Laboratory and numerical studies on the optical properties of complex-systems such as mineral dust particles

Equipe : Optique, Environnement et Télédétection (OET)

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Scientific context

According to the latest IPCC report [1], atmospheric particles, such as sulfate, desert dust or sea-salt particles, are incriminated for their impact on air quality, public health and climate. Quantifying this effect is however very challenging, due to the complexity of these particles, which present a wide range of sizes and shapes. In particular, mineral dust particles present a very complex morphology, with highly irregular shapes, and are a complex mixture of dielectric and semi-conductor particles. To face such a complexity, the interaction of light with these particles through light scattering is often used. Indeed, light scattering is sensitive to the particles size (through spectroscopy) and shape (through polarization) and can be described in the framework of the scattering matrix formalism [2], suitable for addressing such a statistical particles ensemble. In the absence of analytical solutions to the Maxwell's equations for complex-shaped dielectric particles, scattering by mineral dust particles has been studied in laboratory by our group where a π-polarimeter has been built in the exact backscattering direction ($\theta = 180.0 \pm 0.2$°), particularly sensitive to the particles size and shape, which is a world-first [3]. Besides, this π-polarimeter was implemented on the home-built ILM lidar station to allow unambiguous observations of the backscattering process directly in the atmosphere, with a high sensitivity allowing to partition the atmosphere into its different scattering contributions [4] and even detect the nucleation process for the first time with a lidar [5].

Objectives of the internship

This internship is dedicated to the optical properties of mineral dust particles, for which there is no analytical solution to the Maxwell's equations (ME). In particular, the Lorentz-Mie theory cannot be applied to such inhomogeneous non-spherical particles. The objectives of the proposed internship lie in the above context and are twofold:

The first objective is to carry out a light-scattering experiment in laboratory, allowing to extend the range of applicability of the π-polarimeter up to near a π-angles (from 175 to 180°). Indeed, in the absence of analytical solution to the ME'equations, light-scattering numerical simulations are currently performed based on numerical models. However, the validity of these models should be discussed and for that a precise laboratory experiment addressing the scattering matrix elements from 175° to 180° is required. The candidate will participate to the building of such a laboratory, as a first objective of the internship.

In complement, a second objective will be addressed, based on numerical simulations. If the scattering process has proven its efficiency in addressing mineral dust particles, these particles also present other interesting optical properties, allowing for example to study their response to a strong electric field, thus taking benefit from non-linear optics. The second objective of the internship will be to perform a numerical simulation, allowing to identify the main requirements for a laboratory experiment to be sensitive to this process.

The candidate should have knowledges in light scattering, laser physics, and ideally also atmospheric aerosols. Skills in numerical simulations are also required to reach the second objective. This internship can be pursued by a PhD on laboratory experiments aimed at addressing the optical properties of atmospheric particles. The detailed framework of the PhD-topic will be discussed with the candidate during the internship.

References

[1] IPCC, The Physical Basis: Climate Change, (2013).

[2] Mishchenko, M. I., Travis, L. and Lacis, A. : Scattering, Absorption, and Emission of Light by Small Particles, Cambridge, (2002).

[3] A. Miffre, T. Mehri, M. Francis and P. Rairoux, UV-VIS depolarization from Arizona Test Dust particles at exact backscattering angle, *J. Quant. Spec. Rad. Transf.*, **169**, 79-90, (2016).

[4] G. David, B. Thomas, T. Nousiainen, A. Miffre, and P. Rairoux, Retrieving volcanic, desert dust, and sea-salt particle properties from two/three-component particle mixtures after long-range transport using UV-VIS polarization Lidar and T-matrix, *Atmos. Chem. Phys.* **13**, 6757-6776 (2013).

[5] G. David, B. Thomas, Y. Dupart, B. D'Anna, C. George, A. Miffre and P. Rairoux, UV polarization lidar for remote sensing new particles formation in the atmosphere, *Opt. Exp.*, **22**, A1009-A1022 (2014).

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