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AVERAGING TIME CORRECTIONS FOR ESTIMATING EXTREME AIR QUALITY STATISTICS

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ABSTRACT

Available literature yields a variety of estimation techniques and parameterisations for estimating short-term or long-term exposure from, say, extreme value statistics for measured or predicted hourly ground-level concentrations of key air quality indicators close to a given set of emission sources. The simplest case with concentration ratios depending on a power law of the ratio of time periods is an expected form for a wide range of distributions for low probability events. Power-law dependencies are very useful as long as proper consideration is given to source structure, terrain characteristics between source and receptor, pollutant nature, timescales and overlap between adjacent sources. Experimental information for a given source and downwind distance suggests 2-3 regimes of behaviour with differing values of power law exponent p. The influence of source structure is now well-documented. Tall stack sources are relatively well parameterised with $p \approx 0.4$ holding for time periods from 1-2 minutes to many hours. For surface non-point sources, values of $p \approx 0.1 - 0.2$ are supported by field, laboratory and theoretical considerations.

Recent field results for an elevated buoyant source show a dependence of peak-to-mean ratios (and hence p) on stability, exceedance probability and averaging time. We suggest practical approximations for determining peak-to-mean ratios for averaging times from 1 second to several hours that reflect source structure adequately.

An approach based on universal multifractals suggests a powerful relationship between p and the tail index of an extreme-value probability distribution. The power law exponent is naturally linked to the degree of intermittency, threshold crossing, resolution time and long memory parameter of a given time series. This framework produces consistent results for available wind tunnel information and an indicator of the type of probability distribution for a given source structure and downwind distance.

Keywords: Averaging time correction, peak-to-mean ratio, odour prediction, intermittency, probability density multiple scaling.

1. Introduction

Whilst much effort has been devoted to validating and extending deterministic models for the estimation of hourly concentration statistics at receptors around a given emission source distribution, relatively little attention has been given to using this information for estimating extreme statistics non-hourly averaging times. Air pollution time series can be generally characterised as possessing a strong tendency to revert to the mean, significant intermittency and serial dependence. These properties can be shown to be well quantified by the non-stationarity parameter d (related to the spectral exponent β and Hausdorff dimension H of the stationary equivalent of the time series), the intermittency parameter C_1 and the Levy stable index α (that determines the type of probability distribution for the extreme statistics). Figures 1(a) and 1(b) compare wind tunnel results for ground-level concentrations 1000 m downwind of surface area and elevated point sources in neutral atmospheric conditions. For the area source, the concentration record often exceeds one standard deviation above the mean but major excursions are infrequent. The time series has a strong long-memory ($d = 0.78$, $H = 0.28$, $\beta = 0.39$), low intermittency ($C_1 = 0.08$) and $\alpha = 1.04$ is indicative of a log-Cauchy probability distribution. For the 127 m high stack source, the concentration record is characterised by an irregular succession of high peaks and periods of low concentrations. The corresponding long-memory is small ($d = 0.28$), the intermittency high ($C_1 = 0.13$) and $\alpha = 1.75$ is indicative of a log-normal probability distribution. Depending on the time resolution used and