EVALUATION OF A COMMERCIAL AEROSOL LIDAR SCANNER FOR INDUSTRIAL POLLUTION MONITORING

AVALIAÇÃO DE UM SCANNER COMERCIAL DE LIDAR COM AEROSSOIS PARA MONITORAMENTO DA POLUIÇÃO INDUSTRIAL

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Abstract: In recent years, light detection and ranging (LiDAR) technology has gained popularity in various applications, including remote sensing of Particulate Matter (PM) absolute concentrations. Raymetrics PMeye is a unique platform consisting of a state-of-the-art scanning lidar, innovative algorithms and auxiliary sensors, used for large areas PM concentrations monitoring. Using a novel inversion scheme for transforming raw signals to aerosol concentrations, PMeye is one of its kind for aerosol monitor in urban or/and industrial areas. Measurements performed at a steel factory in Latin America, a highly variable area in terms of emission sources, support the effectiveness of the overall system. Measurements evaluation against a light scattering in situ PM counter, placed at major emission sources on various ranges and directions from the lidar, present high correlation and very low mean relative differences.

Keywords: Scanning Lidar. Particulate Matter. Raymetrics. Ternium.

Resumo: Nos últimos anos, a tecnologia de detecção e alcance da luz (LiDAR) ganhou popularidade em várias aplicações, incluindo a detecção remota de concentrações absolutas de matéria particulada (PM). A Raymetrics PMeye é uma plataforma única que consiste em um laçador de escaneamento de última geração, inovador algoritmos e sensores auxiliares, utilizados para o monitoramento de concentrações de PM em grandes áreas. Usando um novo esquema de inversão para transformar os sinais brutos em concentrações de aerossol. O PMeye é um de seu tipo para monitor de aerossol em áreas urbanas ou/e industriais. Medidas realizadas em uma fábrica de aço em latim América, uma área altamente variável em termos de fontes de emissão, apóia a eficácia do conjunto sistema. Avaliação das medidas contra um contador de PM in situ de dispersão de luz, colocado na emissão principal fontes em várias faixas e direções do lidar, apresentam alta correlação e média muito baixa diferenças relativas.

Palavras-chave: PMeye, Raymetrics. LiDAR de scaneamento. Matéria particulada. Concentrações absolutas.

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1 INTRODUCTION

This study evaluates the performance of the Raymetrics' PM*eye* (FREUDENTHALER *et al.* 2018), a unique platform for the remote sensing of Particulate Matter (PM) concentrations, during operation in steel factories in Latin America. PM*eye* is of a state-of-the-art scanning lidar employing a novel inversion scheme for transforming raw lidar signals to PM concentrations using a calibration method that includes the use of a light scattering in-situ PM sensor.

This study focuses on measurements performed in a TERNIUM steel factory in Argentina that demonstrate the effectiveness of remote monitoring of aerosol concentrations. Below we briefly present the system specification, the methodology, and first results.

Figure 1 - Raymetrics PM*eye* scanning lidar installed on administration building rooftop in TERNIUM, San Nicolas

2 INSTRUMENTATION

The PM*eye* system is based on an eye-safe UV scanning depolarization lidar, developed by Raymetrics S.A. The system follows the EARLINET/ACTRIS Quality Assurance procedures and is designed for 24/7 unattended operation. Table 1 presents its basic technical characteristics. Table 2 presents the basic technical characteristics of a Dust Track DRX 8543 aerosol monitor that was initially used for

calibration and then for the system results validation. Raymetrics PM*eye* scanning lidar is shown in figure 1.

Table 1 - PM*eye* lidar technical specifications

Telescope diameter	200mm
Emission wavelength	355 nm
Energy per pulse	30mJ
Repetition rate	20 Hz
Detection wavelength	355p / 355s
Spatial resolution	3.75 m
Scanning range angle	Zenith: -6° to 90° Azimuth: 0° to 360°

Table 2 - Dust Trak DRX 8543 technical specifications

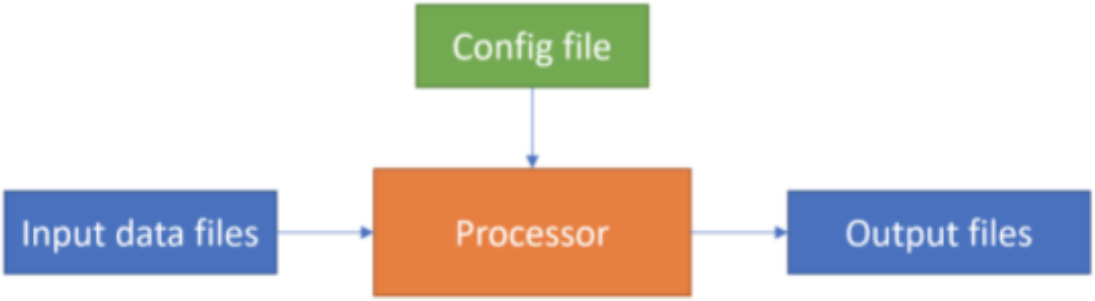
Detection Method	Light scattering laser photometer; 90° off-axis detector
Sample flow Rate	3.0 L/min (±5% of factory set point, internal flow controlled)
Measured Mass Fraction	0-150 mg/m^3
Heated Inlet Sample Conditioner	
Omni-directional Inlet with Water Trap	

During the study, the system was performing horizontal 360° or sectoral scans to monitor and quantify emissions from various plant processes. During scans, the system performed 5s (100 shots) measurements at each line of sight, while for the calibration and intercomparison with the PM counter, 5min averages of these records were used.

3 PROCESSING METHODOLOGY

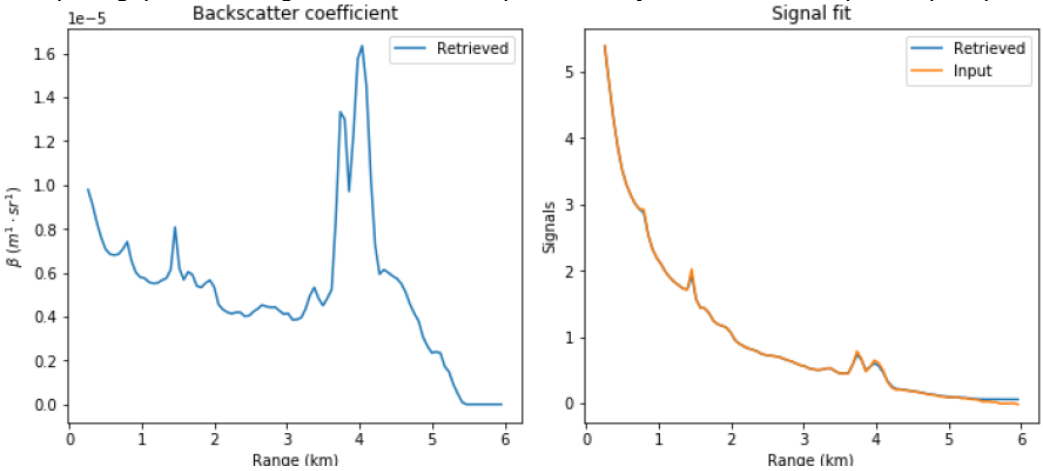
The Raymetrics processing system retrieves higher level products (aerosol optical properties, graphs, surface plots, etc.) from raw lidar signals. It is designed for automatic data processing so, apart from initial setup, requires no user input. The system is organized with a chain of processors. Each processor takes as input one or more data files and produces one or more output files, typically data or images. All processing parameters are controlled by a configuration file, which allowed us to fine-tune the analysis during operation without any software changes (Figure 2). All data are stored in NetCDF4 format, with their internal structure following the Climate & Forecast (CF) convention.

Figure 2 - Flowchart of the Raymetrics processing procedure



Aerosol concentration retrievals are performed as a two-step approach. Firstly, a proprietary inversion algorithm estimates the aerosol backscatter coefficient based on raw lidar signals. The algorithm treats the inversion as an optimization procedure and regularize the solution based on physical considerations e.g., solution smoothness (Figure 3). In this way the inversion is achieved without an explicit selection of boundary conditions, as typically required by vertical lidar inversion schemes. As a second step, source-specific calibration factors are derived based on calibration measurements performed alongside the portable PM counter at various distances and over different emission sources (TWOMEY, 1977).

Figure 3 - Left: retrieved optimal backscatter profile. Right: comparison of the actual lidar signal (orange) with the signal that would be produced by the backscatter profile (blue)



Lidar retrievals were evaluated by performing measurements near different emission sources. The lidar was manually pointed towards the in-situ PM sensor. The pointing uncertainty at the distance of the sensors was estimated to be less than 20 meters. The lidar range resolution was reduced to 15 meters to minimize collocation artefacts and achieve better signal to noise ratio (SNR).

4 RESULTS AND DISCUSSION

Figures 4 and 5 present results from corresponding measurements comparison over the steel plant and the blast furnace of the TERNIUM Argentina plant. Results are presented in arbitrary units. The two measuring sites were located 740m west and 1000m north-east from the lidar location correspondingly.

Figure 4 - Time series of lidar (blue) and in situ counter PM values (orange) over TERNIUM steel shop in arbitrary units

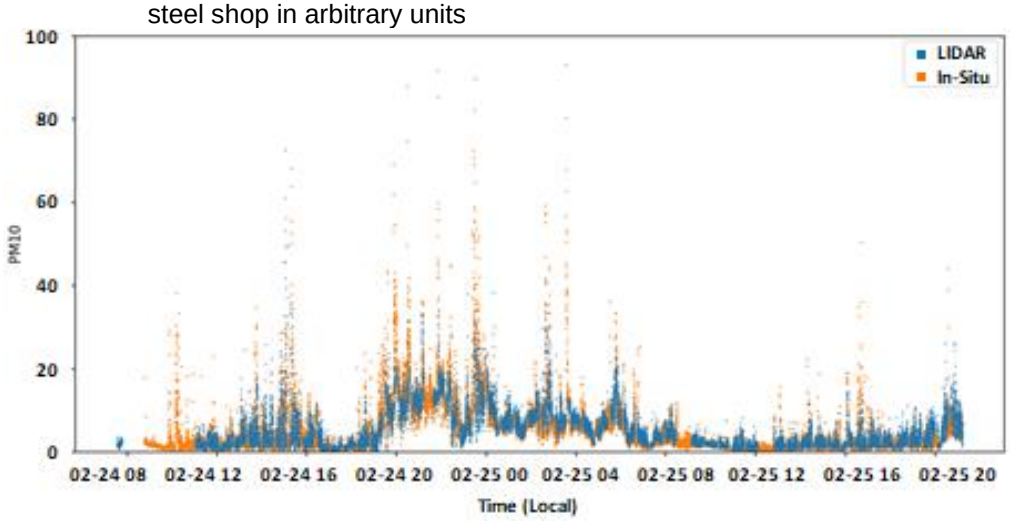
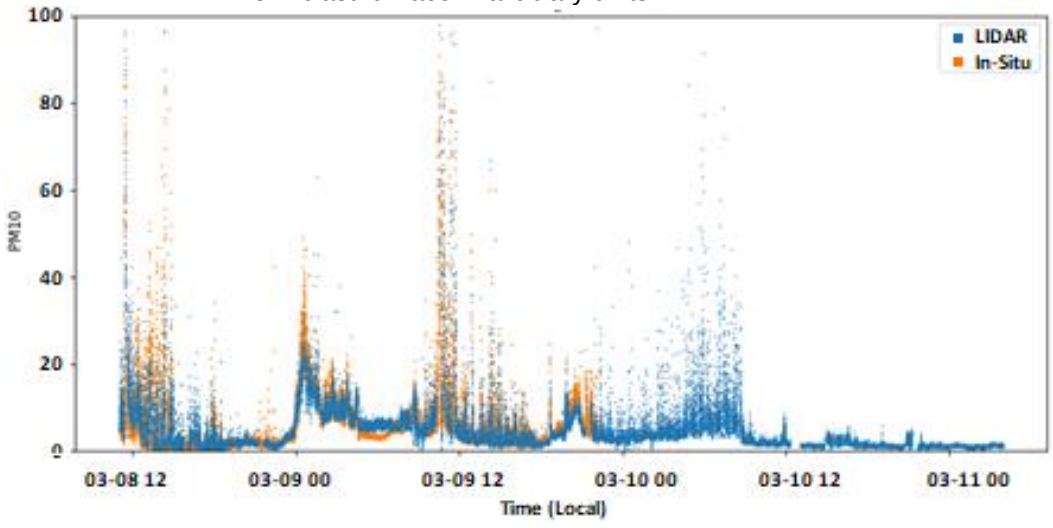


Figure 5 - Timeseries of lidar (blue) and in situ counter PM values (orange) over TERNIUM blast furnace in arbitrary units

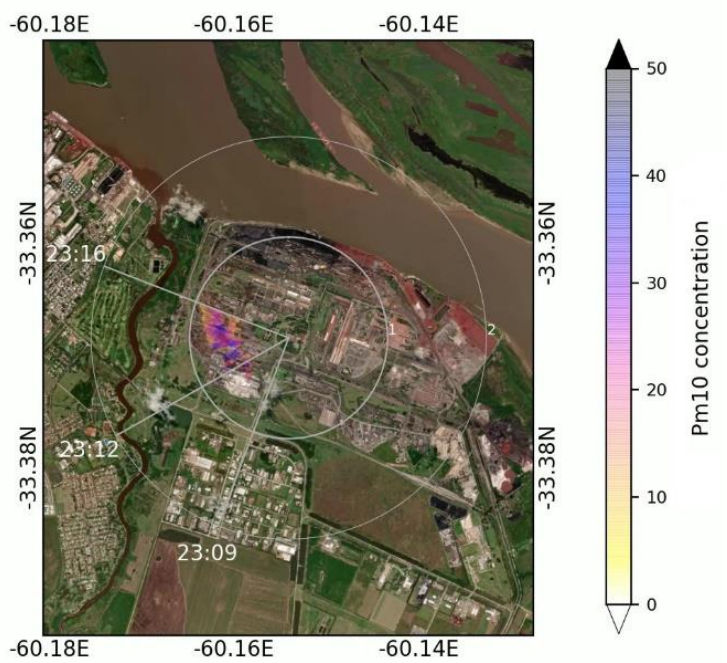


The intercomparison reveals high correlations coefficient and small mean relative differences, as indicatively presented in Table 3. Calibrated and interpolated scanning results using 2 degrees step are presented in figure 6.

Table 3 - Results Comparison

PM10 (µgr/m3)	Steel Shop	Blast Furnace
Average Relative Difference	3.4%	0.6%
R^2	0.76	0.72

Figure 6 - Lidar sector scan PM monitoring example in arbitrary units



5 CONCLUSIONS

An evaluation of Raymetrics PM*eye* platform in a steel factory in Latin America was performed. The systems novel inversion scheme that transforms raw lidar signals to aerosol absolute concentrations has been tested and results comparison with a light scattering in situ PM counter present high correlation and very low mean relative differences.

Therefore, it becomes clear that the scanning lidar can give accurate estimations for PM monitoring in industrial areas.

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