Using machine learning to magnetically fingerprint particulate matter

Adrian Muxworthy (ESE), David Green (Public Health) &Wyn Williams (University of Edinburgh)

Background

High-levels of urban particulate pollution are known to affect human health. European legislature states that the levels of particulate matter, so called PM_{10} (particles < 10 µm in size), should not exceed 50 µg/m^3 on more than 35 days per year in a given city – unless their origin can be shown to be natural, e.g., volcanic ash. To try to meet these European requirements and to minimize high-levels of PM_{10}, it is important to understand the origin of PM_{10}, its spatial distribution and transport mechanisms. However, current provenence analysis of PM_{10} data, that is, determining the origin or source of the PM_{10} is limited.

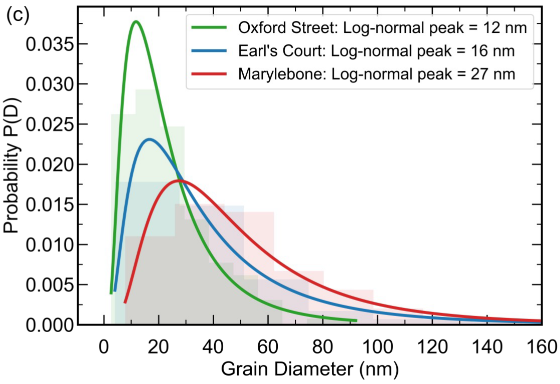

Figure 1. Characterization of grain-size distributions of particulate matter (mostly iron oxides) from various localities in London. From Muxworthy et al. (2022).

This PhD addresses this challege by taking advantage of two recent break-throughs, the first in knowledge, the second in method development. First, Muxworthy et al. (2022) showed that much of the grain-size distribution in urban PM_{10} from London is < 50 nm; most previous studies did not apply methods capable of quantifying this fraction of the grain-szie distribution, meaning that its contribution was (and still is) poorly understood (Fig. 1). Why does this fraction of the grain-size distribution matter? The finest particles are both suspended in the air the longest and have the highest sufrace to volume ratio, which increases their toxicity. There is an urgest need to better quantify this fraction. Second, Pei et al. (2025) developed a machine-learning based method – FORCINN – of inverting for inverting a type of magnetic-hysteresis measurement called first-order reversal curve (FORC) measurement for grain-size distribution (Fig. 2). FORCINN is the first inversion method for this type of magnetic hysteresis data, and is particularly senstive to grains < 300 nm in size, as magnetic particles display strong variations in magnetic behaviour over this grain-size fraction. Pei et al. (2025) tested this method of volcanic rocks (Fig. 2), however, there is no reason why this method cannot be applied to other magnetic systems natural or not.

The PhD project will extend FORCINN to include a greater range of naturally occuring magnetic minerals and their morphologies, and apply the updated version of FORCINN to particulate matter samples from London; the samples are collected by the School of Public Health at Imperial (www.londonair.org.uk). The aim of the study is to develop a full provenence model for these samples.

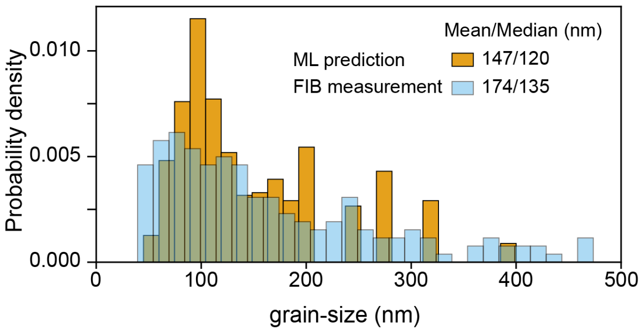

Figure 4. Predicted (ML) and measured (FIB) grain-size distribution for a basalt sample from Vesuvius (Pei et al., 2025). The ML prediction was determined using bulk-sample FORC data.

Student Profile: This project is a combined machine-learning and laboratory project and would suit a candidate with an interest in environmental science. Candidates should have a good degree in any area of science, plus strong numerical skills and an interest in machine-learning approaches.

References

Muxworthy, A.R., Lam, C., Green, D., Cowan, A., Maher, B.A. & Gonet, T., 2022. Magnetic characterisation of London's airborne nanoparticulate matter, Atmos. Environ., 287, 119292, doi:j.atmosenv.2022.119292.

Pei, Z., Williams, W., Nagy, L., Paterson, G.A., Moreno, R., Muxworthy, A.R. & Chang, L, 2025. FORCINN: First-Order Reversal Curve Inversion of Magnetite Using Neural Networks, Geophys. Res. Lett., 52, e2024GL112769, doi:10.1029/2024GL112769.

Please do not hesitate to contact me for further information and informal enquiries:
adrian.muxworthy@imperial.ac.uk