Source Estimation for CBRN incidents based on Field Data

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OBJECTIVES

- Source estimation is the process of inferring the source parameters from the concentration time history obtained from sensor data
  - Source type: instantaneous (puff) / multiple puff / continuous
  - Source locations
  - Source strengths
  - Number of sources
  - Release start and end times

MOTIVATION

- High-fidelity forecasting of toxic plumes in chemical, biological, radiological and nuclear (CBRN) incidents.
- Develop procedures in order to aid human decision-making in critical situations associated with hazardous releases into the atmosphere.

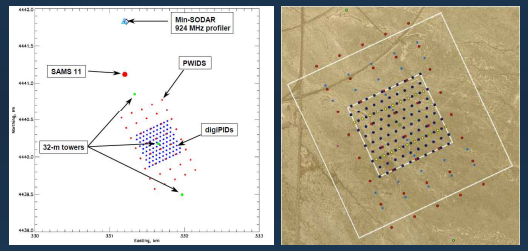


Figure 1: FFT07 Sensor Layout

BACKGROUND

- Fusion Field Trials - 2007 (FFT07) Conducted by DTRA, JSTO-CBD in Dugway Proving Grounds, Utah, from Sep 10-29.
- Meteorological and tracer dispersion data is collected for testing current and future source estimation algorithms.
- Propylene is used as tracer gas.

Release characteristics

- Multiple source releases (up to a maximum of four)
- Single puff (instantaneous), a train of puff and continuous releases

CHALLENGES

- Sensor data is provided only at sparse spatial and temporal intervals
- Dispersion is a complex process with numerous uncertainties in modeling and meteorological conditions
- Neither empirical models nor physical models can represent the dispersion process well
- Logical to combine model prediction s with observations

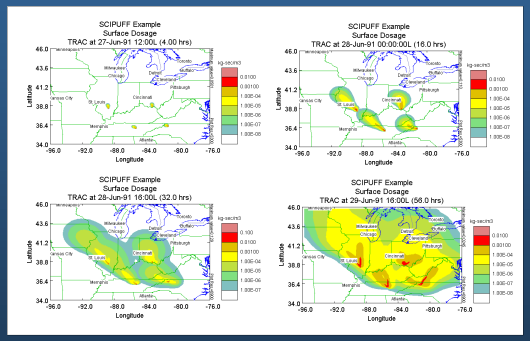


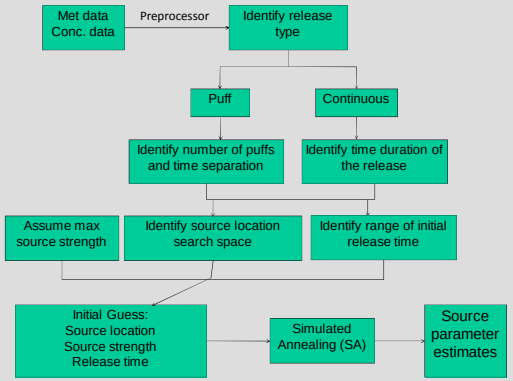
Figure 2: SCIPUFF model prediction field for a simultaneous Chemical release at four locations across the US

DISPERSION MODEL

- A forward dispersion model is used to simulate the chemical dispersion process for predicting the observations.
- SCIPUFF – Second-order Closure Integrated Puff model
  - Uses a collection of Gaussian puffs to represent an arbitrary three-dimensional concentration field.
  - The turbulent diffusion parameterization is based on second-order turbulence closure theory, which relates the dispersion rate to velocity fluctuation statistics.

STRATEGY

- Simulated annealing is used for the purpose of minimizing the error between predicted and observed concentrations.



ALGORITHM BASICS

- SCIPUFF v2.2 is used as the predictive model.
- Algorithms are run in a “batch-processing” mode.
- Source parameters are estimated by minimizing the cost: sum of the squared errors between model prediction and given concentration data at various sensor locations for all times.
- The optimization is performed assuming a maximum of 4 sources.
  - Number of sources is selected based on the Bayesian Information Criterion (BIC).

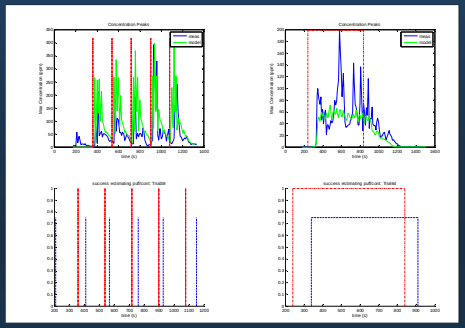


Figure 3: Identification of release type, time separation / duration of the releases

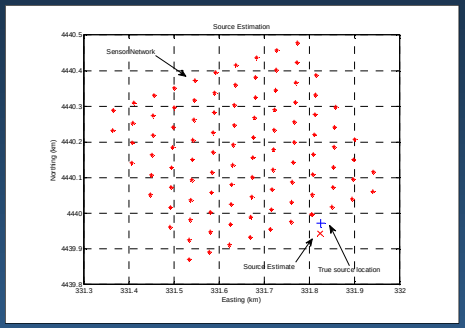


Figure 4: Estimation of source location

FUTURE WORK

- Incorporating the uncertainty information of the model and sensor data in the solution.
- Design a cost function such that the number of sources is optimized for directly.
- A sequential source estimation algorithm instead of a batch processing algorithm.