COMPARISON OF RESULTS FROM THREE URBAN TRACER EXPERIMENTS

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INTRODUCTION

One of the first field studies to understand dispersion in urban areas was conducted in St. Louis, Missouri, during the period 1963-1965 (*McElroy, J.L. and F. Pooler*, 1968, Volumes I and II). Since then, several tracer studies have been conducted in the US and Europe (*Gryning, S. and E. Lyck*, 1984; *Rotach, M.W.* et al., 2004) that have expanded the available data bases on urban dispersion. In this paper, we examine three of these studies to understand how they complement each other in improving our ability to model urban dispersion. These studies are the St. Louis experiment, URBAN 2000 conducted in Salt Lake City (*Hanna, S.R.* et al., 2003) and the Barrio Logan study conducted in 2001 (*Venkatram, A.* et al., 2004a).

THE ST. LOUIS EXPERIMENT

The St. Louis study, conducted over the period 1963-1965, consisted of a series of 26 daytime and 16 evening experiments in which fluorescent zinc cadmium sulfide particles were released near ground level at two different locations. The release, which was typically 1 hour long, was sampled on arcs at 800 m to 16 km from the release point near the anticipated plume centerline using a total of 30 to 50 samplers. A meteorological network of three stations on the outer area of the sampling area and an instrumented television tower measured wind, temperature, and relative humidity.

The horizontal plume spreads in the St. Louis study were derived from observed surface concentration distributions, while the vertical plume spreads were inferred by matching concentration estimates from a Gaussian dispersion model to observed surface concentrations. Thus, the limiting effect of the mixed layer on vertical spread was not explicitly considered in the analysis. The observed plume spreads were fitted to analytical curves by *Briggs, G.A.* (1973). We will refer to these dispersion curves, which are now incorporated in EPA models such as ISC (*EPA*, 1995), as the Briggs Urban (BU) dispersion curves.

The performance of the models discussed in this paper is quantified using the statistics of the ratio C_p/C_o, where C_p is the model estimate, and C_o is the corresponding observation. The bias of the model estimate is described by the geometric mean, m_g, of the ratio. The deviation of model estimates from corresponding observations is quantified in terms of the geometric standard deviation, s_g, of the ratio C_p/C_o: If we assume that the observed concentrations are log-normally distributed about the model estimate, $m_g s_g^{\pm 1.96}$ provides an estimate of the 95% confidence interval of the ratio. We will denote the fraction of the observations within a factor of two of the model estimates by Fac2.

When the Briggs Urban dispersion curves are used to estimate concentrations in the St. Louis study, the m_g is 1.17, and r^2=0.67 for the daytime trials, and for the evening experiments, m_g=0.92, r^2=0.82. The 95% confidence interval is large, 0.15-9.1, during the day, and 0.23-3.7 during the evening trials.
The St. Louis experiment made limited measurements of turbulence. A TV tower located in downtown St. Louis was instrumented at three levels. At two of these levels, 39 m and 140

m, variations of the azimuth angle of the wind was recorded on strip charts. The standard deviation of horizontal wind direction fluctuations, σ_θ, was estimated from these analog records assuming that the distribution of azimuth angles was Gaussian.

These meteorological observations were used in the Gaussian formulation suggested by the Barrio Logan study to estimate ground-level concentrations (*Venkatram, A.* et al., 2004a). In the absence of turbulence measurements in the urban boundary layer, we assumed that the horizontal and vertical turbulence intensities that govern plume spread were one half the values of σ_θ measured at 39 m, which is close to the roughness sublayer height in St. Louis if we assume that the average building height is about 15 m.

Fig. 1 compares the model estimates of centerline ground-level concentrations with the corresponding observations. The results were obtained by assuming that the mixed layer height was 2500 m during the daytime and 150 m during the evening. The model performance statistics indicate an improvement when observed meteorology rather than the empirical BU dispersion curves are used to estimate concentrations. The improvement is seen primarily for the daytime experiments: the 95% confidence interval for C_p/C_o decreases from 0.15-9.1 to 0.28-3.3, and the r^2 improves from 0.67 to 0.78.

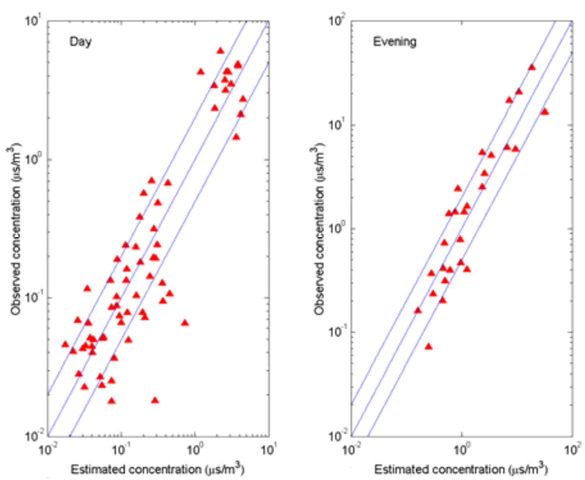

Fig. 1; Estimates of ground-level centerline concentrations using measured meteorology compared with observations from the St. Louis study.

BARRIO LOGAN FIELD STUDY

This study (*Venkatram, A.* et al., 2004a) was conducted in the summer of 2001 in Barrio Logan, a community of about 5,000 people located on the San Diego coastline. Five tracer release experiments were conducted from August 21st, 2001 to August 31st, 2001, in each of which SF_6 was released from a near ground-level point source over periods lasting from 7 to 10 hours. The field study resulted in 45 separate experimental hours. The tracer was sampled with bag samplers at ground-level on four arcs at 200, 500, 1000, and 2000 m. Meteorological measurements were made at three sites to provide information for dispersion modeling.

The results in Fig. 2 correspond to the BU dispersion curves. The initial plume spread was taken to be 50 m, and the meteorological inputs were derived from surface observations at the nearest airport. Model performance is not much worse than that corresponding to meteorological inputs derived from detailed mean and turbulence measurements made in the urban boundary layer. The r^2 decreases from 0.63 to 0.55 and the factor of two fraction decreases from 58% to 46%.

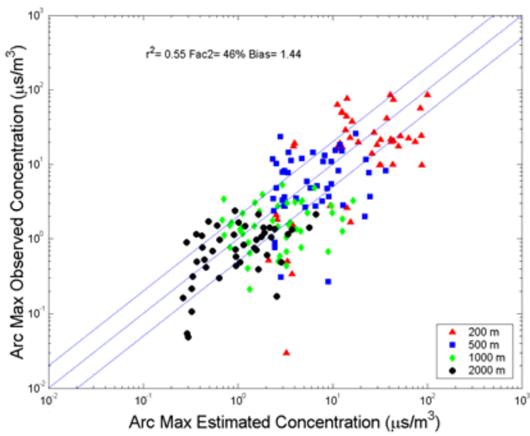

Fig. 2; Comparison of observed concentrations from the Barrio Logan experiment with estimates of ground-level centerline concentrations using Briggs Urban dispersion curves.

URBAN 2000

URBAN 2000 was conducted in Salt Lake City during September and October, 2000 (*Allwine, K.J.* et al., 2002). SF_6 was released during the night and sampled at distances ranging from 0.15 to 6 km from the release point. The study was conducted over 6 nights, resulting in 18 hours of data, which were analyzed by *Hanna, S.R.* et al. (2003). They found that using Briggs curves for neutral conditions in a simple Gaussian dispersion model produced estimates that compared well with observations: close to 72 % of the maximum observed observations on each arc were within a factor of two of the model estimates and the bias was 1.22. This implied that the urban boundary layer was close to neutral even during the night.

Here we compare model results based on the BU curves with those obtained using observed meteorology in a dispersion model developed in the Barrio Logan study (*Venkatram, A.* et al., 2004a). The meteorology was monitored at several sites both upwind and within SLC using sodars and sonic anemometers (*Allwine, K.J.* et al., 2002; *Hanna, S.R.* et al., 2003). In our analysis, we used data collected with sonic anemometers on top of a building at a height of 23 m. We assumed that the measured σ_θ at 23 m was representative of the roughness sublayer (*Rotach, M.W.*, 1999) because the height of measurement was close to the average building height of 15 m (*Hanna, S.R.* et al., 2003). We found that assuming that the σ_θ characterizing the urban boundary layer was 0.45 times the measured value provided the best fit between model estimates and concentration observations. The mixed layer height was taken to be 150

m. Fig. 3 shows the comparison of model estimates with maximum observed concentrations. The model performance statistics are r^2=0.83, m_g=1.05, and Fac2=66%.

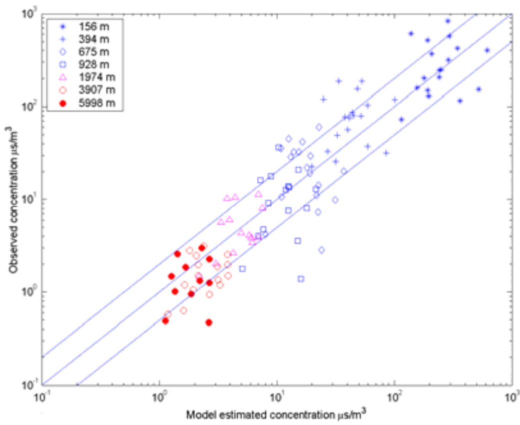

Fig. 3; Estimates of ground-level centerline concentrations using measured meteorology compared with observations from the URBAN 2000 study.

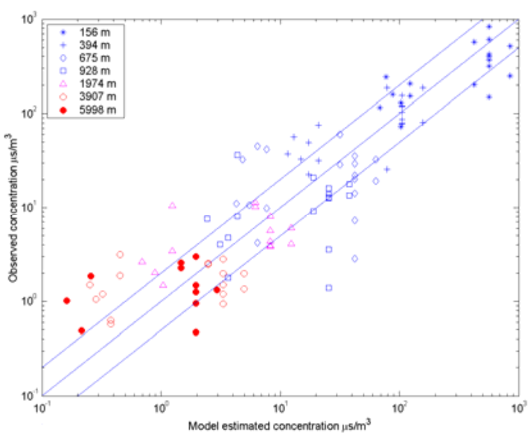

Fig. 4; Estimates of ground-level centerline concentrations using BU dispersion curves compared with observations from the URBAN 2000 study.

Fig. 4 shows a similar comparison when the BU dispersion curves based on meteorology from the Salt Lake City (SLC) airport are used to estimate concentrations. Model performance shows a slight deterioration compared with that based on meteorological inputs from the release site. The r^2=0.77, m_g=0.97, and Fac2=53 %. These statistics change to r^2=0.78, m_g=1.22, and Fac2=57 % and the underestimates at the furthest arcs disappear when the vertical plume spread is limited to 150 m.

CONCLUSIONS

The results presented in this paper indicate that a simple Gaussian dispersion model using available meteorological observations to estimate plume spread can provide adequate descriptions of concentration patterns observed in field studies conducted in St. Louis, Barrio Logan, and Salt Lake City. We also conclude that in the absence of onsite data, airport meteorological observations in combination with the BU curves (*Briggs, G. A.*, 1973) can provide first cut estimates of ground-level concentrations associated with surface releases in a variety of urban areas.

These conclusions apply only to source-receptor distances at which the vertical plume spread exceeds the average building height. Other models might be required when the plume is still embedded in the urban canopy (*Venkatram, A.* et al., 2004b).

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