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Correlation of gravestone decay and air quality 1960–2010

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HIGHLIGHTS

- Gravestone decay provides a quantitative measure of acid flux.
- Land use strongly correlated with spatial variability in gravestone decay.
- Pronounced increase in deposition efficiency of sulfur dioxide (SO_2) after about 1980.

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ABSTRACT

Evaluation of spatial and temporal variability in surface recession of lead-lettered Carrara marble gravestones provides a quantitative measure of acid flux to the stone surfaces and is closely related to local land use and air quality. Correlation of stone decay, land use, and air quality for the period after 1960 when reliable estimates of atmospheric pollution are available is evaluated. Gravestone decay and SO_2 measurements are interpolated spatially using deterministic and geostatistical techniques. A general lack of spatial correlation was identified and therefore a land-use-based technique for correlation of stone decay and air quality is employed. Decadally averaged stone decay is highly correlated with land use averaged spatially over an optimum radius of ≈ 7 km even though air quality, determined by records from the UK monitoring network, is not highly correlated with gravestone decay. The relationships among stone decay, air-quality, and land use is complicated by the relatively low spatial density of both gravestone decay and air quality data and the fact that air quality data is available only as annual averages and therefore seasonal dependence cannot be evaluated. However, acid deposition calculated from gravestone decay suggests that the deposition efficiency of SO_2 has increased appreciably since 1980 indicating an increase in the SO_2 oxidation process possibly related to reactions with ammonia.

1. Introduction

From the onset of the Industrial Revolution until the environmental revolution of the 1970s Britain was plagued by air pollution from industrial, urban, and residential sources (Sale and Foner, 1993; McCormick, 2013). The largest contributors to air pollution were particulate matter (smoke) and acid in the form of oxides of nitrogen (NO_x) and sulfur (SO_x) compounds, particularly sulfur dioxide (SO_2). (Marsh, 1978; Bricker and Rice, 1993). As early as the 1840s there were efforts to measure air pollution in British cities (Mosley, 2009) and Smith (1876) determined that the burning of coal was the principle source of "acid rain." It was not until about 1960 that the network was greatly expanded with the establishment of the National Survey, which measured daily smoke and sulfur concentrations at over 500 locations (Mosley, 2009). Prior to 1960, air quality measurements were limited in spatial and temporal coverage and often described anecdotally, particularly during severe air quality events. Proxy records have been used to reconstruct air quality; these records include physical descriptions (Allen, 1966, 1994; Auliciems and Burton, 1973; Fenger, 2009), particulates in lung tissue samples (Hunt et al. 2003) and sediment cores (Kelly and Thornton, 1996), and lake acidification studies (Battarbee and Renberg, 1990; Battarbee et al., 1990). Air quality measurements are of great interest in studies of ambient

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