

From air pollution to ecosystem exposure: reconstructing Saharan dust and contaminant deposition from contemporary urban-mountain gradient monitoring and peat pyrenean archives

Research field

Atmospheric and environmental sciences; aerosol science; environmental geochemistry; biogeochemistry; palaeoenvironmental reconstruction; ecosystem ecology; emerging contaminants.

Eligibility : Applicants must comply with the MSCA mobility rule: they must not have lived, worked or studied in France for more than 12 months during the 36 months preceding the application deadline.

Attractiveness:

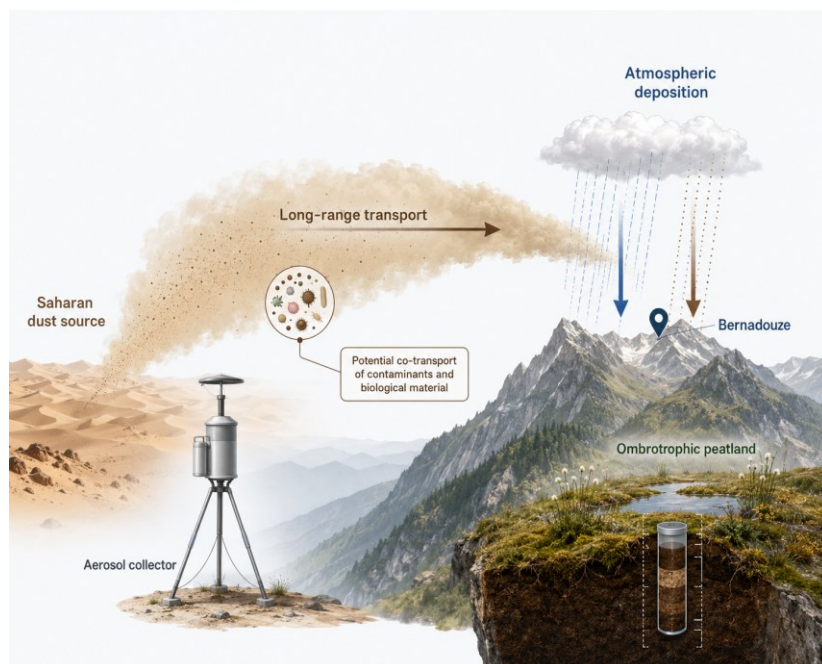
The position offers a highly competitive salary of more than €3,500 gross per month, together with the benefits and international training opportunities provided by the MSCA COFUND BEST programme.

We are seeking a curious and motivated PhD candidate interested in atmospheric pollution, Saharan dust and ecosystem exposure. The project combines contemporary monitoring along an urban-to-mountain gradient with long-term reconstruction from Pyrenean peat archives. We welcome analytical or environmental chemists, geochemists, atmospheric scientists and aerosol scientists. Experience with ICP-MS, XRF/micro-XRF, particle analysis, aerosols or environmental sampling would be particularly valuable. The candidate should enjoy interdisciplinary research combining laboratory work, data analysis and field campaigns in the Pyrenees. The position is based at CRBE, Toulouse INP–AgroToulouse, with international co-supervision by Jorge Pey at IPE-CSIC in Zaragoza.

Excellent English is required; French or Spanish would be an advantage.

Applicants must comply with the MSCA mobility rule: they must not have lived, worked or studied in France for more than 12 months during the 36 months preceding the application deadline.

Recruitment will take place through the competitive international MSCA COFUND BEST selection process.



Objectives

Air pollution and mineral dust are generally investigated through atmospheric concentrations, whereas their deposition—the actual transfer of particles and associated contaminants to terrestrial ecosystems—remains much less well constrained. This PhD project will bridge this gap by connecting present-day atmospheric observations with deposition monitoring, long-term environmental archives and ecological responses.

Its main objectives are to:

1. Identify and quantify Saharan dust events and distinguish them from local and regional anthropogenic sources using elemental composition, geochemical tracers, atmospheric observations and transport models.
2. Investigate the co-transport and deposition of trace metals and emerging contaminants, particularly atmospheric microplastics.
3. Reconstruct long-term variations in Saharan dust and atmospheric pollution over the past centuries to millennia using ombrotrophic peat archives.
4. Assess the effects of mineral dust, nutrients and associated contaminants on forest and wetland vegetation.
5. Connect short-term atmospheric processes with long-term environmental change and provide new indicators relevant to air-quality assessment, ecosystem monitoring and environmental policy

Scientific context

Air pollution is one of the leading environmental threats to human health, contributing to an estimated 6.7 million premature deaths worldwide each year (WHO, n.d.). The challenge is particularly acute in southern Europe, where urban emissions, heatwaves and intense Saharan dust intrusions can occur simultaneously (“La canicule de juin 2026 dopée aux aérosols sahariens | CNRS Terre & Univers,” 2026). These compound events may sharply increase $PM_{2.5}$ and PM_{10} concentrations and exacerbate cardiovascular and respiratory risks.

Recent research has revealed increasing dust concentrations across much of Europe. A continent-wide study combining atmospheric measurements, modelling and an Alpine ice-core record reported increasing background dust concentrations and more severe dust intrusions during the past decade, together with an

approximately 110% increase relative to pre-industrial levels in the Alpine record (Vasilakos et al., 2026). These results suggest that European dust exposure is being reshaped by both North African desertification and changes in atmospheric circulation.

Saharan dust has consequences extending far beyond air quality. It transports mineral particles, nutrients, microorganisms and anthropogenic contaminants over thousands of kilometres. Its deposition may fertilise nutrient-poor terrestrial and aquatic ecosystems, while dust deposited on snow reduces surface albedo and can accelerate snowmelt. However, the ecological consequences of these inputs depend not only on the atmospheric particle load but also on the quantity, composition and bioavailability of the material deposited.

Emerging contaminants including microplastics add a new dimension to this issue. These persistent particles can undergo long-range atmospheric transport and are now detected in urban, rural and remote environments. Together with emerging trace metals and other anthropogenic substances, they belong to the wider category of “novel entities”, for which the planetary boundary is considered to have been exceeded (Richardson et al., 2023). Nevertheless, their co-transfer with mineral dust and their deposition onto terrestrial vegetation remain poorly understood.

The project will build on the ongoing collaboration between Jorge Pey (IPE CSIC, Spain) and Gaël Le Roux (CNRS, CRBE Univ Toulouse) within ECOAIR, a major European POCTEFA project (P.I. Pr. Miguel Escudero) investigating air pollution across the Pyrenean cross-border territory. The PhD will consolidate this research effort while introducing an innovative focus on deposition records from the Toulouse, Auradé and Bernadouze observatories. By combining these contemporary records with peat archives, the project will establish a temporal continuum extending from individual pollution events to environmental changes over centuries and millennia.

The project directly addresses the TIRIS Toulouse University pillars Health and Well-being and Global Changes and Impacts, while also contributing to Sustainable Transitions through the development of improved environmental indicators and evidence supporting air-quality and ecosystem-management policies.

Methodology

The project will use an interdisciplinary approach combining atmospheric monitoring, environmental geochemistry, particle characterisation, palaeoenvironmental reconstruction, ecological observations and statistical modelling.

1. Contemporary atmospheric monitoring and deposition

Atmospheric particulate matter and deposition samples are collected from contrasting observatories, including urban Toulouse, the agricultural site of Auradé and the mountain wetland and forest environment of Bernadouze. These sites provide a unique gradient from major anthropogenic emission sources to rural and mountain environments exposed to long-range atmospheric transport.

The deposition records will be compared with available atmospheric PM measurements, meteorological observations, satellite products, air-mass back trajectories and regional dust-transport models. This will make it possible to identify Saharan dust intrusions and determine how efficiently atmospheric particles are transferred to terrestrial surfaces.

2. Geochemical and particle characterization

The elemental composition of aerosols, deposition samples, peat and vegetation will be determined using complementary analytical techniques including ICP-MS, ICP-OES and X-ray fluorescence. Lithogenic tracers

will be used to identify mineral dust, while trace metals will provide information on anthropogenic contamination and mixing between natural and human-derived sources.

Particle imaging and spectroscopic methods will be used to characterise particle size, morphology and composition. Atmospheric microplastics will be identified and quantified using suitable microscopic and spectroscopic approaches (Raman, FTI-IR, Colspec), depending on particle size and sample matrix.

3. Source attribution and event reconstruction

Geochemical fingerprints will be combined with atmospheric transport information to distinguish Saharan dust from local soil resuspension, agricultural emissions, traffic, combustion and other urban sources. Multivariate statistics, enrichment factors, elemental ratios and source-apportionment approaches will be applied to identify the principal particle sources and their temporal variability.

High-resolution event monitoring will allow individual Saharan dust and pollution episodes to be investigated, including interactions between mineral dust, trace metals and microplastics.

4. Long-term reconstruction from peat archives

Ombrotrophic peatlands receive water and particles predominantly from the atmosphere and therefore constitute valuable archives of past atmospheric deposition (Le Roux et al., 2012). Peat cores will be selected from suitable Pyrenean sites from Toulouse peat library and investigated at high temporal resolution.

Chronologies will be developed using radiocarbon and, where appropriate, short-lived radionuclides such as ^{210}Pb and ^{137}Cs . Mineral dust accumulation will be reconstructed using ash content, lithogenic elements, rare earth element patterns, particle-size measurements and complementary microscopic observations. Trace metals and microplastics will be investigated to reconstruct the development of anthropogenic atmospheric contamination.

Comparison between peat records and the approximately ten-year atmospheric monitoring record will enable recent observations to be placed within their longer-term environmental context.

5. Ecological effects on vegetation

The project will examine the interception and retention of deposited particles by forest and wetland vegetation. Differences among plant functional groups and environmental settings will be investigated using vegetation, surface-deposition and, where appropriate, soil or peat samples.

Elemental and particle analyses will be used to assess whether vegetation acts primarily as a passive collector or whether deposited mineral nutrients and contaminants are transferred into plant tissues. This component will provide an initial assessment of the ecological consequences of Saharan dust and contaminant deposition in mountain forests and wetlands.

Expected results

The project is expected to deliver:

- The first integrated comparison of atmospheric particle concentrations and deposition across the Toulouse–Auradé–Bernadouze urban, agricultural and mountain gradient.
- High-resolution deposition chronologies documenting Saharan dust, local pollution, trace metals and atmospheric microplastics.
- A quantitative assessment of the relationship between atmospheric particle loads and their effective deposition onto terrestrial ecosystems.
- A multi-centennial to millennial reconstruction of Saharan dust and contaminant deposition based on peat archives.

- New knowledge of whether the recent intensification of Saharan dust exposure is exceptional when viewed in a long-term context.
- An initial evaluation of the interception, retention and potential uptake of dust-associated nutrients and contaminants by forest and wetland vegetation.
- Scientific publications, open and reusable datasets, presentations at international conferences and results suitable for communication to air-quality managers and environmental stakeholders.

More broadly, the project will establish an original framework connecting atmospheric exposure, environmental deposition, long-term archives and ecological effects. This integrated approach may subsequently be transferred to other regions affected by desert dust and emerging atmospheric contaminants.

Material conditions for conducting the research

The PhD candidate will be hosted at the Centre de Recherche sur la Biodiversité et l'Environnement—CRBE, Université de Toulouse/CNRS/IRD, on the Toulouse INP-ENSAT campus. The candidate will benefit from an interdisciplinary research environment covering environmental geochemistry, ecology, atmospheric contaminants, microplastics and palaeoenvironmental reconstruction.

The project will have access to the Toulouse, Auradé and Bernadouze observatories, as well as to the laboratory and analytical facilities available through CRBE and its Toulouse-based partners (Observatoire Midi-Pyrenees, Toulouse INP). These facilities provide the equipment required for sample preparation, elemental and isotope analysis (ICP OES, MS, TIMS), particle characterization (Flowcam, Keyence digital microscope, horiba grain size analyzer) microscopy (SEM, μ XRF, FT-IR, Raman) and environmental data processing.

The PhD candidate will be based at **Toulouse INP—AgroToulouse**, an engineering school hosting part of the **Centre de Recherche sur la Biodiversité et l'Environnement (CRBE)**. Located beside the UNESCO-listed Canal du Midi, the campus offers a pleasant, green, peri-urban working environment and is easily accessible from Toulouse city centre by bicycle, public transport or car. It lies at the heart of one of Toulouse's major scientific clusters, close to Université de Toulouse laboratories, the French space agency (CNES), and INRAE—the French National Research Institute for Agriculture, Food and Environment. The candidate will therefore benefit from a particularly rich, interdisciplinary environment spanning environmental sciences, agronomy, ecology, atmospheric research, Earth observation and space science.

International dimension

The project has a strong international and cross-border dimension. It is embedded in ECOAIR, a European POCTEFA project bringing together French and Spanish research teams and stakeholders across the Pyrenean region.



The project will be jointly developed through the complementary expertise of Jorge Pey, specialising in aerosol monitoring, atmospheric composition and source attribution, and Gaël Le Roux, specialising in atmospheric deposition, environmental geochemistry, emerging contaminants and long-term peat archives. The existing collaboration established through ECOAIR will provide access to atmospheric observations, cross-border monitoring activities and expertise in Saharan dust and air pollution. The PhD will offer a genuinely cross-border training experience between Toulouse and IPE CSIC (Jaca/Zaragoza). The candidate will spend a substantial research period at IPE-CSIC in Zaragoza under the co-supervision of Jorge Pey, gaining access to its expertise, atmospheric aerosol collections and facilities for studying present-day aerosol deposition, palaeodust and global change. Through ECOAIR, the candidate will also engage with researchers at the University of Zaragoza and other French and Spanish partner institutions.

The successful candidate will interact with an international network of scientists working on atmospheric aerosols, desert dust, microplastics, environmental archives and ecosystem responses.

Research will be conducted in an English-speaking scientific environment, and the thesis will be written in English. The candidate will be encouraged to undertake research visits or short secondments with collaborating teams, participate in international training schools and conferences, and contribute to joint publications involving ECOAIR partners and the wider European and Mediterranean atmospheric-science community.

The combination of internationally relevant scientific questions, advanced analytical approaches and access to contrasting environments—from urban Toulouse to remote Pyrenean ecosystems—will provide the candidate with a distinctive interdisciplinary profile and strong opportunities for future careers in research, environmental monitoring or science-based policy.

Further collaborations include:

- ECOAIR partners in France and Spain;
- the teams responsible for the Toulouse, Auradé and Bernadouze monitoring sites;
- Toulouse-based analytical and atmospheric-science facilities;
- specialists in atmospheric modelling and air-mass trajectory analysis;
- researchers working on peat chronologies, mountain wetlands, forest ecology and environmental microplastics.

These collaborations will allow the PhD candidate to work across disciplinary boundaries and to connect atmospheric processes with terrestrial deposition, long-term environmental records and ecological responses.

Candidate profile

We are looking for a curious and motivated candidate eager to work across the boundaries of atmospheric science, environmental chemistry, geochemistry and ecology.

Applicants should hold a Master's degree—or an equivalent qualification—in analytical or environmental chemistry, geochemistry, atmospheric science, aerosol science, Earth sciences or a closely related discipline. Experience in one or more of the following areas would be particularly valuable:

- * elemental analysis by ICP-MS, ICP-OES, XRF or micro-XRF;
- * analysis and characterisation of atmospheric particles;
- * aerosol or atmospheric-deposition monitoring;
- * environmental sampling and clean-laboratory procedures;
- * geochemical data processing, source apportionment or statistical analysis;
- * peat records, palaeoenvironmental reconstruction or mountain ecosystems.

The successful candidate does not need to be an expert in all these fields. More importantly, they should be enthusiastic about interdisciplinary research and willing to move between laboratory analysis, atmospheric observations, environmental archives, data interpretation and fieldwork in the Pyrenees.

The project will involve field campaigns in urban, agricultural, forest, wetland and mountain environments. Candidates should therefore enjoy collaborative fieldwork and be comfortable working outdoors under occasionally demanding conditions.

Excellent written and spoken English is required, as English will be the main language used for scientific communication, publications and international collaboration. Knowledge of French or Spanish would be an advantage, but is not mandatory. The candidate will work within an international French–Spanish network and spend a substantial research period at IPE-CSIC in Jaca/Zaragoza. Previous experience in an international or collaborative research environment would be appreciated.

We particularly value scientific curiosity, rigour, initiative, organisational skills and a willingness to learn. The candidate should enjoy teamwork while also being able to develop increasing independence throughout the PhD.

Recruitment will take place through the competitive ****MSCA COFUND BEST selection process****. Applicants will therefore be expected to present their academic background, motivation and suitability for the project to an international selection panel. The supervisory team will support shortlisted candidates in understanding the scientific project and preparing for the formal BEST selection procedure.

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