PROPOSITION DE POST-DOCTORAT

Development of Bayesian inverse algorithms for the retrieval of aerosol lidar products

Référence : **PDOC-DOTA-2019-02**
(à rappeler dans toute correspondance)

Start : 2^{nd} semester 2019	**Application deadline :**

Duration: 12 months, possibly extendable to 24 months - Net yearly salary: about 25 k€ (medical insurance included)

Keywords

Inverse methods, Optimization, Machine Learning, Digital filtering, Lidar, Signal processing.

Profile of the candidate:

Ph.D. degree or equivalent in the field of applied mathematics, and/or applied physics.

Context :

The global warming concerns imply the study of atmospheric aerosols, including soot aggregates emitted by aircraft engines. Particulate matter emitted by aircraft remains in the upper troposphere and lower stratosphere and affects the global radiative budget: ice condensates around soot aggregates nuclei to form contrails. Besides, soot is a factor of health damage by entering the lung cells. Real-time monitoring and characterization of soot aggregates required accurate determination of soot particle size and morphology. International aviation agencies (FAA, EPA, and EASA), industrials and scientists are working together on new particulate matter certifications for aircraft engines, which are more accurate and reliable regarding environmental concerns.

Project :

One goal of PROMETE research project is to address the need of active remote-sensing of fine particulate matter emitted from aircraft engine (e.g. soot and other particulate emissions). LiDAR (LIght Detection And Ranging) is an active remote sensing technique for measuring the backscattered light from particles or molecules in the atmosphere. Inversion of the lidar signal is a well-known ill-posed problem. A wide range of techniques have been proposed to estimate the lidar products (i.e. backscattering and extinction profiles) [1, 2]. Those techniques usually require prior knowledge of the atmosphere constituents to ensure a stable inversion.

Objectives:

One way to tackle the challenging inversion problem of lidar signals is to use non-linear optimal estimation methods to retrieve the radiative and microphysical properties of aerosols [3]. This Bayesian framework provides a formal way of handling the ill-posedness of the retrieval problem and its associated uncertainties. For several decades, it has been successfully applied to the analysis of passive remote sensing detectors [4], but it has also recently been adapted to Raman lidar observations, with promising results [3]. In order to assess the relevance of the estimation, it is essential to account for all sources of uncertainty: model parameter, measurement errors… in the retrieval of the aerosols properties and optimal estimation has the advantage of providing a full uncertainty budget on a profile-by-profile basis.

The objective of this postdoc is to develop an inversion algorithm for lidar signals with high spatial and temporal resolution, especially in the frame of short-range lidar measurements. For example, Bayesian inversion (such as optimal estimation) seems to be well suited for our problem with some adaptations. As a matter of fact, the distribution of noise is not necessarily Gaussian for low signal-to-noise ratio observations, and optimal estimation cannot be directly applied in this case. Moreover, in order to account for large amount of temporal data, it can be interesting to take advantage of machine learning methods instead of performing repeated calls to a complex forward model. Some ideas in this direction have been proposed very recently [5-8], such as using quantile regression neural networks to estimate the a posteriori distribution of remote sensing retrievals [7].

Activities:

The candidate will be in charge of the following activities:

1) Providing a state-of-the-art about lidar inverse and optimal estimation algorithms.
2) Developing retrieval algorithms for both synthetic lidar signal and measured lidar signals from metrological validation campaigns

This includes making use of and improving a forward lidar model, mainly to account for multiple scattering, modeling the experimental error, and implementing and testing the inversion retrieval algorithms.

The candidate will also have to analyze the sensitivity of the retrievals to the a priori distribution of aerosols profiles and to find the more appropriate ones.

3) Dissemination of the results and publications.

The post doc will be involved at all steps of the PROMETE project. He/she will investigate how to develop new inverse methods dedicated to short-range lidar signal with high spatial and temporal resolution, but will also be associated to the development of the forward lidar model, in collaboration with DRDC (Defence Research and Development Canada). In order to validate the proposed inverse algorithm, several synthetic test cases based on our lidar simulator will be considered. The performance of the new algorithm will also be tested and assessed on real data from metrological validation campaigns.

Expected outcomes:

- New inversion algorithms for lidar signals with high spatial and temporal resolution
- Validation of the lidar signal processing and inversion workflow
- Dissemination of the results and publications.

References:

[1] Klett, J. D., Appl. Optics, 20, 211–220, 1981.

[2] Fernald, F. G., Appl. Optics, 23, 652–653,1984.

[3] Povey, A. C, Atmos. Meas. Tech., 7, 757–776, 2014.

[4] Rodgers, C. D., Inverse Methods for Atmospheric Sounding: Theory and Practice, 2011.

[5] Efremenko, D. S. et al I. J. Of Remote Sensing, 38, 1-27, 2017

[6] Qin W., Remote Sensing, 10, 1022, 2018

[7] Pfreundschuh S., Atmos. Meas. Tech., 11, 4627-4643, 2018

[8] Adler, J., Oktem O., arXiv:1811.05910v1, 2018

Collaborations :

RDDC-DRDC (Canada)

Host Laboratory at ONERA:

Department : DOTA

Location (ONERA center) : Toulouse or Palaiseau

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