VARIATION IN THE PROBABILITY DISTRIBUTION FUNCTION OF PASSIVE CONTAMINANT CONCENTRATION

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Dispersion of a passive tracer in an atmospheric turbulent boundary layer is very complicated stochastic process. Time series of pollutant concentration measured at different positions can vary a lot due to this fact. Concentration characteristics can be very intermittent in some part of flow field even if the process in general is stationary. Long averaging time is required for obtaining statistically credible mean value of concentration.

The scope of this study is to find general description of probability distribution functions (PDFs), which describe temporal variation of passive contaminant concentrations released from ground level point source within the urban atmospheric boundary layer.

Contrary to previous works of Hanna (1984) or Yee (1991) where exponential and clipped-normal distribution were used, we found the Weibull distribution (Fig.1) to be most suitable form for those PDFs. The Weibull distribution is a continuous probability distribution often used in the field of life data analysis due to its flexibility. It can imitate the behavior of other statistical distributions such as Normal and Exponential. The PDF can be written as

$$f(x,a,b) = \frac{a}{b}\left(\frac{x}{a}\right)^{b-1} e^{-\left(\frac{x}{a}\right)^{b}},$$

where a is scale parameter and b is shape parameter.

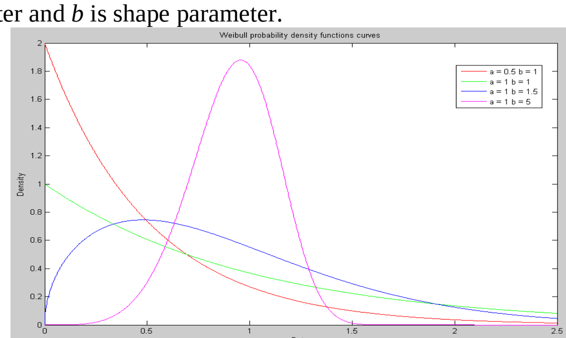

Figure 1: Different shapes of Weibull distribution.

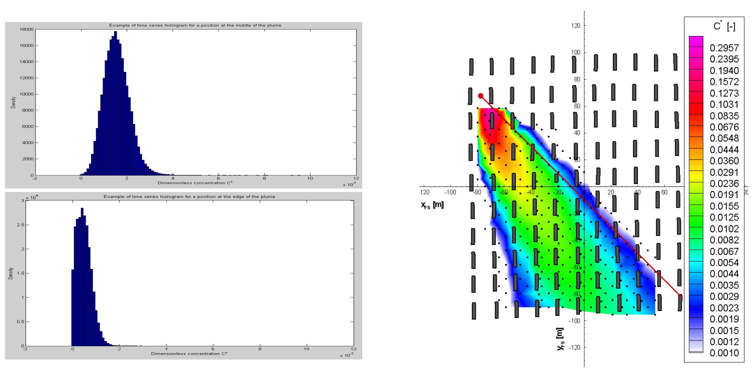

Figure 2: Examples of dimensionless concentration histograms (plume centre upper left, plume edge lower left) and mean concentration distribution at half building height within the MUST set-up.

This distribution is able to capture both distinctive types of concentration PDF's behaviour: an asymmetric exponential type with majority of very low concentrations and rapid decrease for higher concentrations observed at the edge of the plume as well as near symmetric log-normal concentration PDFs observed near the plume centreline (Fig.2).

The MUST wind tunnel experiment (Bezpalcova, 2006) was chosen as an example of highly temporal resolve concentration data set. The tracer gas was released from the ground level point source and the concentration was measured at half building height through the building array. The concentration time series were analysed with attempt to find dependence of shape and scale parameters of Weibull's PDF on position. The spatial distribution of PDF's parameters is shown in Fig.3. There is no obvious link between scale parameter values (Fig.3, left figure) and localization except in the middle of the plume where the distance from the source makes scale parameter values decrease. On the other hand, each position, which shape parameter value of the Weibull PDF is higher than 1, belongs to the middle of the plume (Fig.3, right figure) and its PDF is very close to the normal PDF.

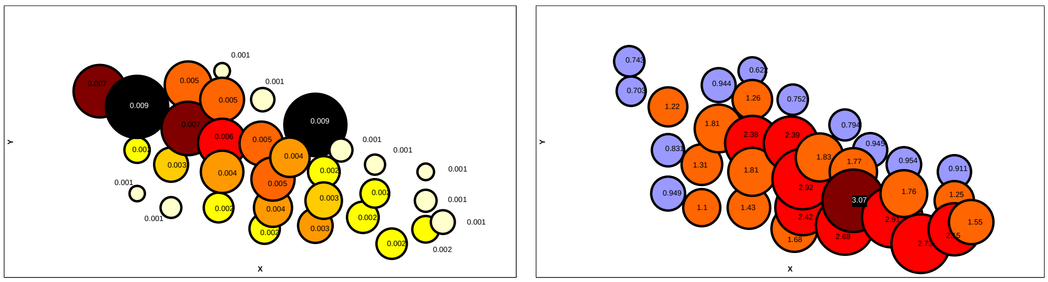

Figure 3: Spacial distribution of scale (left) and shape (right) parameters within the plume.

We tried to express two parameters of Weibull PDF as a function of gross time series parameters such mean and standard deviation values of the concentration time series. While the scale parameter has no dependency on concentration fluctuation intensity $\sigma C^*/C^*$, the shape parameter can be for every point with the plume calculated as

$$b = 1.2\left(\frac{\sigma C^*}{C^*}\right)^{-0.83}$$

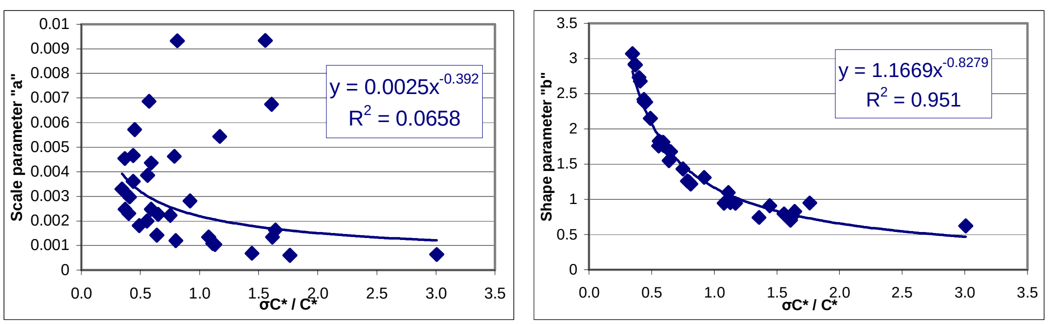

Figure 4: Dependency of Weibull distribution parameters on intensity of concentration fluctuation.

Acknowledgement

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