OIL SPILLS DETECTION FROM FLUORESCENCE LIDAR MEASUREMENTS

Jeni VASILESCU[1], Luminita MARMUREANU[2], Emil CARSTEA[3], Constantin P. CRISTESCU[4]

Sistemele Lidar de fluorescență sunt tehnici des utilizate în monitorizarea poluării din mediul acvatic, bazându-se pe identificarea semnăturii de fluorescență specifică fiecărui component. Principalul scop al acestei lucrări este de a analiza petele de petrol detectate în campania experimentală din august 2007 în zona românească a Mării Negre. Sunt analizate metodele de procesare prin regresie liniară şi prin relaționare a canalelor, precum şi prin rețelele neuronale artificiale. S-a observat că pentru analiza distribuției de contaminanți petrolieri de-a lungul unei traiectorii, cele mai potrivite metode sunt cea a relaționării canalelor şi cea prin regresie liniară. Pentru determinarea tipului de petrol cea mai potrivită este rețeaua neuronală artificială.

Fluorescence LIDAR is a useful tool in water pollution monitoring, based on the fluorescence signature of each contaminant. The main goal of this study is to analyze the oil spills detected in late 2007 summer campaign on the Romanian side of Black Sea. Artificial neural network (ANN), linear regression and channels relationship (CRM) methods are evaluated in order to identify the best option for oil spills detection and characterization. It was found that linear regression or channels relationship are suitable to use in order to reveal the distribution of oils on a sea path while ANN is suitable for identifying the type of oils.

Key words: fluorescence Lidar, oil spills, CRM, ANN

1. Introduction

LIDAR represents an active remote sensing technique extensively used for atmospheric, water basins, soil and forestry monitoring [1]. The Lidar methods were used on remote sensing of natural waters first of all for oil spills detection [2], [3] and then for the distribution and characterisation of the dissolved organic matter (DOM) and phytoplankton [4].

The major goal of the paper is to reveal the contribution of Lidar systems on water basins monitoring and to estimate the distribution of oil spills during

[1] CS, ACS, CS National Institute of R&D for Optoelectronics, Bucharest – Magurele, Romania
[2] ACS, National Institute of R&D for Optoelectronics, Bucharest – Magurele, Romania
[3] CS National Institute of R&D for Optoelectronics, Bucharest – Magurele, Romania
[4] Prof, Physics Department, University POLITEHNICA, Bucharest, Romania, e-mail: cpcris@physics.pub.ro

2007 summer Black Sea campaign. Three processing methods are evaluated in order to identify the best option for oil spills detection.

2. The instrument used during the Black Sea campaign

The FLUORES system performed first laser remote measurements of oil spills near the Romanian Black Sea coast during 2007 summer campaign. The system is useful for real time evaluation and diagnosis of water basins, detecting the fluorescence of water components: oil spills, natural and anthropogenic organic matter and pigments (chlorophyll a). Oil films as well as emulsions presence can be detected in real time at very low concentrations. The principle of this technique is based on laser induced fluorescence, involving the capture and analysis of fluorescence spectra, induced in the target object by illumination with a laser beam. This Lidar system consists of three units: the laser, the detection system and the acquisition unit. The laser radiation at 308nm is emitted by an excimer laser while at 367 and 460nm are emitted by a tuneable dye laser. The returned radiation is collected on the entire visible spectral range (300-800 nm). The detection unit includes a telescope with 180 mm aperture and focal distance 635 mm, a polychromator with two concave diffraction gratings and an optical detector which combines an image intensifier and a linear CCD camera. FLUORES (Fig. 1) can be used for measurements in water basins and vegetation.

In the case of a homogeneous water column, where the attenuation coefficient and fluorescence efficiency are constant, the intensity of the returned Lidar signal ϕ is considered proportional to the concentration of the fluorescing molecule [5]:

$$\phi(\lambda_{ex}, \lambda_{em}) = \alpha n \sigma_F(\lambda_{ex}, \lambda_{em}) / \sigma_R(\lambda_{ex}) \quad (1)$$

where α is a lidar equation constant, σ_F and σ_R are the cross-sections of fluorescence and Raman scattering and n is the volume concentration of the fluorescing species. All the data used in this paper were measured on august 2007 onboard a research vessel along Romanian Black Sea coast (Fig.2).

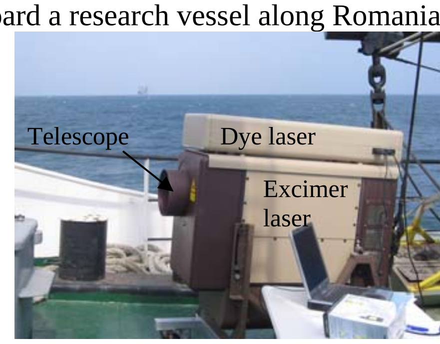

Fig. 1 FLUORES system

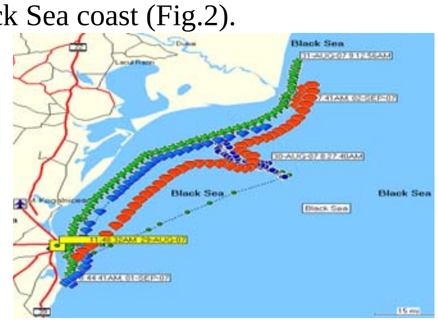

Fig. 2 Lidar measurements map

3. Results and discussion

3.1 Method for testing the alignments

In the case of an ideal Lidar system the fluorescence return signal contains fingerprints of water components from at least 50-100m depth. In a real water system with suspended particles and absorbers, the penetration depth of the laser beam depends on turbidity at the sounding time, the waves intensity and laser performance. In order to avoid all negative issues, it is necessary to test all the alignments of the system against the mirror position, the laser power and the laser beam path into the water column. Laser-mirror alignments need two steps: first, setting up of the system and adjusting the mirror positions in order to see the laser spot at the centre of the mirror, and second, adjusting the relative position of the mirror in order to guide the laser beam normal to the water surface. The test for good alignment is the position of the laser fluorescence on a paper sheet placed in front of the mirror. The fluorescence aria and location indicate the relative alignment of the system against the mirror position. In the case of proper alignment, a strong spectrum of the paper backscattered radiation containing the laser radiation (308 nm), the paper fluorescence fingerprint (maximum at 430 nm) and the second harmonic of the laser radiation (616 nm) is detected (fig 3).

A good alignment assumes detection in both cases: when the ultraviolet excitation is used the spectrum of the returned radiation contains the water Raman peak, DOM and oil fingerprints; when the visible radiation is used the spectrum of the returned radiation contains the water Raman peak overlapping on the DOM fingerprint and the chlorophyll *a* fingerprint (fig 4).

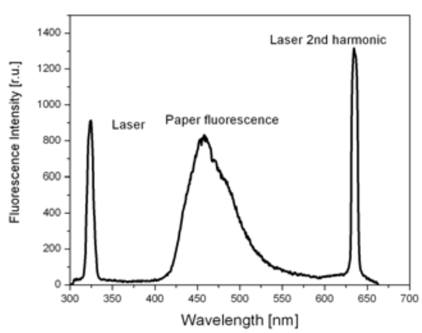

Fig. 3 Lidar system mirror alignment

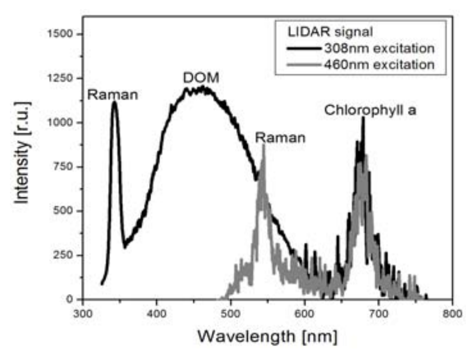

Fig. 4 Fluorescence signatures (Lidar signal for 308 and 460nm excitation wavelength)

3.2. Detection techniques of oil spills from fluorescence Lidar signals Linear regression

A linear regression model assumes a random vector $(Y_i, X_{i1},....., X_{ip}), i = 1,..., n$ with an imperfect relationship between dependent variables Y_i and independent variables $X_{i1},\ldots,X_{ip}$. Additional influence on Y_i, not related to the independent variables is captured by a set of proportionality constants. In fact, a linear regression models the relationship between two variables by fitting a linear equation to observed data. The linear regression processing method can not be applied in case of all measured data, it is fitting only to data which have a certain correlation degree measured by a correlation coefficient. The most used linear regression technique is the least-squares method. In the special case of fluorescence data, the measured signal or spectral interval depends on detection sensitivity of the elements of the CCD camera or the wavelength.

In order to analyze fluorescence data using a linear regression method it is necessity to construct a calibration file. Figure 5 shows the data included in the calibration file used for the analysis of summer 2007 data in the case of 308 nm excitation wavelength: laser peak, Raman line, oil and DOM fingerprints, and laser second harmonic [6] .

The Lidar measurements during 2007 summer campaign were performed almost continuously, on profiles near the coast, inside harbours and in platforms proximity. These areas showed differences on anthropogenic influences and pollutants present in marine water. Around and inside Constanta harbour was observed an oil film near the ships paths, this film was evidenced using the linear regression processing method. As can be seen in fig. 6 the relative concentration of oil spill was lower (approximately 5 times smaller) than the DOM relative concentration.

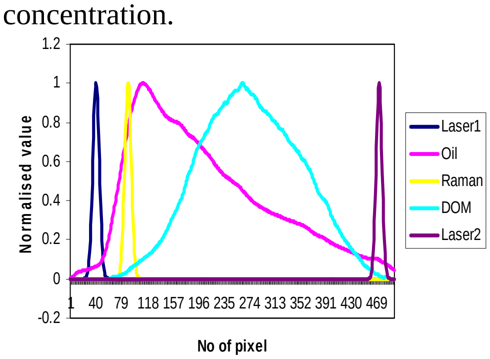

Fig. 5 Calibration file for UV excitation laser beam

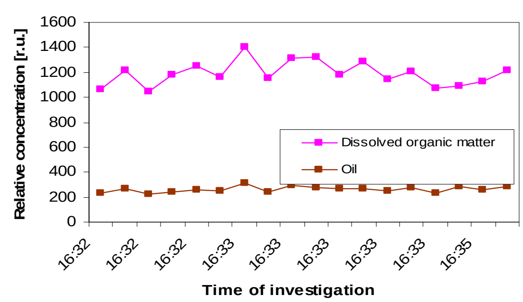

Fig. 6 Distribution of oil spills analysed through linear regression

Channels relationship

The channels relationship method (CRM) is a simple mathematical method, which computes the ratio between relative intensities of the normalized fluorescence signal. The fluorescence signal is divided into an arbitrary number of channels. These are related to the necessary sensitivity of the analysis or distinct spectral fluorescence fingerprints. The fluorescence fingerprints are dominant/ important only for some spectral intervals used.

The CRM processing method analysed data archived during the august campaign using a Labview program (fig. 7). The signal can be split into maximum 551 channels, which represent the integrating aria between the graphic points selected. When the analysis is based on the ratio between fluorescence signal intensity and Raman line intensity (only 2 channels) the method is known as the fluorescence ratio technique. Figure 8 shows CRM processed data, where the ratio represents the relation between DOM fluorescence and oil spill fluorescence integral area. It is obvious that oil concentration is important for three signals (marked 1, 2, 3) where the ratio is approximately three times higher than in previous measurements. This method doesn't allow identification of signals with closed spectral fingerprints.

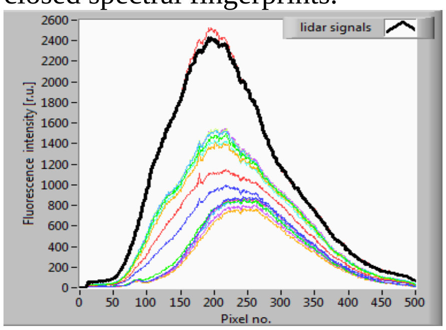

Fig. 7 Lidar signal with oil spills

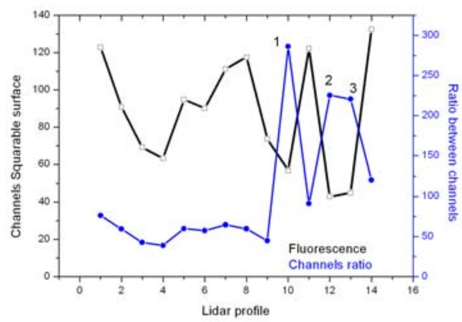

Fig. 8 Lidar signal analyzed through linear regression

Neural networks

Artificial Neural Network (ANN) represents a mathematical projection of human neural network. The architecture of a neural network depends on the data set to be analyzed. The units of ANN are the neurons at the bases of the layers, including input, output and hidden layers. The data for analysis must be constrained to a pattern and the ANN needs to be taught to identify this pattern. The hyperbolic tangent function is the most used transfer function for the ANN due to its monotonicity and continuity, while the multilayer perceptron (MLP) is the most utilized type of networks [7].

The data achieved during 2007 campaign were analyzed using ANN. For input, 35 channel files with 50 mixed data sets, containing fluorescence fingerprint of oil spills, oil emulsion and DOM were used. The Momentum learning rule and 1000 maximum number of epochs for training were considered. Figure 9 shows the MLP errors on training and classification. The MLP with three hidden layers presented the smallest training errors. Even if the errors at production and testing are small, the ANN recognizes only eight signals from ten and consequently, the ANN needs a more extended data set for training. After several retrains the ANN recognized sometimes all signals and the errors are diminishing to 4.5%. This processing method is useful for online recognition of oil spills, the sensitivity is dependent on training data set and training rule.

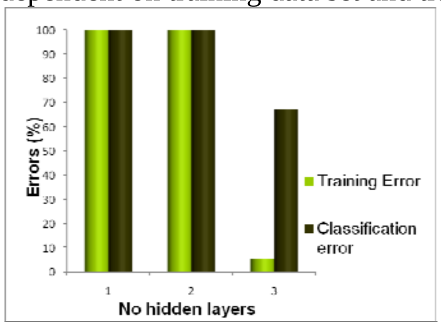

Fig. 9 Multilayer Perceptron errors for Lidar data classification

5. Conclusions

The main advantage of Lidar methods is the real time observation of fluorescence water components, which can be further used to identify the oil spills concentration along the ship trajectories. The accuracy of the obtained information is dependent on the technical performances of the device and on the sensitivity of the data processing method. Three different processing methods were used to analyze the oil spills observed during 2007 Black Sea campaign: linear regression, channels relationship and artificial neural networks. The accuracy of oil spills identification depends on the database already available. Linear regression or channels relationship are suitable to be used for revealing the distribution of oils on a path while ANN is suitable to be used to identify the type of oils.

Acknowledgements

The LIDAR data classification was carried out using the NeuroSolutions software (www.nd.com).

REFERENCES

[1] *R. Measures,* Laser remote sensing: fundamentals and applications, *Krieger Publishing Company*, Malabar, Florida, 1992

[2] *GD Hickman, JE Hogg,* Remote Sensing of Environment **1**, 47, 1969

[3] *R.M. Measures, M. Bristow*, Canadian Aeronautics and Space Journal **17**, 421, 1971

[4] *R. Reuter, H. Wang, R. Willkomm, K. Loguay, T. Hengstermann, A. Braun*, EARSEL Advances in Remote Sensing, **3**, 152, 1995

[5] *S. Babichenko,* Spectral fluorescent signatures in diagnostics of water environment, Vali Press, Tallin, 2001

[6] *J. Vasilescu, L. Belegante, C. Sliwinski, C. P. Cristescu,* UPB Sci Bull, Series A, **70**, 41, 2008

[7] *A.K. Jain, R.P.W. Duin and J. Mao*, IEEE Transactions on Pattern Analysis and Machine Intelligence, **22**, 4, 2000.