Plume Dispersion from the MVP Field Experiment. Analysis of Surface Concentration and its Fluctuations

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Fires are often followed with air pollution transport and dispersion. Studies of air pollution concentration near the surface are important because human activities mainly involve the near surface layer. The concentration can be described as the mean value and its turbulent fluctuations. The latter is especially important when the pollutant is a highly toxic or flammable material, which has been observed to exhibit the same order of the mean value (Hanna and Insley, 1989). For dispersions from continuous source emissions, namely plume dispersions, there are two distinct types of concentration fluctuations: fluctuations within the plume and variations of the plume positions. These are supposed to be determined by turbulence eddies acting differently on the plume at different downwind distances.

Surface concentration and its fluctuations from plume dispersion under unstable conditions in a coastal environment are investigated using the Model Validation Program (MVP) field experimental data. The goal of this study is to better understand plume dispersion under such conditions. Procedures are described to derive the plume surface concentration from moving vehicle measurements. Convective boundary layer scalings are applied and cumulative density functions (CDF) are studied.

The results indicate that the relative concentration fluctuation intensity ($\sigma_c/C(y)$) decreases with the normalized downwind distance (X) and that it is relatively small at the plume central line and largely increased at the plume edges, consistent with other field and laboratory results. The relation between $\sigma_c/C(y)$ at the plume centerline (σ_c/C) and X for elevated sources can be described by $\sigma_c/C = a + b/X$ (Figure 1). The crosswind plume spread (σ_y) is found to satisfy Deardorff and Willis's (1975) form of $\sigma_y/h = a_1 X/(1 + a_2 X)^{1/2}$ scaled with convective layer depth h. For elevated sources, the normalized crosswind integrated concentration (C^y) is found to satisfy a relation of $C^y = 16X^{-3/2}$, with Yaglom's (1972) scaling rule on the free convective layer being applied (Figure 2).

Empirical CDFs based on the gamma and the clipped probability density functions show agreements with the experimental CDFs, with the former being better than the latter when $(c - C)/\sigma_c > 0.5$. A new clipped-gamma CDF form is proposed based on the analysis of the present data, showing a better agreement (Figure 3).

We suggest that a parameter $u_0^*(12-0.5h/L)^{1/3}$, with combined efforts of surface friction velocity (u_0^*), Monin-Obukhov stability length (L) and unstable boundary layer height (h), replace the convective velocity scale (w^*) under weak convective conditions in a coastal environment.

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Biography

Among the CAMP program, Dr. Yimin Ma works in research fields of air pollution dispersion and mesoscale numerical modeling. The Comprehensive Atmospheric Modeling Program (CAMP) is one of several research programs within the School of Computational Sciences at George Mason University that was initiated in 1997. CAMP is an atmospheric modeling group offering a competitive research environment and advanced degrees in the area of atmospheric modeling from local scale (urban) to regional (mesoscale) scales and estimation of transport and dispersion from a wide variety of source scenarios.

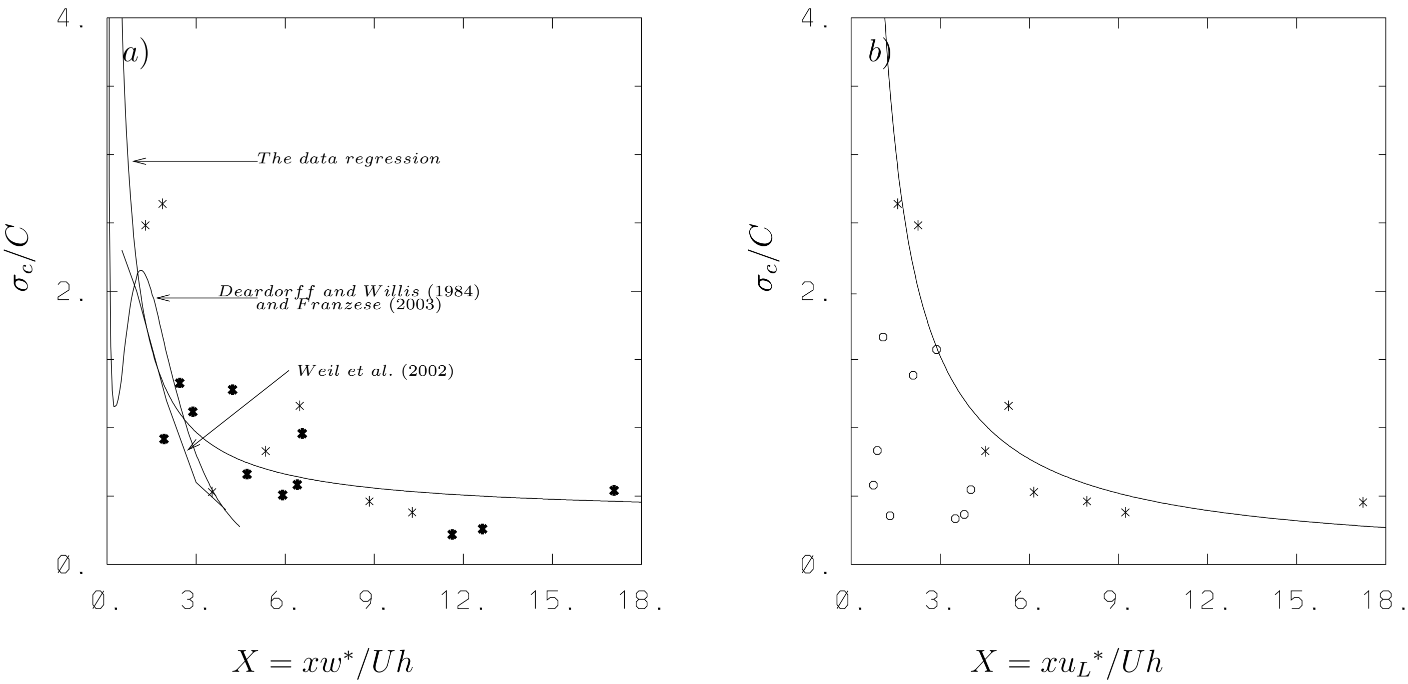

Figure 1: Concentration fluctuation intensity at the plume centerline versus the normalized downwind distance for the strong convective condition (a) and the weak convective condition (b), where $u_L = u_0^*(12 - 0.5h/L)^{1/3}$ is defined. The curves in (a) represent the modeling results from Franzese (2003), water tank results from Deardorff and Willis (1984) and Weil et al. (2002). Also the regressions with equation $\sigma_c/C = a + b/X$ for the elevated release are indicated as curves. "o" refers to near surface release while "*" refers to elevated sources. In (a), the values from the weak convective condition are also shown while the strong convection values are indicated with bold font.

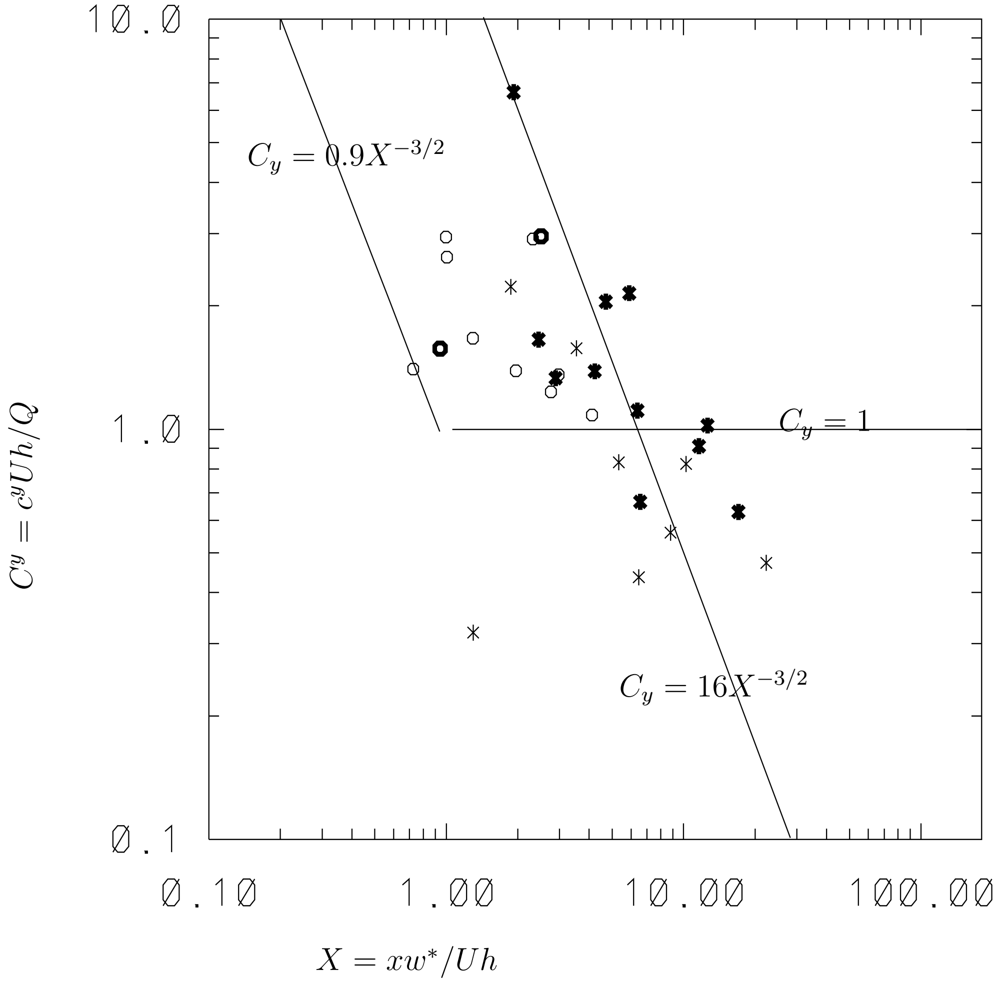

Figure 2: Normalized near surface CWIC versus the dimensionless downwind distance with convective scaling. Straight lines represent $C_y = 0.9X^{-3/2}$ when $X < 1$ and $C_y = 1$ when $X > 1$ for the surface release, and $C_y = 16X^{-3/2}$ for the elevated releases. "o" refers the surface releases and "*" the elevated releases. Highlighted symbols refer to the data from the strong convection and the normal ones refer to the data from the weak convection.

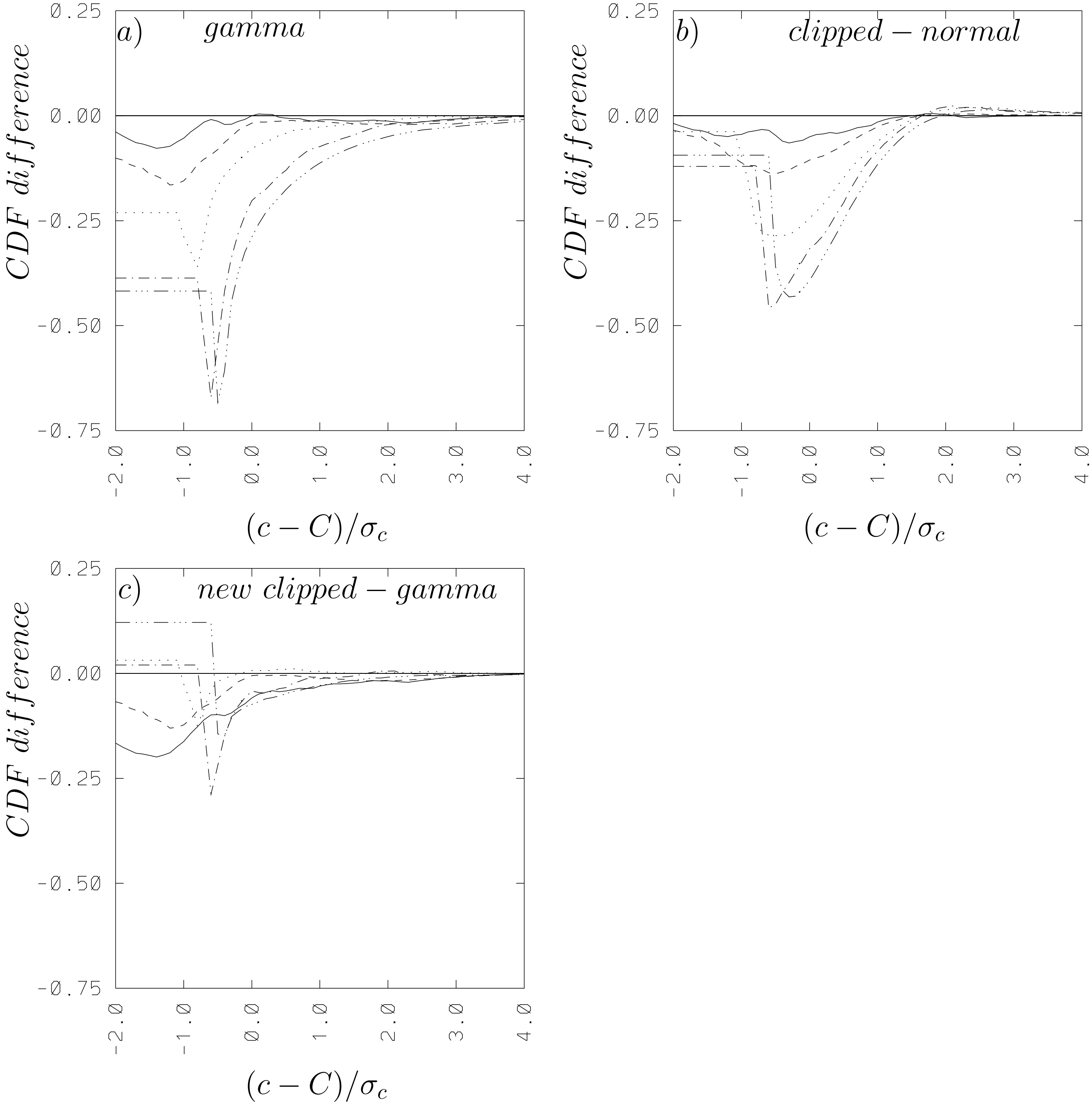

Figure 3: The differences of the CDFs between the gamma form and the observed (a), between the clipped-normal forms and the observed (b), and between the new clipped gamma form and the observed (c), sorted with various ranges of σ_c/C. The curves with solid, dashed, dotted, dash-dot and dash-dots forms correspond to the ranges of 0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0, 2.0-2.5, respectively.