PhD project co-funded by CNES :
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PhD project title : **Satellite and ground-based remote sensing of volcanic aerosols : impacts on air quality, aviation safety and climate (co-financed by CNES)**

A cocktail of particles may coexist within a volcanic plume, including liquid water droplets, ice crystals, ash and sulfate aerosols. Sulfate aerosols are formed in the atmosphere from precursory sulfur dioxide (SO_2) gas following a complex chain of chemical and physical processes. How secondary sulfate aerosols form and evolve in the peculiar atmospheric environment that prevails within volcanic plumes is still poorly understood (e.g. Boichu et al., ACP 2019).

Standard satellite retrieval analyses (e.g. from MODIS) provide an estimation of the optical depth of aerosols but do not allow for discriminating the composition of aerosols and their origin. Whereas ash particles have received much attention, a single paper reports the detection of sulfate ammonium aerosols using polar-orbiting satellite observations in the infrared spectrum range (Clarisse et al., ACP 2013).

In order to fill this gap, we propose in this PhD project to seize the opportunities offered by the recent achievements in retrieving, using GRASP (Generalised Retrieval of Aerosol and Surface Properties) algorithm (Dubovik et al., 2014), the composition of aerosols (including volcanic ammonium sulfate and ash particles) from multi-spectral, multi-directional and polarimetric POLDER satellite imagery (Lei Li PhD thesis, 2018; Li et al., ACP 2019).

To better describe and understand the lifecycle of sulfur in volcanic plumes, the successful candidate will develop a multi-sensor approach for jointly analyzing observations of volcanic SO_2, ash and sulfur-rich aerosols over a multi-year period covering the POLDER archive. We will study contrasting volcanic activities and atmospheric impacts by focusing on specific case studies of emissions from both stratospheric ash-rich eruptions and passively degassing volcanic activity in the lower troposphere.

To reach this objective, SO_2 satellite observations from a variety of sensors spanning the UV to IR range (UV OMI, UV OMPS, IR IASI, as well as the recently launched UV TROPOMI onboard Sentinel-5P, with increased spectral and spatial resolutions) will be exploited to unambiguously identify the volcanic cloud and constrain the emission, dispersal and destruction rate of the volcanic SO_2 gaseous precursor. A combination of spaceborne aerosol observations (POLDER, as well as MODIS, IASI and CALIOP) will jointly be used to explore the formation and atmospheric evolution of secondary sulfur-rich aerosols, in presence or not of coexistent ash particles. Various ground-based remote sensing observations, from the international AERONET network of photometers or LIDAR stations, will allow the candidate to validate and complement satellite-derived aerosol properties.

Exploring this broad panel of ground/satellite observations will allow further progress in our knowledge of optical, microphysical and radiative properties of volcanic particles, which is fundamental to rigorously assess their impact on the composition of the atmosphere, air quality, aviation safety and climate.

This PhD project also aims at exploring the POLDER archive in preparation of the upcoming EPS-SG (Eumetsat Polar System – Second Generation) mission that will gather onboard the Metop-SG A satellite the 3MI (POLDER heritage) and IASI-NG (IASI heritage) sensors as well as the UVSN spectrometer similar to TROPOMI. The synergistic analysis of co-located observations of volcanic SO_2, sulfate aerosols and ash particles soon made possible with this upcoming satellite mission should bring crucial information to understand the atmospheric evolution of volcanic plumes and their impacts.

Key words: Volcanic plumes, sulfate aerosols, sulfur dioxide gas, ash, atmospheric aerosol composition, satellite and ground-based remote sensing

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