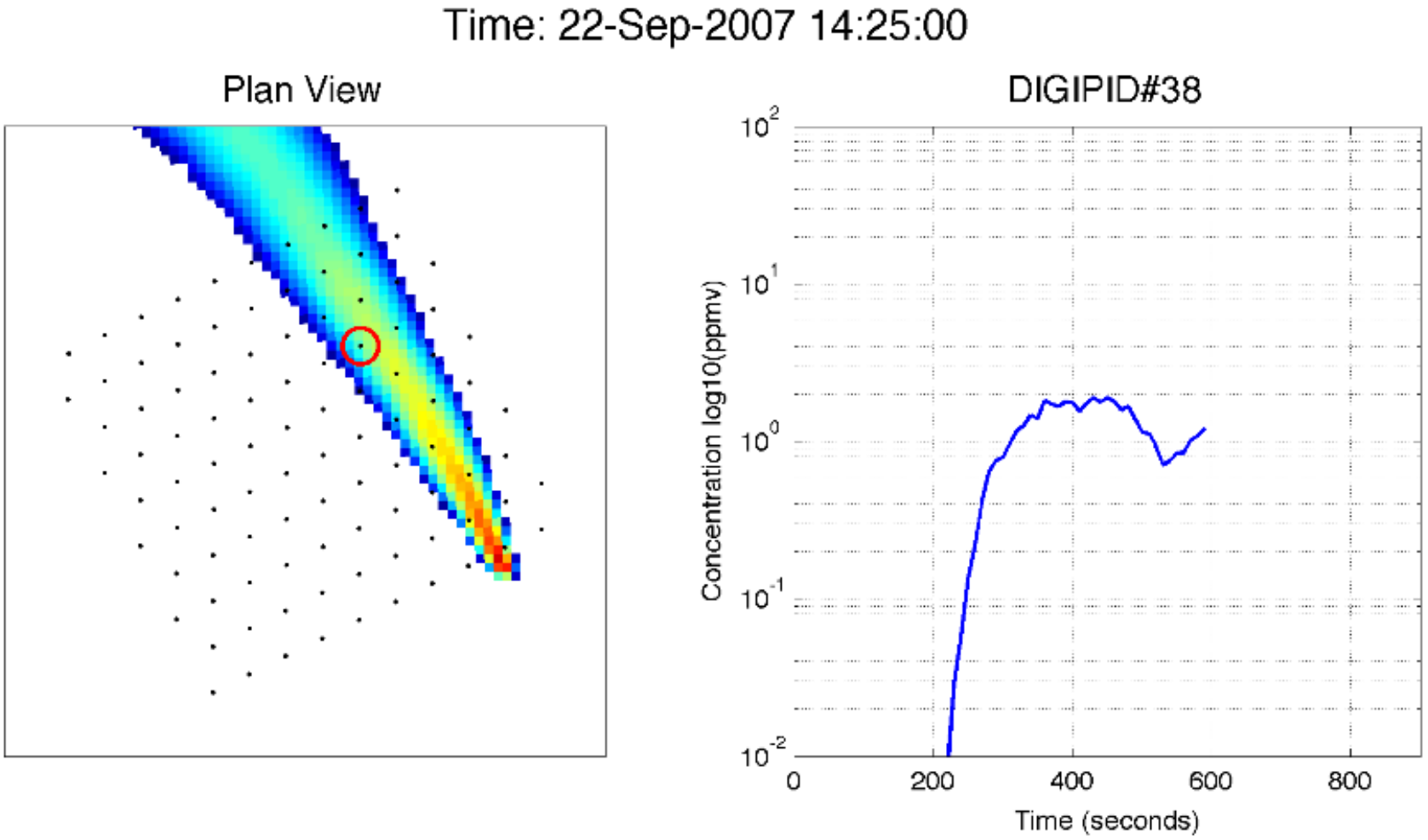
(Exterior CB Release and Atmospheric Environment)



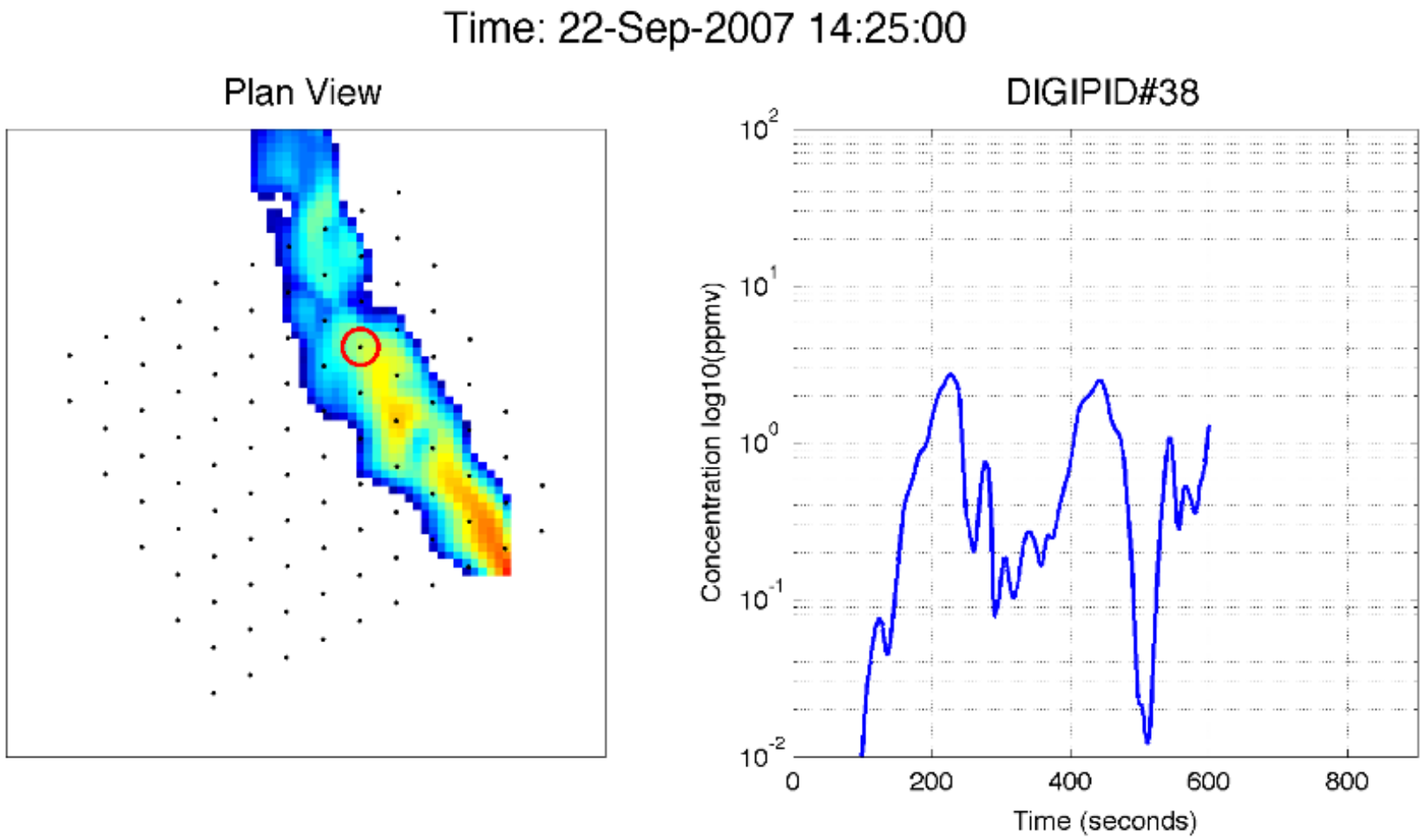
From: Slade (1968)

- **Near-field dispersion characteristics**
  - **Gaussian-based models capture the mean properties**
  - **Large-Eddy-Simulation (LES) based models are capable of capturing the near-instantaneous plume**

Diagnostic Met + Gaussian Puff



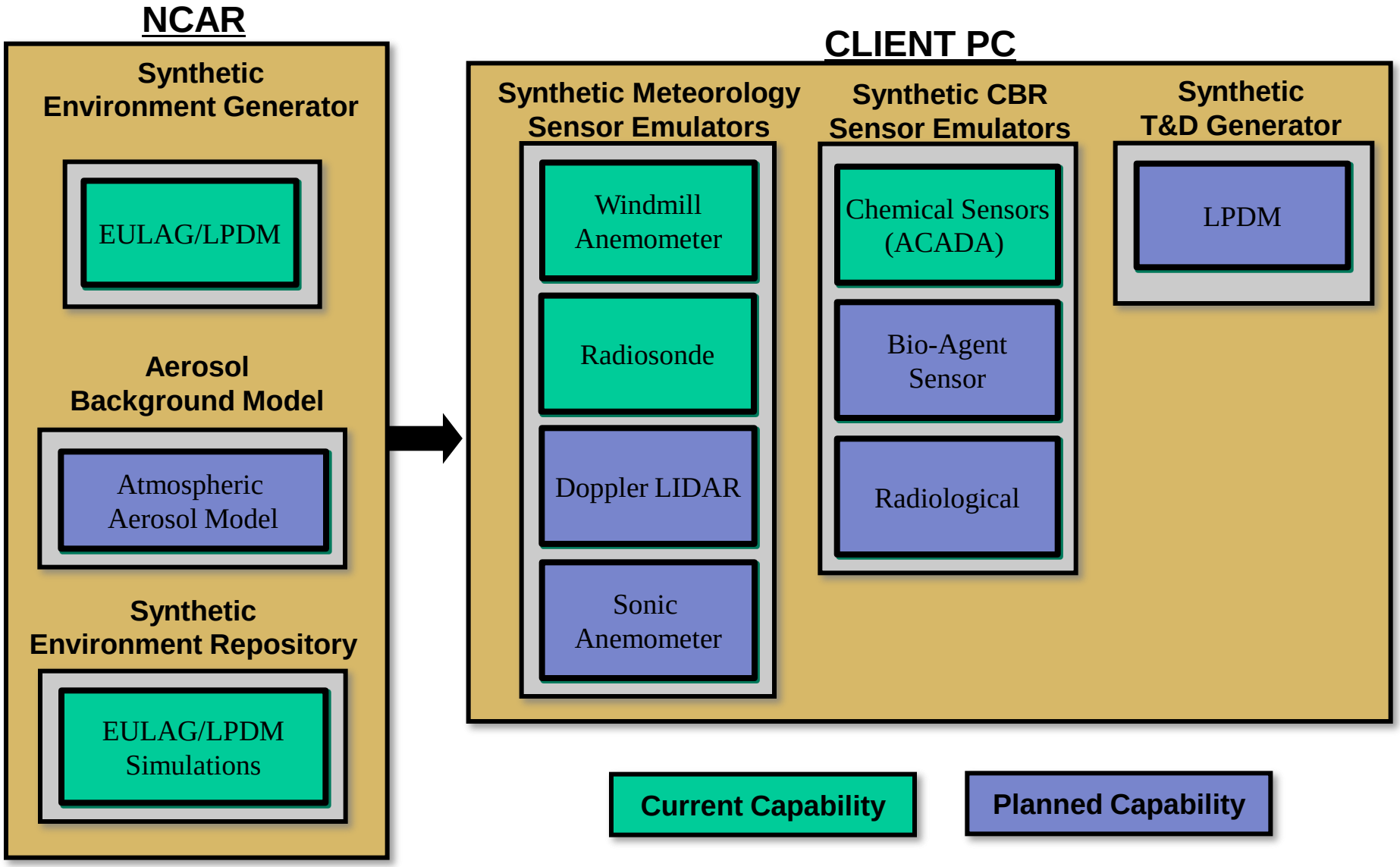
Large Eddy Simulation + Lagrangian Particle Dispersion



Outline

- **Motivation**
- **Virtual Threat Response Emulation and Analysis Testbed (VTHREAT)**
  - **Overview**
  - **Synthetic Environment Generation Models**
  - **Evaluation**
- **VTHREAT applications**
  - **CB Field Test Design**
  - **CB Source Term Estimation (STE) Algorithm Development**
  - **CB Sensor Test and Evaluation**
- **Future Work**
  - **Aerosol Background Modeling**

VTHREAT Overview



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EULAG

(EULerian/semi-LAGrangian Model for Fluid Flows)

Optional nonhydrostatic fluid equations: Anelastic or Compressible / incompressible Boussinesq,

Optional modes for integrating fluid PDEs: Eulerian (flux form) or semi-Lagrangian (advective form)

Applications: classical fluid dynamics, cloud turbulence, atmospheric flows from PBL to global and planetary scale, MHD, ocean flows, T&D aplications, flows over complex topography and buildings

Numerical algorithms:

- **Nonoscillatory forward-in-time (NFT) advective transport (MPDATA)**
- **Preconditioned non-symmetric Krylov-subspace elliptic solver GCR(k)**
- **Generalized-coordinate formulation for grid adaptivity**

Strategies of simulating turbulent dynamics:

- **Direct numerical simulation (DNS)**
- **LES type turbulence closure (1 ½ order, prognostic tke), Smagorinsky or ILES model**

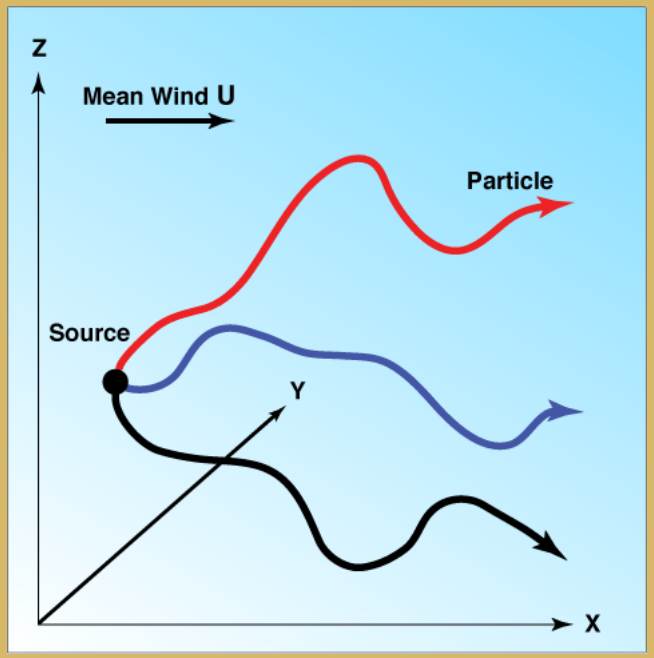
T&D applications

- **Structured, time-dependent grids, "terrain-following" transformation (orographic flows) or immersed boundary approach (urban flows)**
- **Passive tracer to asses transport and dispersion of passive contaminants**

LPDM

(Lagrangian Particle Dispersion Model)

- **LPDM model driven by EULAG meteorological solution**
  - **Weil et al., 2004, J. Atmos. Sci.**
  - **Provides a very detailed T&D solution**
  - **Flexible solution for producing synthetic T&D from numerous sources**
  - **Lower computational costs**
  - **Evaluated relative to laboratory and field data**



$v(x_0,t) = u_{RES}(x_p,t) + u_{SGS}(x_p,t)$

u_{RES} = resolved LES velocity

u_{SGS} = stochastic sub-grid-scale (SGS) velocity

Thomson's (1987) stochastic model for u_{SGS}

Concentrations: $C^y = Q \int p_1(x - x_s, z - z_s, t_d)\, dt_d$

$t_d = t - t_{em}$

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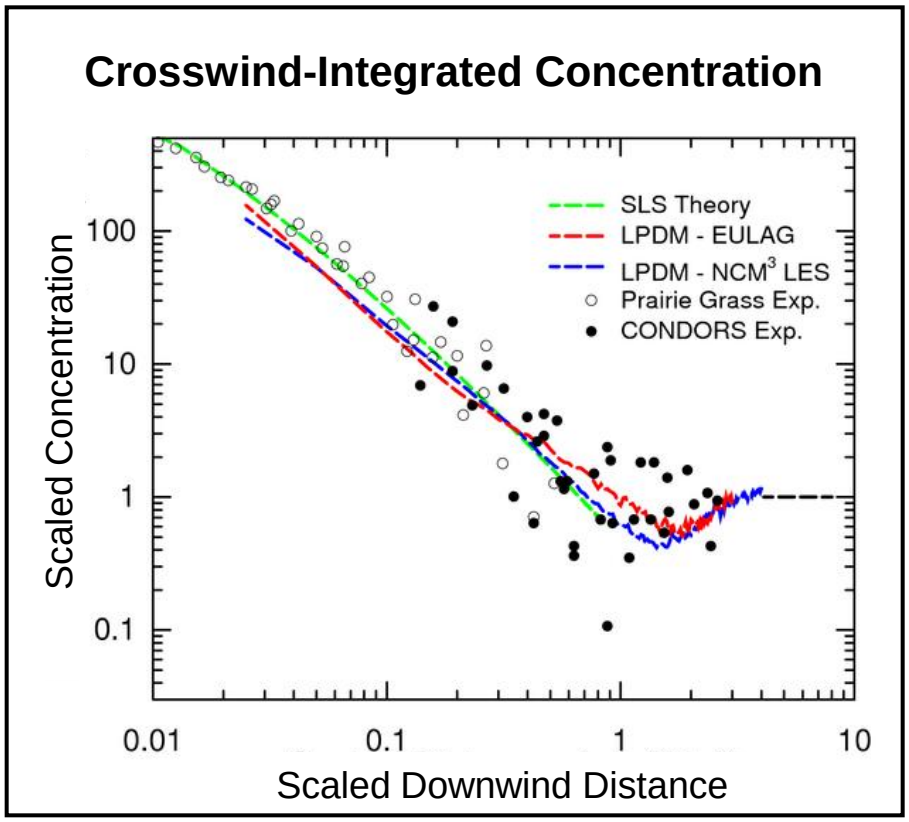
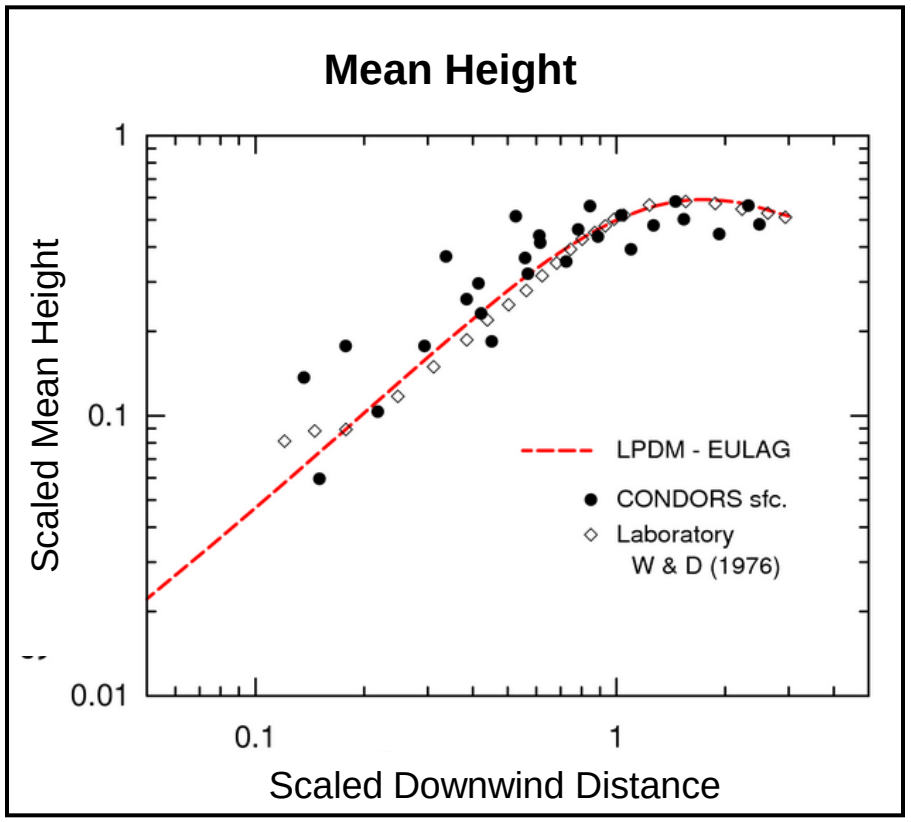
VTHREAT Validation





Scaled Downwind Distance = $w_* x/(Uz_i)$

Scaled Concentration = $C^y Uz_i/Q$

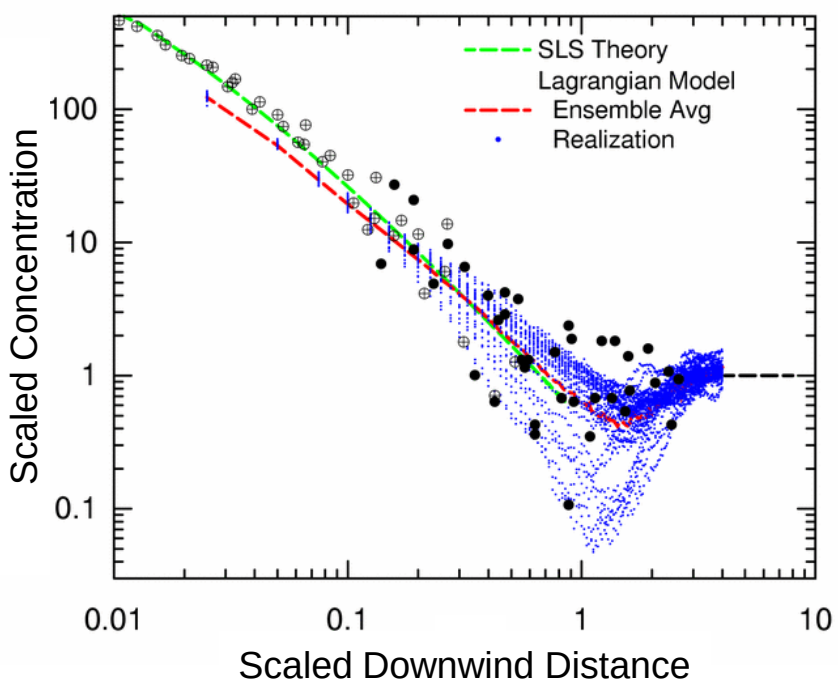
Scaled Mean Height = $\overline{z}_p/z_i$

VTHREAT Evaluation

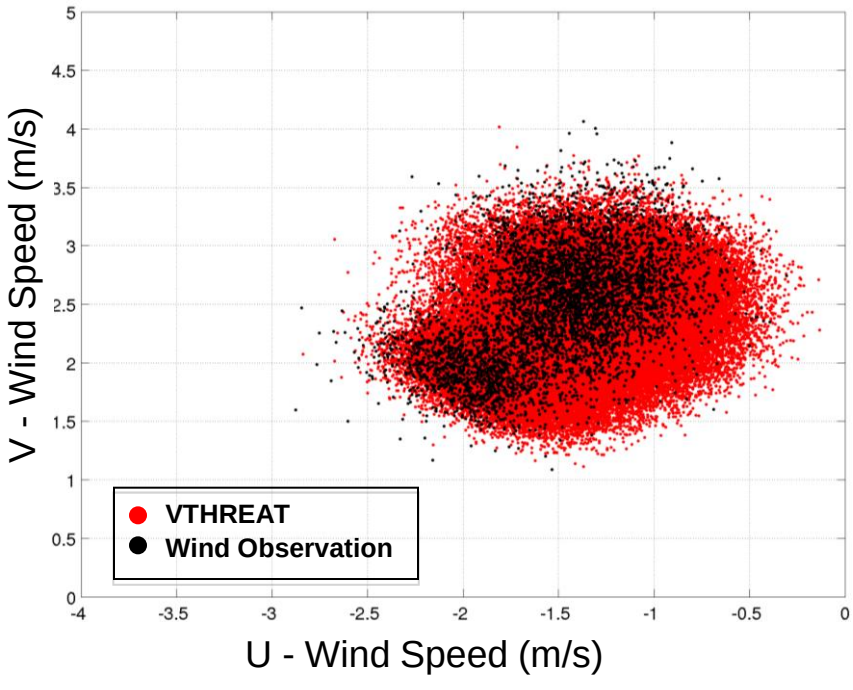
(Assessing the Suitability for the CB T&E Application)

- **Virtual CB T&E tool requirements**
  - **Realistic agent mean lateral/vertical and downwind dispersion**
  - **Realistic agent concentration and wind fluctuations**
  - **Realistic background interference signals**

Crosswind-Integrated Concentration



Surface Wind Fluctuations



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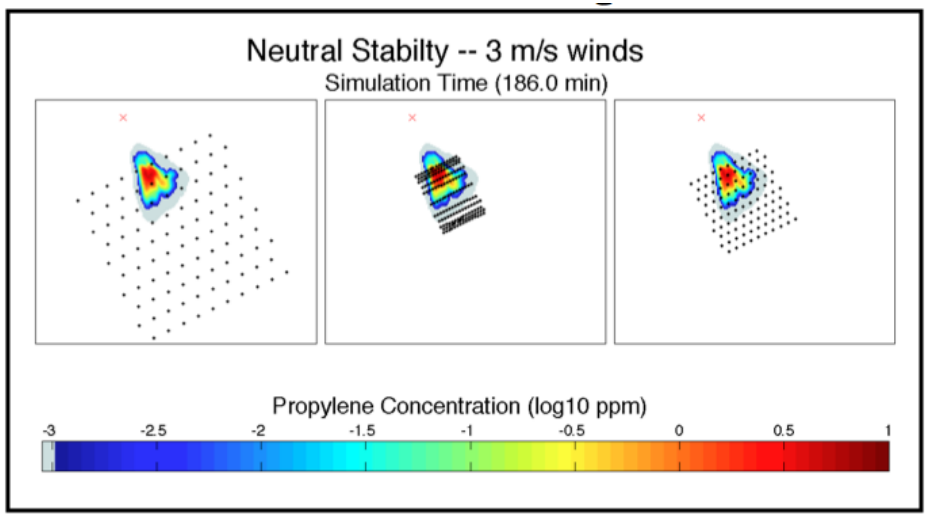
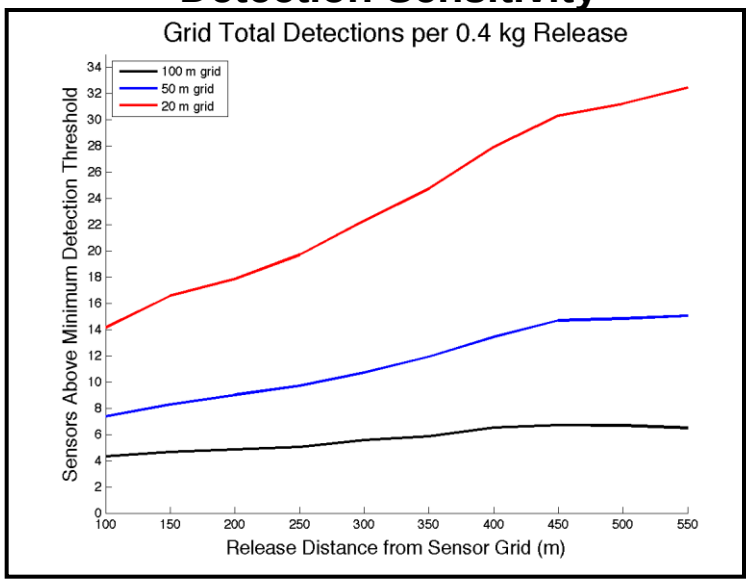
CB Field Test Design

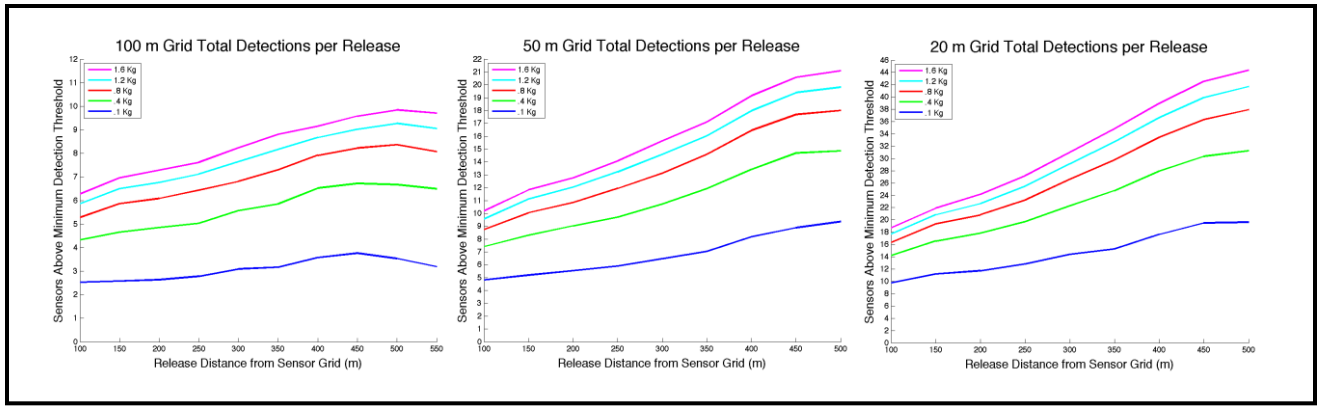
Plume Coverage



Sensor Grid Detection Sensitivity



Detection Sensitivity to Release Concentration



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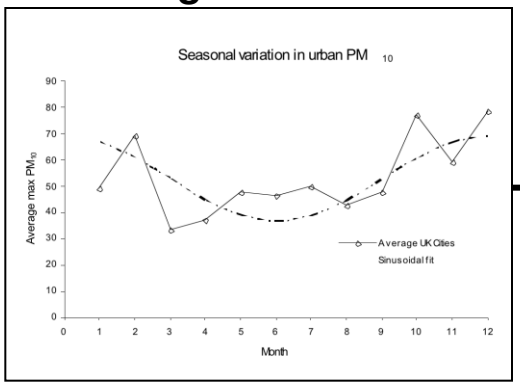
Incorporation of Relevant Background Fields

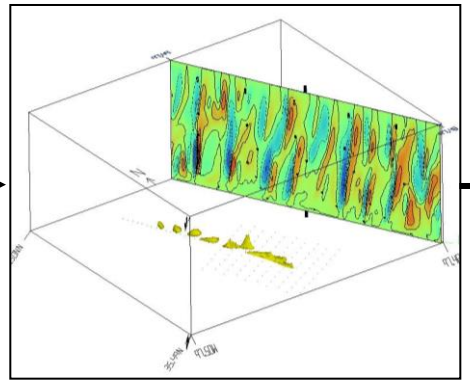
- **Realistic background signals physically consistent with agent release**
  - **Aerosol background for biological sensors**
  - **Ambient chemical interference fields for chemical agent sensors**

- **Implementation plans**
  - **Utilize aerosol background information from PD TESS program**
  - **DTRA-JSTO funded DSTL aerosol background model**
  - **Couple aerosol concentration with the EULAG LES model**

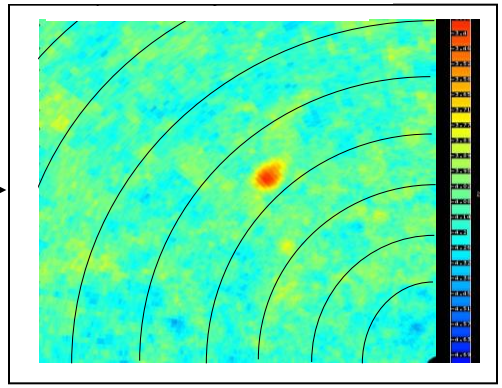
DSTL Aerosol Background Model



EULAG/LPDM Model

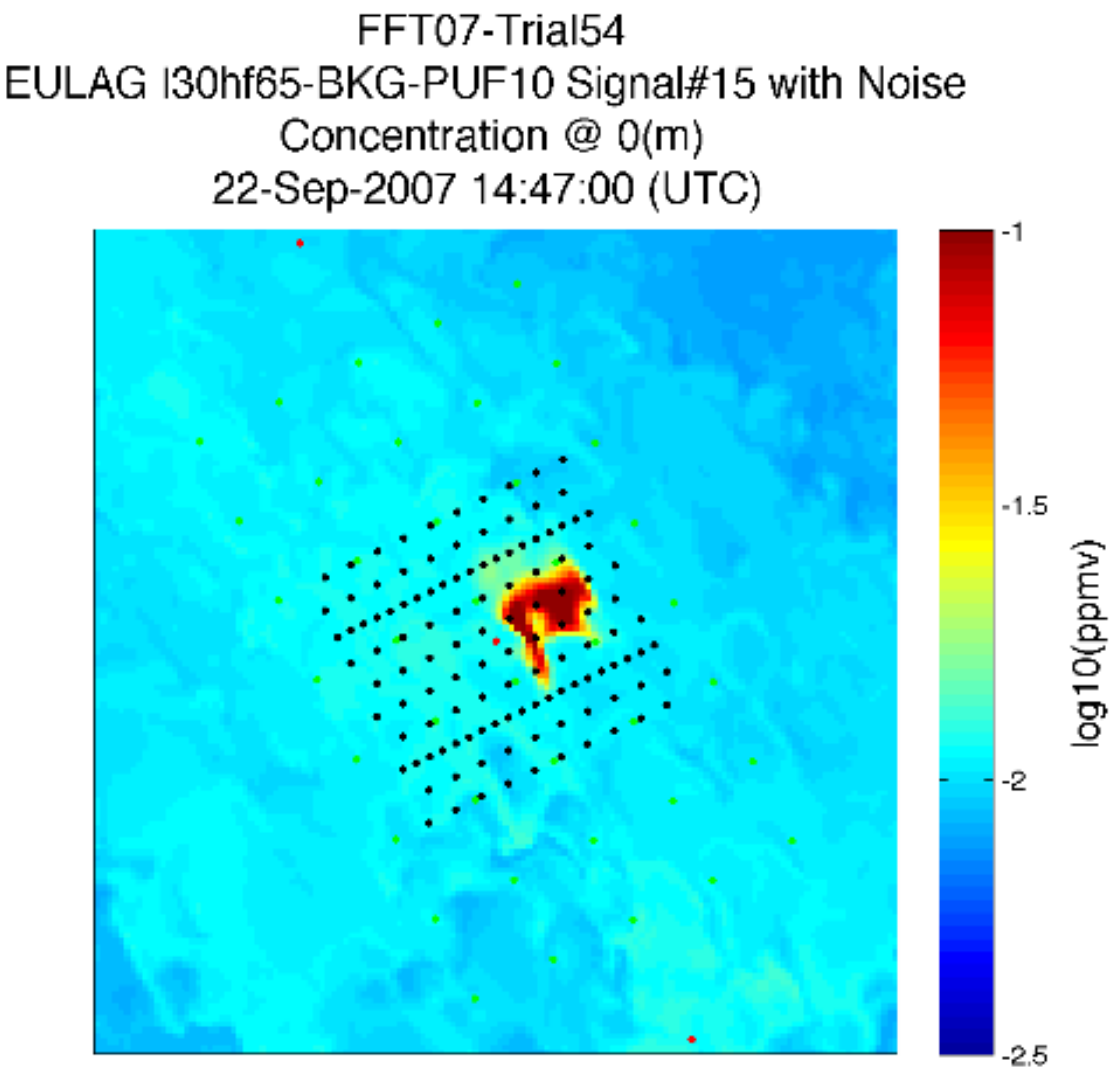


VTHREAT LIDAR Emulation



CB Release and Relevant Background Fields

(Preliminary Demonstration)



Summary

- **The problem**
  - **A capability gap exists for evaluating CB sensors in a more robust way.**
  - **“Virtual” testing can be used to fill this gap**
- **One solution**
  - **Generation of synthetic test environments**
- **Model validation**
  - **Turbulent dispersion characteristics are being validated against a range of experimental and laboratory datasets**
- **Applications**
  - **Support field test design**
  - **Sensor data algorithm development**
  - **CB sensor test and evaluation.**
- **Looking ahead**
  - **Simulated chemical dispersion imbedded within a background interferent signals**

Questions?

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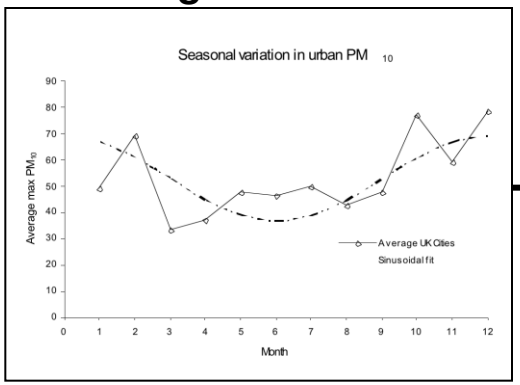

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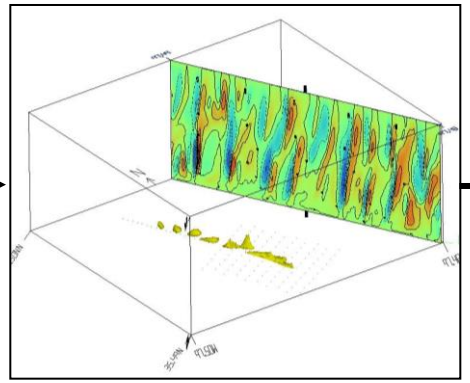

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