ÉCOLE DOCTORALE
SCIENCES DE LA TERRE ET DE L'ENVIRONNEMENT
ET PHYSIQUE DE L'UNIVERS, PARIS

ed560.stepup@u-paris.fr

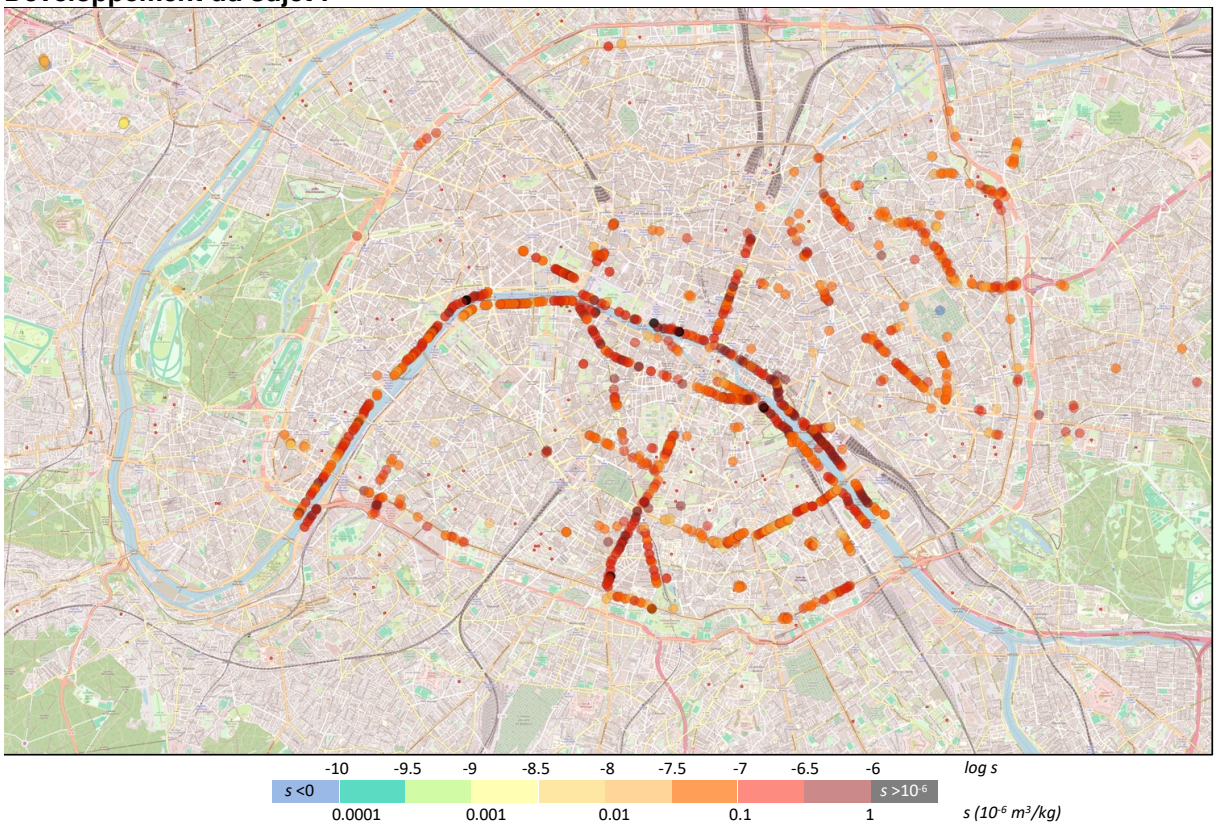
Titre du sujet : Identification of Sources of Anthropogenic Metallic Nanoparticles in Urban Areas: Geochemical and Magnetic Approaches

Directeur (trice) :
Yann Sivry (MCF), sivry@ipgp.fr
Co-encadrant(es) : **A**ude Isambert (MCF), isambert@ipgp.fr
Claire Carvallo (MCF, Sorbonne University), claire.carvallo@sorbonne-universite.fr

Equipe d'accueil : **IPGP- Equipes PAMCE et ACE– UMR7154**

Financement : **Contrat doctoral avec ou sans mission d'enseignement**

Développement du sujet :



Background

Fine or ultrafine particles (UFPs, or PM0.1 for 'particulate matter' when <0.1 µm) of human origin have deleterious effects on health, as well as on the quality of the environment and ecosystems. In urban environments, these nano-objects are emitted by a variety of sources, including those related to road traffic. These PUFs can be rich in metallic elements including iron, and therefore highly magnetic. This major source of pollution must be combined with the potentially more localized impacts of other human activities depending on the local context. Currently, fine particle monitoring is carried out by air quality measuring stations, 15 of which are located in Paris, and only a fraction of them also allow the counting of ultrafine

particles. The Ecorc'Air citizen science project, set up in 2021 and led by scientists from IPGP, Mines-PSL, and SU, was developed to improve this monitoring. This project uses plane tree bark as passive pollution sensors. This ubiquitous tree in the city, renewing its bark every year at the end of winter, allows for a large number of sampling points. Magnetic analysis methods have proven to be an effective means of tracing heavy metal pollution and are also perfectly suited to characterizing and quantifying the most harmful fine and ultrafine particles (< 100 nm). A map of magnetic susceptibility measurements in bark, used as a proxy for fine metal particle concentration, can thus be produced annually by increasing the spatial and temporal resolution of existing monitoring via conventional measuring stations.

In addition to these routine measurements, which have enabled the mapping of more than 5,000 trees since the project began, the question of the origin of ultrafine particles deposited on bark is particularly crucial, given the current objective of reducing UFPs in urban areas, and can be addressed using chemical and magnetic measurements. Preliminary studies ([1], [2], [3]), based on a limited number of potential sources, have already demonstrated that these two approaches separately provide promising results. However, a comprehensive, combined study is currently lacking to separate the relative contributions of the different sources sampled by a passive sensor. This is an essential step in implementing effective UFP reduction measures.

The steps of this project will be as follows.

The numerous bark samples collected during previous Ecorc'Air campaigns (over 5,000) are already available to test the predictive capacity of such measurement series, using Random Forest-type machine learning algorithms. After identifying the sources of anthropogenic UFPs and collecting statistically significant representative source samples, the following will be done:

1) to characterize the detailed magnetic properties (size distribution and nature of magnetic minerals) associated with each particle source identified and collected in an urban area (strong-field magnetization measurements, magnetic susceptibility measurements at varying temperatures and frequencies). A particularly innovative aspect will be the quantification of the fraction of superparamagnetic grains (ultrafine particles) using the MFK2 triple-frequency susceptibility meter recently acquired by the PAMCE laboratory.
2) to further the chemical characterization of UFP sources, based on recent work carried out in the ACE team (S. Coural's thesis): detection by spICP-ToF-MS coupled with two selective degradation methods (TMAH and O_2 plasma).
3) to combine the chemical and magnetic characterizations from the two previous stages to test a machine learning algorithm that will i) refine the attribution of UFPs measured in NPs to each of their urban sources and ii) lay the foundations for a better understanding of the magnetic properties of the sources.

Candidate Profile

Scientific training at Master's level in geosciences or an engineering degree (physics, chemistry, environment). Skills in chemistry/geochemistry and/or magnetism will be a plus. Prior knowledge or a willingness to train in the use of algorithms in Machine learning is required.

This thesis will be carried out in close collaboration with Christine Franke (Center for Geosciences, Mines ParisTech) and Laure Turcati (Particitae Platform, OSU Ecce Terra, Sorbonne University).

Bibliographic references :

[1] Carvallo, C., Isambert, A., Franke, C., Turcati, L., Sivry, Y., Coural, S., et al. (2024). Ecorc'Air: A citizen science project for the biomonitoring of vehicular air pollution in Paris, France. *Community Science*, *3*, e2024CSJ000084. https://doi. org/10.1029/2024CSJ000084

[2] Letaief, S., Carvallo, C., Franke, C., Isambert, A., Pierre Camps P. Contributions and limitations of environmental magnetism to characterize traffic-related particulate matter sources. Geophysical Journal International, 2024, 237 (3), pp.1505-1525. 10.1093/gji/ggae108 . hal-04529506

[3] Thèse de Sophie Coural, 2025, UPCité - IPGP. Étude des nanoparticules atmosphériques en milieu urbain à l'aide d'écorces d'arbres comme bioindicateurs naturels.