Assessing the Performance of Atmospheric Dispersion Models

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Types of Dispersion Model

- A wide range of dispersion models exist:

    – Gaussian plume/puff models;

    – Lagrangian particle models;

    – Computational fluid dynamics (CFD) models.

- These have different levels of fidelity.

Gaussian puff

CFD

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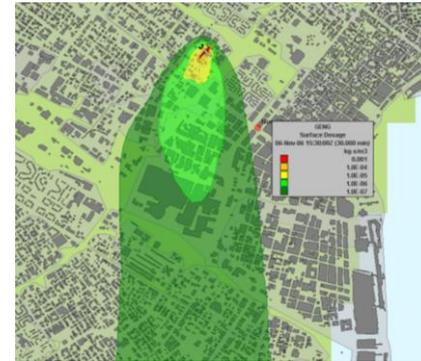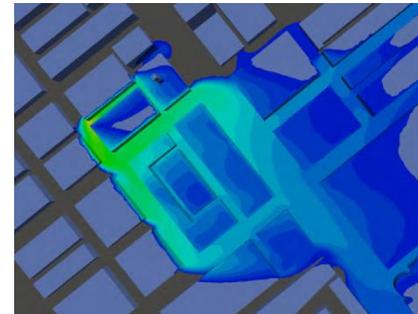
Model Performance Metrics

- Performance is difficult to quantify in a single metric;

- Many statistical measures are used e.g.:
  - Factor-of-two (FAC2);
  - Fractional bias (FB);
  - Normalised mean square error (NMSE);
  - Geometric variance (VG).
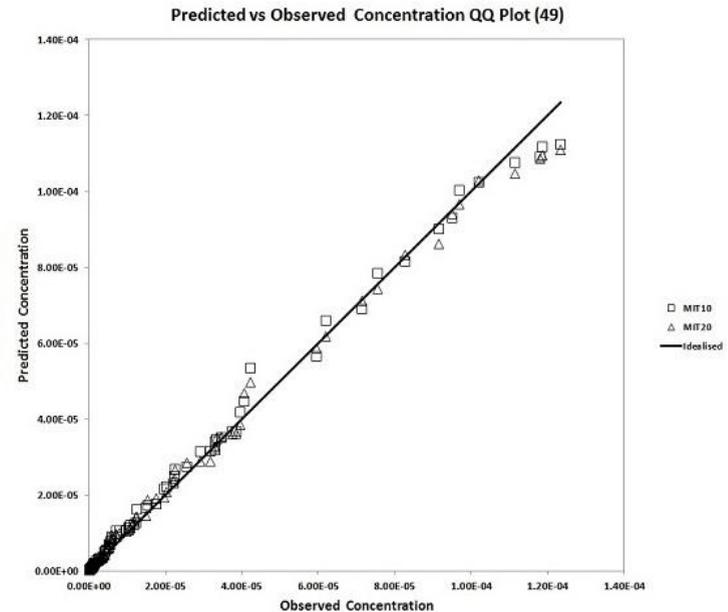
Quantile-quantile plot

Model Performance Metrics

- Criteria for a good model used by Hanna *et al.* are frequently cited[1];
- Different people prefer different measures[2]:

2-D Measure-of-Effectiveness

Observation (A_{OB})

False negative area (A_{FN})

Area of overlap (A_{OV})

False positive area (A_{FP})

Prediction (A_{PR})
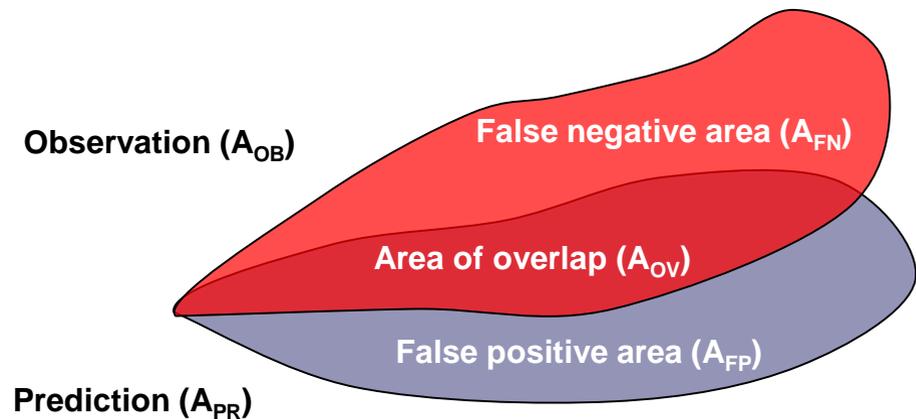
$$MOE = (x, y) = \left(\frac{A_{OV}}{A_{OB}}, \frac{A_{OV}}{A_{PR}} \right)$$

[1]Hanna, S.R., Hansen, O.R., Varam, S.D., FLACS CFD Air Quality Model Performance Evaluation with Kit Fox, MUST, Prairie Grass and EMU observations., Atmospheric Environment, 2004, **38**, 4675–4687.
[2] Warner, S., and N. Platt, J. F. Heagy, S. Bradley, G Bieberbach G. Sugiyama, J. S. Nasstrom, K.T. Foster, D. Larson User-Oriented Measures of Effectiveness for the Evaluation of Transport and Dispersion Models, Institute for Defense Analyses Alexandria, Virginia Paper P-3554, Jan 2001.

Validation Against Field Data

- Validation of models against field data is typically limited by the number of:

    – Concentration samplers deployed;

    – Sampling times;

    – Meteorological measurements made;

    – Meteorological conditions covered;

    – Experimental locations;

    – Releases made (small sample size).

Trial MADONA 1992 (FTR 127)

Project Prairie Grass

- Open prairie, 600 samplers on 5 arcs 50-800 m;

- Stable to unstable conditions;

- 70×10 minute releases.

Source location
Midget Impinger samplers at 1.5 m height
Midget Impinger samplers placed at heights of 0.5, 1, 1.5, 2, 2.5, 4.5, 7.5, 10.5, 13.5 and 17.5 m

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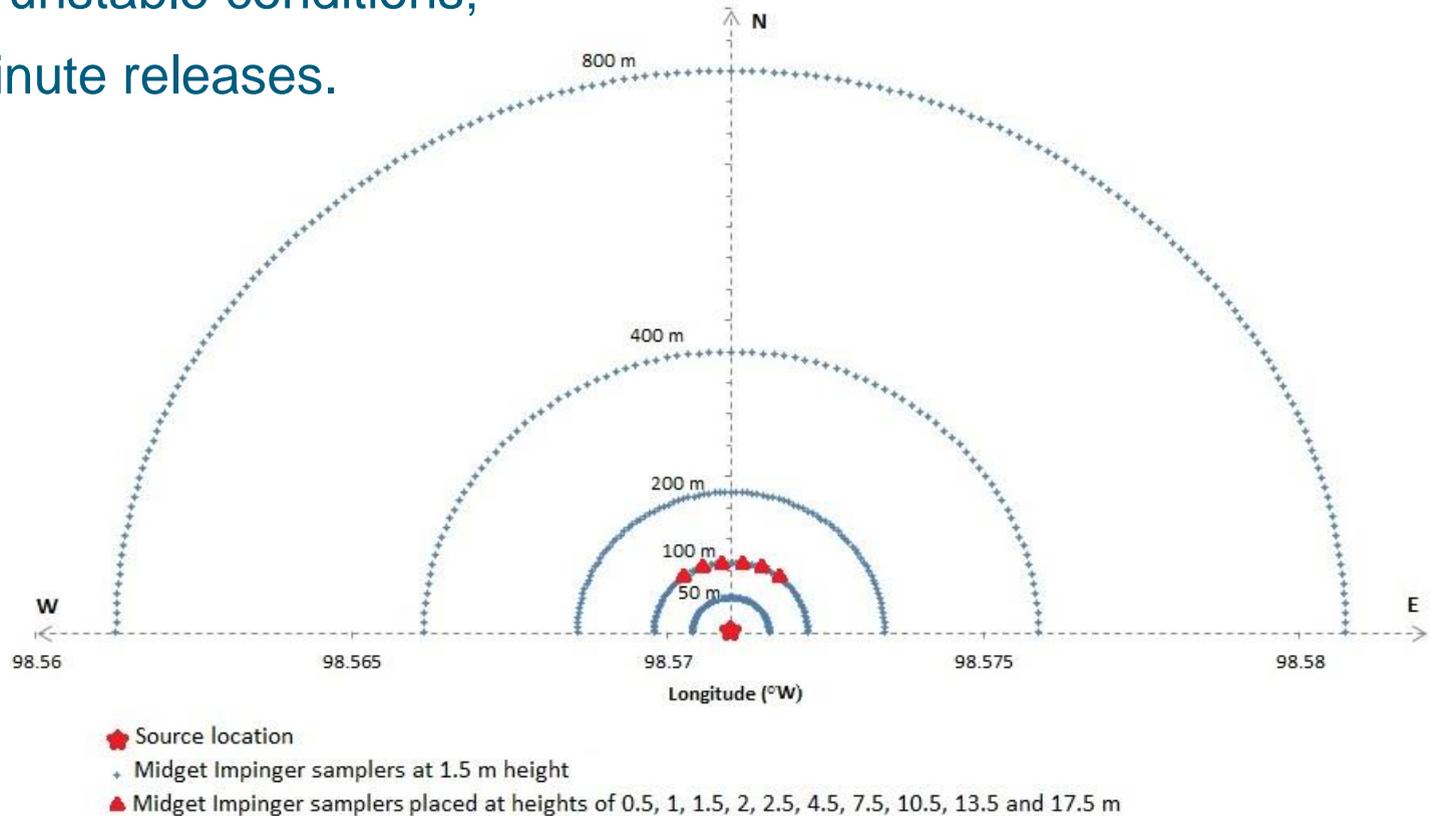
MUST Experiment

- 48×DPID[1] and 26×UVIC[2] samplers;
- 68 releases, 4-22 minutes.

CONEX containers

Instrument towers with UVICs

DPID samplers at 1.6 m

200 m

0° wind direction
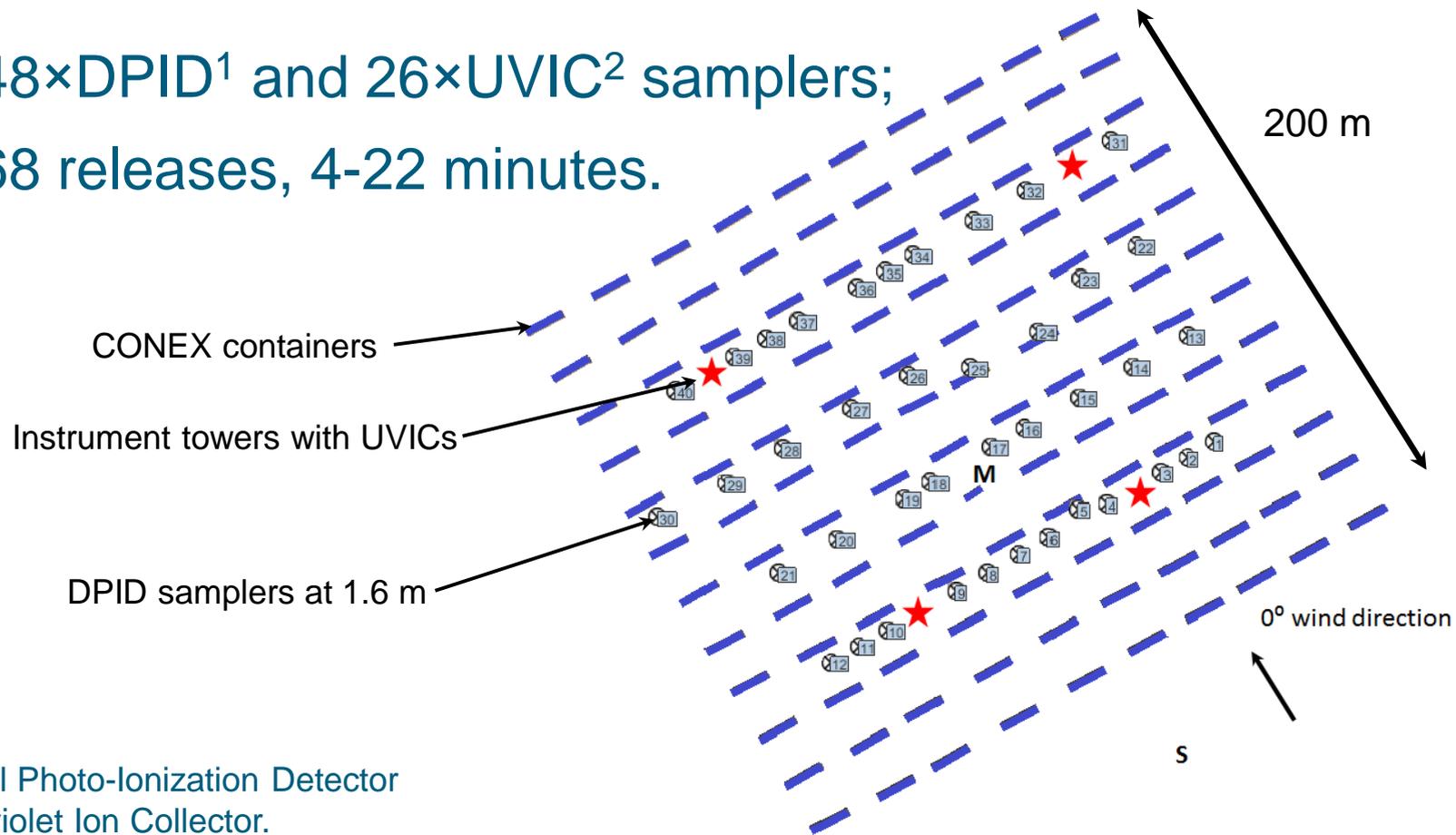
[1]Digital Photo-Ionization Detector
[2]Ultraviolet Ion Collector.

Joint Urban 2003

- Oklahoma City Central Business District (CBD);

- 130 samplers in CBD,1,2, and 4 km arcs;

- 30×30 minute continuous releases (also puff releases);

- Releases made during daytime and nighttime.

JU2003_SP1 IOP10 release 3 false negatives

False negatives indicate potential error in wind direction

Distance /m

Sampler locations
Samplers in analysis
False negatives
Partial false negative

Distance /m

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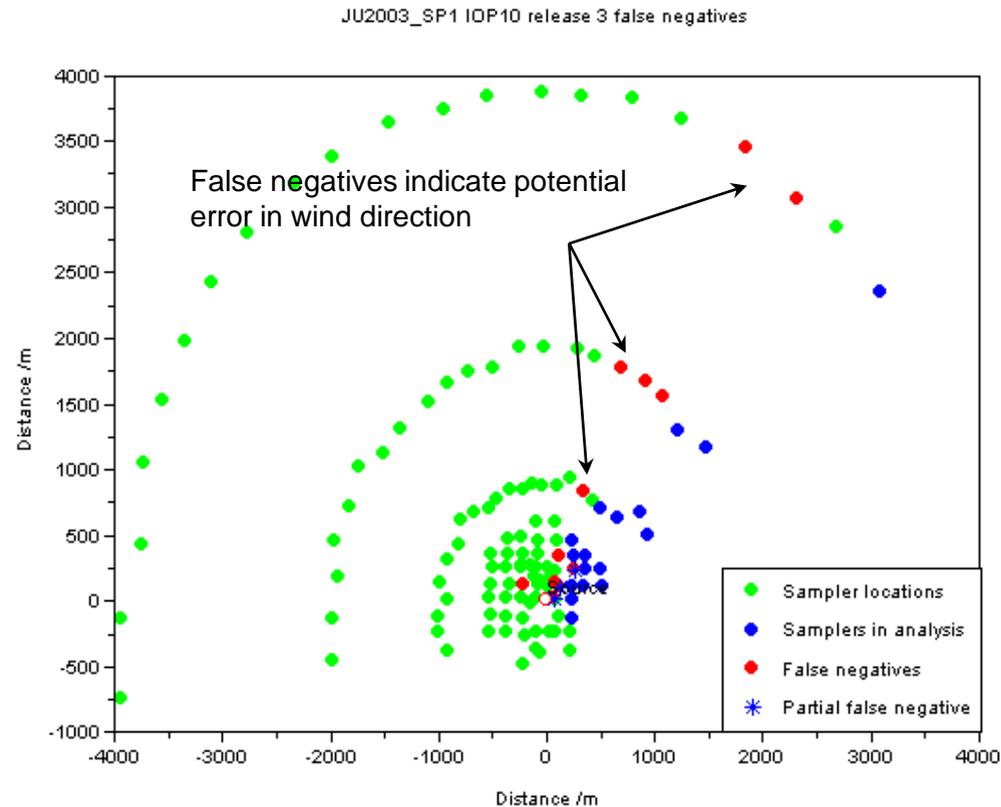
Wind Tunnels

- Constant conditions enable statistically representative data to be gathered;

- Limit turbulence scale;

- Generally limited to neutral stability conditions.
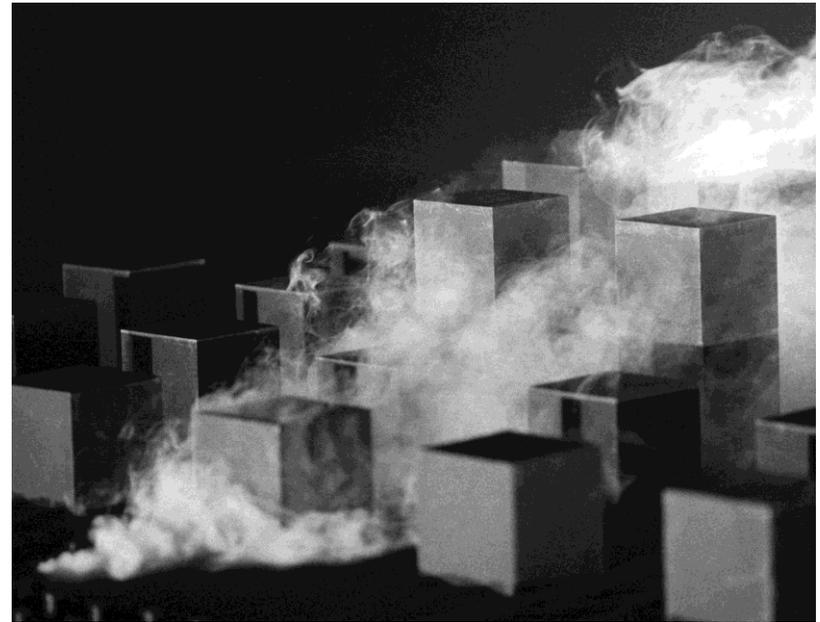
UDM wind tunnel experiments (Hall)

Performance Assessment

- Requires selection of performance metrics;

- Definition of data comparison process:

    – Determination of concentration threshold values;

    – Selection of concentration averaging time;

    – Selection of criterion for including data:

        • Accept all;

        • Both above threshold;

        • One above threshold.

Performance metrics decrease

Making Performance Transparent

- The diversity of metrics and processing choices makes comparison of performance difficult.

- May be tackled by having a standard reference model that is:

  – Founded on accepted theory;

  – Simple in formulation;

  – Applicable to a range of environments.

Proposed Reference Model

- Model of Francese and Huq (2011)[1] developed as a framework for the analysis of field data;

$$c = \frac{Q}{\pi U \sigma_y \sigma_z} \exp\left(-\frac{y^2}{2\sigma_y^2} - \frac{z^2}{2\sigma_z^2}\right)$$

- Assumes uniform wind profile and reflections;
- Horizontal spread from Taylor (1921);
- Vertical spread Hunt and Weber (1979).

Franzese P, and Huq P Urban dispersion modeling and experiments in daytime and nighttime atmosphere, Boundary Layer Meteorology **139,** 395-409.

Model Comparisons (Daytime)

- Non dimensional concentration vs non-dimensional distance;

- 4 urban experiments.
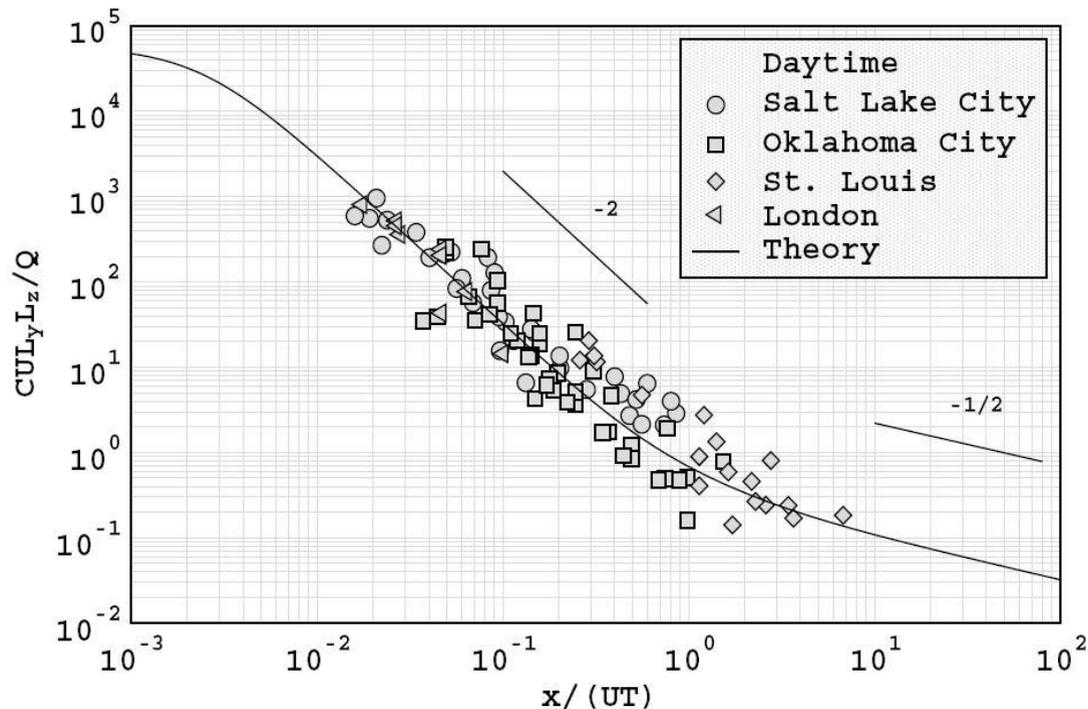
Model Comparisons (Nighttime)

- Non dimensional concentration vs non-dimensional distance;

- 3 urban experiments.
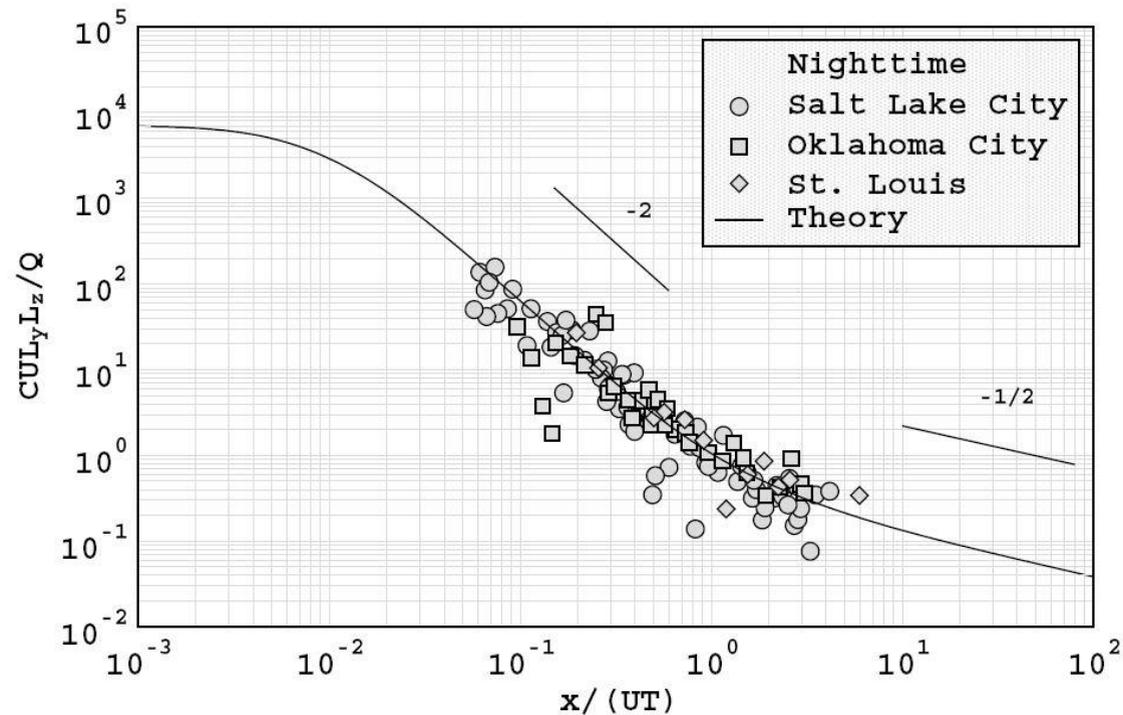
Planned Work

- Application of approach to assess relative performance of different models for a range of data sets, including DAPPLE and JU2003;

- Final specification of model for continuous releases;

- Expansion of reference model to handle short duration releases.

Conclusions

- There is inconsistency in the methods used to quantify the performance of dispersion models;

- Validation data is limited and typically small samples;

- Comparisons embody subjective decisions on inclusion/exclusion of data;

- A well-defined process and reference model are required to make performance transparent;

- The authors intend to develop a method based on the model of Francese and Huq (2011).

Questions?