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Concentration fluctuations and mean time of exceeding of hazard thresholds on industrial sites

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Knowledge on both the mean field and fluctuations of concentration is necessary to estimate risks linked to pollutant exposure on industrial sites. While time-averaged concentrations provide meaningful information for chronic risk exposure, local exceedance of high concentration values potentially trigger chemical reactions or exceed harmful limits for living organisms. Information on threshold exceeding is thus a key parameter for toxicity assessment and accident management, hence the focus of this work on concentration fluctuations.

Several models for the probability distribution functions (PDF) of pollutant concentrations have been proposed in the literature. Several authors agree on the fact that the gamma distribution provides a reliable model for the one-point concentration PDF in case of localised releases of pollutants in atmospheric boundary layers (Cassiani et al., 2020). However, the accuracy of the gamma distribution was still not properly investigated within domain characterised by a complex geometry.

This is indeed the aim of this experimental study, focusing on the one-point concentration PDF due to a localised release of pollutant within a group of buildings. Furthermore, we aim at verifying models predicting average times of exceeding concentration thresholds (e.g. Bertagni et al., 2020).

Wind and concentration fields were characterised on the small-scale model of an idealised industrial site in a wind tunnel reproducing the atmospheric boundary layer. Higher order statistics were computed from concentration time series collected with a fast flame ionisation detector of frequency 400 Hz. In addition to the work presented hereby, this experimental dataset could be used to validate numerical dispersion models in future studies.

Best agreement between the experimental one-point concentration PDF and the gamma distribution are observed in the mid- and far-field. In contrast, the gamma distribution induces a systematic underestimation of concentration fluctuations in the near-field. Notably the Gamma

distribution does not capture the occurrence of high intensity peaks measured sporadically, especially in recirculating regions in building wakes.

Mean threshold exceeding times are computed assuming a gamma distribution and hence show best correlation with experimental data in the mid- and far-field. Frequency of threshold exceeding show less accurate results for higher limits.

Summarising, the gamma distribution is shown to be a reliable model for the one-point concentration PDF in the mid- and far-field, but exhibits poor correlation in the near-field due to the presence of recirculation zones and intense meandering motion of the pollutant plume. The model for mean times of threshold exceeding, relying on the assumption of a gamma distribution, show a similar behaviour.

References

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