Self-similarity of moments of concentration fluctuations in a plume

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Experimental evidence shows that a half-Gaussian or exponential equation can describe the wall-normal mean concentration profile of a ground-level source[1,2]. The profile is Gaussian further from the wall for an elevated source and becomes a reflected-Gaussian downstream due to the wall effect. As the plume grows, the profile slowly evolves to one resembling that of a ground-level source. While this evolution also applies to the vertical profile of concentration variance, no research has reported the self-similarity of higher moments. In this study, we performed experiments in the Boundary Layer Wind Tunnel of the School of Civil Engineering at the University of Sydney, where gas mixtures of three densities were released into a turbulent boundary layer ($Re_\tau \approx 1780$) at two heights. The downstream concentrations were measured at three streamwise distances, δ, 2δ, and 4δ, where δ is the boundary layer thickness. We found that normalised skewness and kurtosis profiles of concentration, Sk_c and Ku_c, are also self-similar inside the plume. The profiles of elevated sources collapse onto one single curve upon normalisation. Although the ground-level source exhibits a collapse, it differs from the elevated sources, as shown in figure 1. The normalising method is similar to that for the mean and variance. The vertical axis is ξ, the relative distance normalised from the plume centreline, whereas Sk and Ku are normalised by the respective magnitudes at the centreline, Sk_{c_0} and Ku_{c_0}. The self-similarity of the first four moments suggests self-similarity of the probability density functions for concentration. In the full paper, we will present the evolution of Sk and Ku in more detail and the scaling of probability density functions.

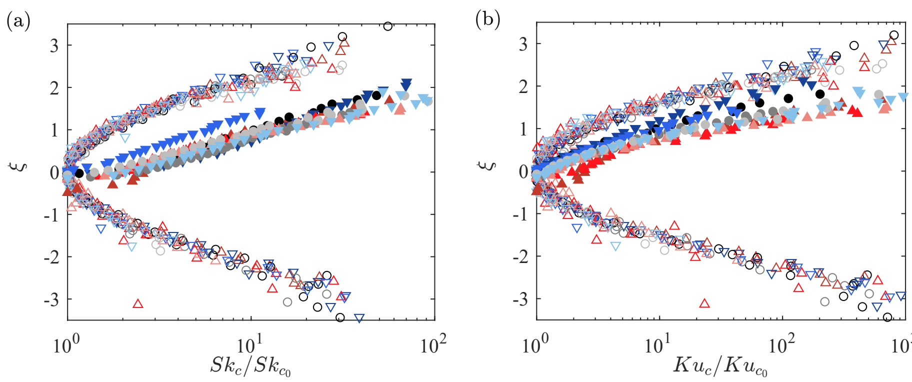

Figure 1: (a) Skewness. (b) Kurtosis. Legend: all filled symbols: ground-level source; all hollow symbols: elevated source; Red: light plume; black/grey: neutral plume; blue: heavy plume.

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[1] Fackrell and Robins, *J. Fluid Mech.* **117**, 1 (1982).

[2] Nironi et al., *Boundary-Layer Met* **156**, 415 (2015).