IDENTIFICATION OF DUST AEROSOL SOURCES AND FLUXES AT THE SCALE OF THE AMAZON BASIN

Main supervisor (25 %): HDR Professor : Cécile Quantin (GEOPS – University Paris-Saclay) Co-supervisor (75 %): Damien Guinoiseau (GEOPS – University Paris-Saclay)

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Keywords

Aerosol dust, Amazon Basin, Geochemistry, Radiogenic isotope systems (Sr-Nd-Pb)

Profile and skills required

Technical skills :
-The candidate must have a master degree in Earth or Environmental Sciences (e.g. atmospheric chemistry, (bio)geochemistry)
-Motivated students with very good analytical chemistry skills is mandatory for this PhD scholarship.
-A first experience in isotope geochemistry is an advantage.
-Field campaign experience would be appreciated.

Languages :
-Applicants must have excellent written and spoken English skills and be highly motivated to work in an international team.

Scientific context

In a context of rapid perturbations initiated by climate change, the presentation of the Amazonian rainforest as an essential carbon sink on Earth is challenged in its Southeastern part due to severe deforestation and ecosystem stress promoted by the intensification of dry periods (Gatti et al., 2021). In this region, the role of atmospheric dust inputs in the active contribution to the biogeochemical cycles of elements (e.g. phosphorus, potassium or iron) has been proposed for 40 years to explain the persistence of the Amazonian rainforest despite its growth on highly weathered terrains (Reichholf, 1986; Swap et al., 1992). In the context of CO_2 mitigation policies, reducing dust emissions on Earth will likely lower the net biogeochemical effect of aerosols to mitigate atmospheric CO_2 (Mahowald, 2011). The implication of dust on the Amazonian rainforest has also been noticed at geological timescales, although the accumulation of atmospheric deposition is often ignored in weathering-erosion balance.

In South America, most of this dust is blown from the Saharan-Sahelian region (Kok et al., 2021) through the easterlies winds that prevail during the boreal winter when the Intertropical Convergence Zone (ITCZ) is at its southern position. The detection and characterization of dust events have been considerably refined through satellite observations (e.g. Ben-Ami et al., 2012; Yu et al., 2018). The most recent generations of models estimate an annual dust deposition flux of 8.5 (2.9-9.7) Tg/yr (Kok et al., 2021). In addition, the discrimination of North African dust emission sources has been significantly improved over the past decade using a combination of mineralogical (e.g. illite/kaolinite ratio) and of chemical/isotopic (e.g. εNd, $^{87}Sr/^{86}Sr$ or Pb isotopes) proxies (Abouchami et al., 2013; Guinoiseau et al., 2022; Jewell et al., 2020; Scheuvens et al., 2013). As a result, by combining Sr and Nd isotope measurements with satellite imagery, the first study performed on dust collected in French Guiana highlighted interannual variability between central and western North African sources (Barkley

et al., 2022). These central and western sources are lithologically (paleolakes vs. alluvial deposits, resp., Bakker et al., 2019) and chemically variable (Si-rich due to diatomites vs. Si-Al-rich due to silicates, resp.). So the identification of North African dust sources is a prerequisite and is mandatory for correctly extrapolating dust-derived elementary fluxes (e.g. nutrients like P, K, Fe, or transition metals) on a multi-annual scale.

PhD project and objectives

PhD project :

In South America and particularly within the Amazon Basin, the role of atmospheric dust inputs in the active contribution to the biogeochemical cycles of elements (e.g. phosphorus, potassium or iron) is assumed to explain the persistence of the Amazonian rainforest despite its growth on highly weathered terrains. Dust aerosols acts as a source of bio-essential nutrients like phosphorus, potassium or iron and thus they impact directly their respective biogeochemical cycles.

The PhD project focuses on the determination of dominant North African dust sources reaching the Amazon Basin through dust filter sampling performed on two observatories; the ATMO coastal site at Cayenne, French Guiana and the Amazon Tall Tower Observatory (ATTO), a 300-m tower located in an isolated place 150 km northeast of Manaus, Brazil. Source apportionment and elemental flux estimates will be performed by combining geochemical and radiogenic isotope (Sr-Nd-Pb) measurements on collected dust, supported by on site analysis (PM10 concentrations), mineralogical observations, satellite imagery (CALIPSO) and air-mass back trajectories (HYSPLIT). Prior to this work, a methodological improvement will be needed to characterize the importance of seasalt, anthropogenic and natural end-members in collected dust. Dust filters from ATTO collected during 2019 dust season (January-May) are already available to initiate the project. Long-term sampling campaigns are planned within the frame of a collaboration involving local (ATMO Guyane, FRANCE and the University of São Paulo, BRAZIL) and international partners (Max Planck Institute for Chemistry, Mainz, GERMANY and the University of Miami, USA) for the period 2024-2025 and for the successive dust seasons (2024-2026) in the two observatories ATMO and ATTO. Simultaneous sampling will help estimate the decrease in dust flux with continentalization and its potential impact on the chemical and isotope signature of transmitted dust. This PhD scholarship is part of a larger project (EVIDAM project, selected for the 2nd round of selection of the French ANR Agency) that will assess the impact of all atmospheric deposits (wet, dry, dust, biomass burning) at the scale of the Amazon basin.

Objectives

-Implementation of a methodological protocol to characterize the importance of marine, anthropogenic and natural components found in the collected dust.
-Determination of the sources of North African dust transmitted to the Amazon basin during the boreal winter period (December-May), mainly using geochemical and isotopic tools (Sr-Nd-Pb), supported by satellite observations.
-Demonstration of the reduction of dust flux with the continentalization of air masses (reduction of the dust flux between the coastal and continental part of the Amazon Basin during the penetration of air masses from the Northwest)
-Determination of the elementary fluxes (in particular nutrients, P, K, Fe, transition metals) associated with this dust and characterization of the importance of these contributions at the scale of the Amazon basin.

Methods

-Sampling of atmospheric dust in the field (on filter) using large volume samplers (HiVol sampler)
-Improvement of a chemical treatment used to isolate the marine, anthropogenic, and natural (= lithogenic) fractions constituting the dust.
-Use of isotopic geochemistry (radiogenic isotopes of Sr, Nd, and Pb) to determine the sources of transatlantic dust (chemical purification in a cleanroom and measurements on a mass spectrometer).
-Coupling of isotopic results with satellite observations and models for reconstructing the retro-trajectories of air masses and confirming the major sources and the possible inter-annual variability.
-Use of elementary geochemistry and previous results to constrain the elementary fluxes transmitted to the Amazon basin on an annual scale.

Expected results

-Implementation of a robust and validated protocol for the chemical analysis of solid aerosols collected on filters (marine, anthropogenic and lithogenic components).
-Identification on a multi-year scale of the most representative North African dust sources.
-Determination of the effect of continental penetration of air masses on the flux of dry aerosols.
-Determination of an integrated elementary flux over the Amazon basin.
-Comparison of these fluxes with the estimate of the weathering flux in the main watersheds constituting the Amazon basin.

Details about PhD supervision

-Main supervision : Pr. Cécile Quantin et Dr. Damien Guinoiseau – Université Paris-Saclay

-Scientific collaborations : Dr. Charlotte Skonieczny – Université Paris-Saclay.
Dr. Stephen J.G Galer – Max Planck Institute of Chemistry, Mainz.
Dr. Christopher Pöhlker – Max Planck Institute of Chemistry, Mainz.
Dr. Cassandra Gaston – University of Miami, Miami.
Pr. Paulo Artaxo – Universidade de São Paulo, São Paulo.
Kathy Panechou – Observatoire ATMO Guyane, Cayenne.

Material (specific security conditions) and financial scientific conditions of the research project

Security formation :
-Training in the practice of geochemistry in a clean room is needed when the doctoral student arrives.
-Safety training for on-site sampling campaigns is mandatory (ATMO, French Guiana, ATTO, Brazil).

Financial support :
-Submission of the EVIDAM project to the 2023 Young Researcher call from the French ANR Agency by Damien Guinoiseau, co-supervisor of the thesis. The project is qualified for phase 2 of selection.
-Partial financial support by the Max Planck Institute for the operational part of the sampling on the ATTO site (use of devices and laboratory on-site, amenities on site).
-Financial support from the Max Planck Institute for carrying out chemical and isotopic measurements.

Promotion of the research work of the doctoral student (dissemination, publication and confidentiality, right to intellectual property)

-Publication of peer-reviewed A-rank scientific articles.
-Participation in national (Réunion des Sciences de la Terre) and international (Goldschmidt, AGU) conferences.
-Dissemination of the results obtained to local populations (French Guiana, State of Amazonas in Brazil): organization of an annual ATTO workshop in Manaus, Brazil, already in place.
-Publications in open access according to the DEAL agreement already signed between the Max Planck company (project partner) and the main publishers.

International collaborations

This thesis subject is part of a more global project (EVIDAM project) that will assess the impact of all atmospheric deposition (wet, dry, dust, biomass combustion) at the scale of the Amazon basin. As part of this project, an international team has been brought together around the thesis project leaders. Strong interactions are therefore expected with:
-Dr. Charlotte Skonieczny – Paris-Saclay University.
-Dr. Stephen J.G Galer – Max Planck Institute of Chemistry, Mainz.
-Dr. Christopher Pöhlker – Max Planck Institute of Chemistry, Mainz.
-Dr. Cassandra Gaston – University of Miami, Miami.
-Pr. Paulo Artaxo – University of São Paulo, São Paulo.
-Kathy Panechou – ATMO Guyane Observatory, Cayenne.

Part of the dust samples will be sampled at the ATTO observatory in Brazil, a research infrastructure with strong scientific dynamism and where interactions with international scientists are important.

During this thesis project, several scientific exchanges at the Max Planck Institute of Chemistry of Mainz are planned in order to carry out some of the isotopic measurements in an ultra-clean context because some elements are really sensitive to pollution (in particular, the isotopic measurement of Pb).

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