Université de Lille

Area Cross Disciplinary Project Lille

Aerosol at the heaRt of the Earth/Atmosphere system

PhD thesis (starting in Autumn 2026)

Laboratory: Univ. Lille/Laboratoire d'Optique Atmosphérique

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AREA Work Package: Contribute to WP3, WP2 and WP1

Global volcanic gas emissions from satellite and ground-based observations

Abstract

Volcanic degassing, rich in sulfur dioxide (SO_2), is a crucial indicator for detecting any modification of the volcanic activity associated to subsurface magmatic processes. Furthermore, sulfate aerosols, produced from SO_2 oxidation in the atmosphere, significantly modify the Earth atmospheric chemistry and radiative budget. Their long-range transport can degrade air quality over continental scales (Boichu et al., ACP 2019). Injected into the stratosphere by major explosive eruptions, SO_2 gas emissions also have a direct impact on climate (Boichu et al., JGR 2023).

When available, ground observations, based on UV-DOAS spectroscopy, are sensitive to moderate degassing. However, the vast majority of active volcanoes are not instrumented for gas monitoring from the ground. Thanks to hyperspectral sensors offering a high spatial resolution such as Sentinel-5P/TROPOMI, monitoring volcanic degassing from space has made considerable progress in the past years (Theys et al. 2019). To leverage this improved detection method, we developed the new « disk method » which allows the automated and robust analysis of hyperspectral imagery (S5P/TROPOMI, Suomi-NPP/OMPS, Aura/OMI) for evaluating daily SO_2 flux at any volcano in the world (Grandin, Boichu et al., JGR 2024). Associated with this new algorithm, a novel open access web application, named « SO2 Flux Calculator », has been developed and integrated into the « Volcano Space Observatory » (VSO) web portal (https://vso.icare.univ-lille.fr), in complement to the VOLCPLUME web platform for the 4D monitoring of volcanic plumes.

We propose to a motivated PhD student to study global volcanic gas emissions using these new VSO tools and algorithms for satellite imagery exploitation.

In a first stage, a sensitivity analysis, varying the different algorithm parameters for flux calculation, will be carried out. In a second stage, an exhaustive intercomparison of SO_2 flux from VSO satellite-based analysis and ground observations from the international Network for Observation of Volcanic and Atmospheric Change (NOVAC) will be developed. For 20 years, this network has been coordinating the installation, maintenance and data analysis from UV-DOAS spectrometers scanning the sky above > 50 volcanoes among the most active in the world (Arellano et al. 2021). This work will be conducted in collaboration with Chalmers University (Sweden).

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This research will allow the validation of satellite-based gas emissions and develop a thorough analysis of the limitations and complementarity of ground/satellite observations. It will lay the foundation for an automated analysis of satellite imagery toward the production of a novel « Volcanic SO_2 Flux » satellite product which will be distributed to the international community by AERIS national center, of special interest for volcanological observatories and atmospheric monitoring services.

This PhD project will enable a leap forward in the near-real time monitoring of volcanic degassing. Analysis of multi-scale impacts on the atmosphere, especially on aviation safety and air quality, could be considered on volcanic targets of interest. A joint analysis of degassing with other geophysical observables (in particular ground deformation of the edifice or seismicity) may be also conducted to improve our understanding of eruptive dynamics.

This internship takes place in an interdisciplinary environment, within the framework of the Horizon Europe EOSC FAIR EASE project, supporting Open Science, in close cooperation between the Laboratoire d'Optique Atmosphérique (LOA, Univ. Lille), the Institut de Physique du Globe de Paris (IPGP, Univ. Paris Cité) in charge of French Volcano Observatories, and the Data Terra Research Infrastructure with AERIS/ICARE and FormaTerre national centers for Atmospheric and Solid Earth data and services, respectively. This project is also supported by the CNES French Spatial Agency.

The PhD student will actively contribute to the ACTRIS Research Infrastructure by participating to the ACTRIS-NEXT Horizon Europe project which will be soon launched, the AREA Cross Disciplinary Programme of the University of Lille, and the CPER ECRIN project.

Keywords: Volcanic degassing, satellite/ground-based remote sensing, UV-DOAS spectroscopy, air quality, aviation safety, climate, volcano monitoring

Requirements: Background in physics, environmental/atmospheric/Earth sciences, computer science, data science or equivalent. Strong interest in data analysis, atmospheric and climate studies, volcanology. Experience in programming (Python is preferred).

References:

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- Boichu, M., R. Grandin et al. (2023), Growth and global persistence of stratospheric sulfate aerosols from the 2022 Hunga Tonga–Hunga Ha'apai volcanic eruption, J. Geophys. Res., doi:10.1029/2023JD039010.
- Boichu, M. et al. (2019), Large-scale particulate air pollution and chemical fingerprint of volcanic sulfate aerosols from the 2014–15 Holuhraun flood lava eruption of Bárgarbunga volcano (Iceland), Atmos. Chem. Phys., doi:10.5194/acp-19-14253-2019.
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