EMS7/ECAM8 Abstracts,
Vol. 4, EMS2007-A-00404, 2007
7th EMS Annual Meeting / 8th ECAM

High concentrations of pollutant in short-range dispersion

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In problems involving the dispersion of hazardous gases in the atmosphere, the distribution of high concentrations is often of particular interest. We address the modelling of the distribution of high concentrations of a dispersing pollutant at large Péclet number, concentrating on the case of steady releases. We argue, from the physical character of the small scale processes, and from the statistical theory of extreme values, that the high concentrations can be fitted well by a generalised Pareto distribution (GPD). This is supported by evidence from a range of experiments. We show, furthermore, that if this is the case then the ratios of successive high order absolute moments of the concentration are linearly related to the reciprocal of the order. The linear fit thus obtained allows the GPD parameters to be determined from the moments. In this way the moments can be used to deduce the properties of the high concentrations, in particular the maximum possible concentration $\theta_{\max}$. We argue, on general physical grounds, that $\theta_{\max}/C_0$ (where C_0 is the centreline mean concentration) decreases to zero very far from the centreline, but that the decrease takes place on a length scale much larger than the plume width (because it is controlled by the relatively slowly acting molecular diffusion, rather than the fast turbulent advection). Thus, over the distances for which accurate measurements can be made, we expect $\theta_{\max}/C_0$ to be approximately constant throughout the plume cross-section. On the centreline, we argue that $\theta_{\max}/C_0$ increases downstream from the source, reaches a maximum and then decreases, ultimately tending to 1 far downstream. In support of these deductions we present results for some high quality data for a steady line source in wind tunnel grid turbulence. Finally, we apply to this problem some existing models for the relationships between moments. This allows us to derive an expression for $\theta_{\max}/C_0$ which depends on a total of 5 parameters, and (weakly) on C/C_0 (where C is the local mean concentration). Comparison with the data is encouraging. We also discuss possible methods for modelling the spatial variation of these 5 parameters.