Airborne Laser (LiDAR) Bathymetry for Precision Capture and Survey of River Beds and Belonging Territories

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Key words: Hydrography, Airborne Laser Altimetry, Shallow Water Areas, Full Waveform Analysis, European Water Framework Directive

"... The deep water is useful in many ways, but it is harmful - may to drown in it. But it can be avoided - learn to swim. "
Democritus

SUMMARY

The report examines an innovative and effective technology for a detailed study and a precision monitoring of river beds, watercourses, lakes and dams, namely air laser (LiDAR) bathymetry. It provides an opportunity to be determined at the same time as the depths of shallow systems and the topography of the floodable of them belonging territories and all this with an unbeatable level of consistency and detail. In the report is made a critical comparative analysis of data obtained by scanning a portion of Ogosta river with two different laser scanners - *RIEGL* LMS-Q680i and *RIEGL* VQ-820-G Topo-Hydrographic Airborne Laser Scanner, as well as a number of conclusions and recommendations for the use of examined technology in practice. Highlighted is the need for close collaboration and partnership between research units, business and social-management area for the full and multi-faceted use of the great potential of these modern sensors, optimizing the methods to transform data into information systems and improving the use of water resources and population protection in emergencies and disasters.

РЕЗЮМЕ

Докладът разглежда една иновативна и ефективна технология за детайлно изучаване и високоточен мониторинг на речни корита, езера и язовири, а именно въздушната лазерна (LiDAR) батиметрия. Тя осигурява възможност да се определят едновременно както дълбочините на плитководни системи, така и топографията на заливаните от тях прилежащи площи и то с ненадминато ниво на последователност и детайлност. В доклада е направен критичен сравнителен анализ на данните, получени от сканирането на част от поречието на река Огоста с два различни лазерни скенера - *RIEGL* LMS-Q680i и *RIEGL* VQ-820-G Topo-Hydrographic Airborne Laser Scanner, както и редица изводи и препоръки за използване на разгледаната технология в практиката. Изтъкната е и необходимостта от постигане на тясното сътрудничество и партньорство между научно-изследователските звена, бизнеса и социално - управленческата сфера за пълноценното и многостранно използване на големите потенциални възможности на тези съвременни сензори, оптимизиране на методите за трансформиране на данните в информационните системи и усъвършенстване на използването на водните ресурси и надеждна защита на населението при аварии и бедствия.

INTRODUCTION

From ancient times people inhabit mostly the territories around rivers, lakes and other water sources. Water is not only life determining, but in many cases it dictates and the course of human history – for example, spills and low tides of Nile river are determined to a large extent the overall life of the Egyptians. To this day, continuously develop and refine methods for measuring and studying watersheds.

The main and primary goal of science, the policy and business should be to satisfy the interests and needs of people and the environmental protection. One of the most radical and ambitious programmes adopted by the EU is a famous water framework directive (WFD). Its main objective is the improvement of the quality of aquatic ecosystems all across Europe and the reliable protection of the population in flood. We need to emphasize its fundamental and interdisciplinary nature. It puts the environment at the Centre, in the heart of the objectives of the management in Europe. For her performance, it is necessary to study the complex interactions between the hydromorphological, physical and chemical, biological, and human impacts on the environmental conditions in the various pools and objects around them. The effective and sustainable implementation of the WFD requires the development of new methods for the monitoring of the waters, as well as better reporting of biophysical and anthropogenic pressure in terms of the ecological balance of watersheds in Europe. Previous studies have suggested that many EU Member States are struggling to meet their commitments under the framework directive on water, but in practice are not in a position to respond adequately to its objectives.

To address these and of a number of other tasks in hydro engineering foundational role plays the availability of information about the topography of lakes, dams, rivers, floodplain terraces, estuaries or coastal areas. Despite the huge advances in computer technology and mathematical modelling (for example 2D and 3D-modeling) of hydraulic objects, it is important to ensure real numerical data and models. The digital elevation models of the coastal areas traditionally are created on the basis of simplified and interpolated data, obtained on the basis of cross-sections, manually collectand during ground-based measurements of terrain or through eholot data.

Due to the lack of spatial information with high resolution for water masses on rivers, of shallow areas such as meadows, estuaries, river shores or dunes, the modelling and study of these structures is in the general case labor intensive, and sometimes even impossible for task execution. Frequent lately riparian and coastal flooding in populated areas undoubtedly give rise to an urgent and pressing need of improving methodsfor documentation of the watersheds.

In recent years, increasingly clearly stands out and having the need to qualitatively, quickly and economically feasible study of the dynamics of the water level, the structure and zone variations of lakes, dams, rivers and riparian zones (as well as the degradation of the rivers, the streams or reservoirs, and a number of other coastal sequestration processes).

Society needs and requires a reliable, timely and detailed information about the size of the water quantities and for probability and the risk of dangerous flooding. Only upon this premise could take adequate measures for the prevention and mitigation of the consequences of floods.

This is important to learning not only the water quantities, but also the actual form of the watersheds, sediments, overwhelms, or man-made structural changes of watersheds. Furthermore, it is essential and any additional information such as the availability of data for the ground surface and roughness. The innovative technology of airborne laser bathymetry has an ambitious aims to decide and it is of high technical and professional level of all these problems. Globally, the latest trend in this regard is the use of digital models with perfect quality and high resolution derived from topographic aerial laser data. Over the past few years, the spatial laser (LiDAR) scanning quickly developed and refined and is increasingly widely used mainly in the following three main areas — terrestrial, mobile and airborne. Extraction of high-quality spatial data with their main characteristics as XYZ coordinates, and 16-bit high resolution information about the intensity of the objects represents a uniform basis for all three of the above directions.

After the scientific development of any new technology is necessary to comprehensive practical verification and performance evaluation and study of the accuracy and reliability of the final results and data. These report is dedicated to airborne laser bathymetry, as made a critical comparative analysis of data obtained by scanning a portion of Ogosta river with two different laser scanners - RIEGL LMS-Q680i and RIEGL VQ-820-G Topo-Hydrographic Airborne Laser Scanner.

Practical main objective is to address a bit more detail differences between referreds two types of airborne scanners from one and the same manufacturer based on the wavelength of the laser pulses. But before this we stop for a bit of the entire (RIEGL LMS-Q680i) and realtime (RIEGL VQ-820-G Topo-Hydrographic Airborne Laser Scanner) waveform analysis – a technology that provide high density, quality and precision of the received data. For guaranteed receipt the reflected signal from a small in size objects must have met the conditions, illustrated in Fig. 1.

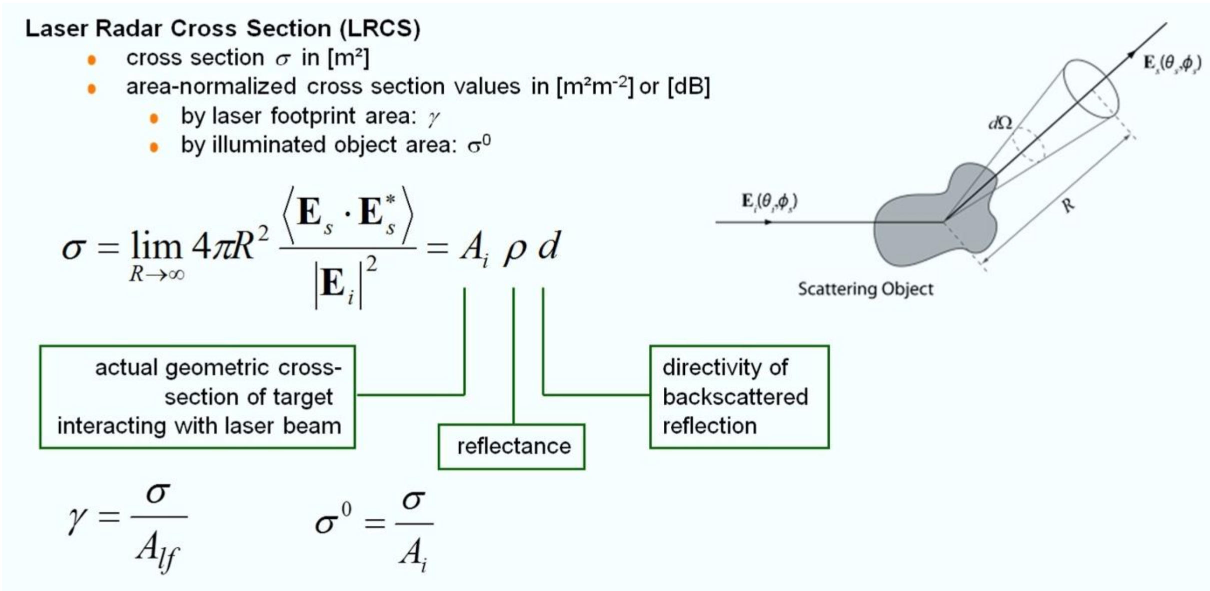


Fig.1 Radiometric calibration of the reflected signal

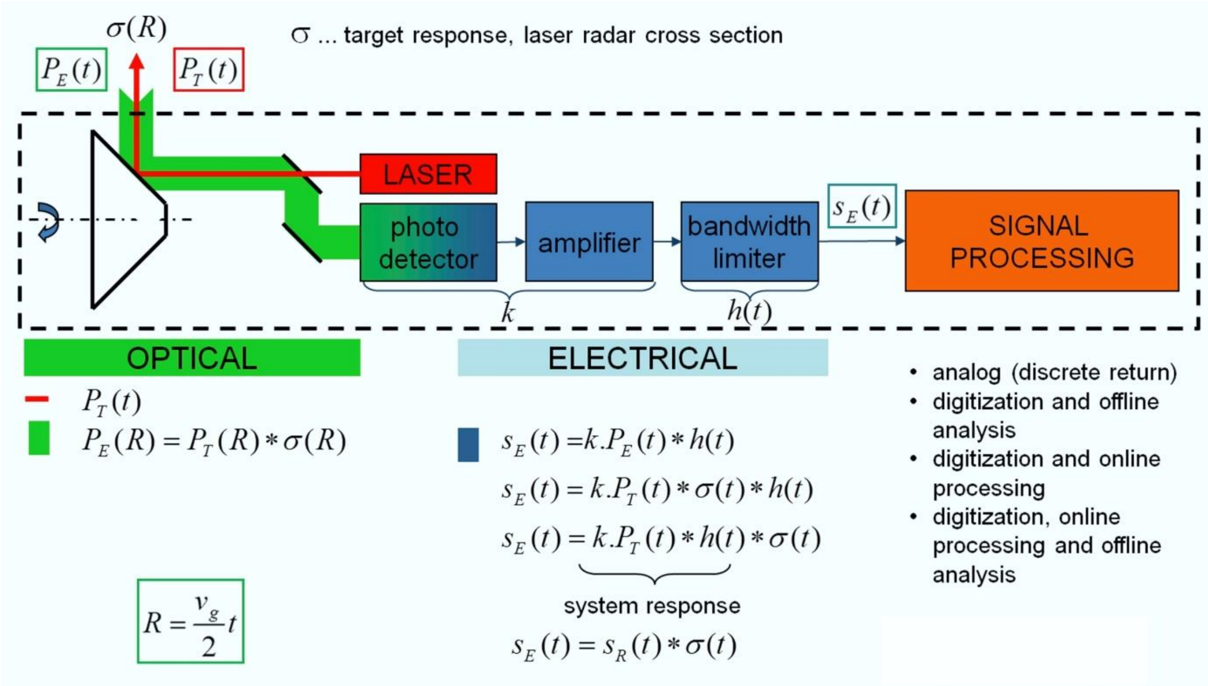


Fig. 2 Block diagram of RIEGL LiDAR instrument

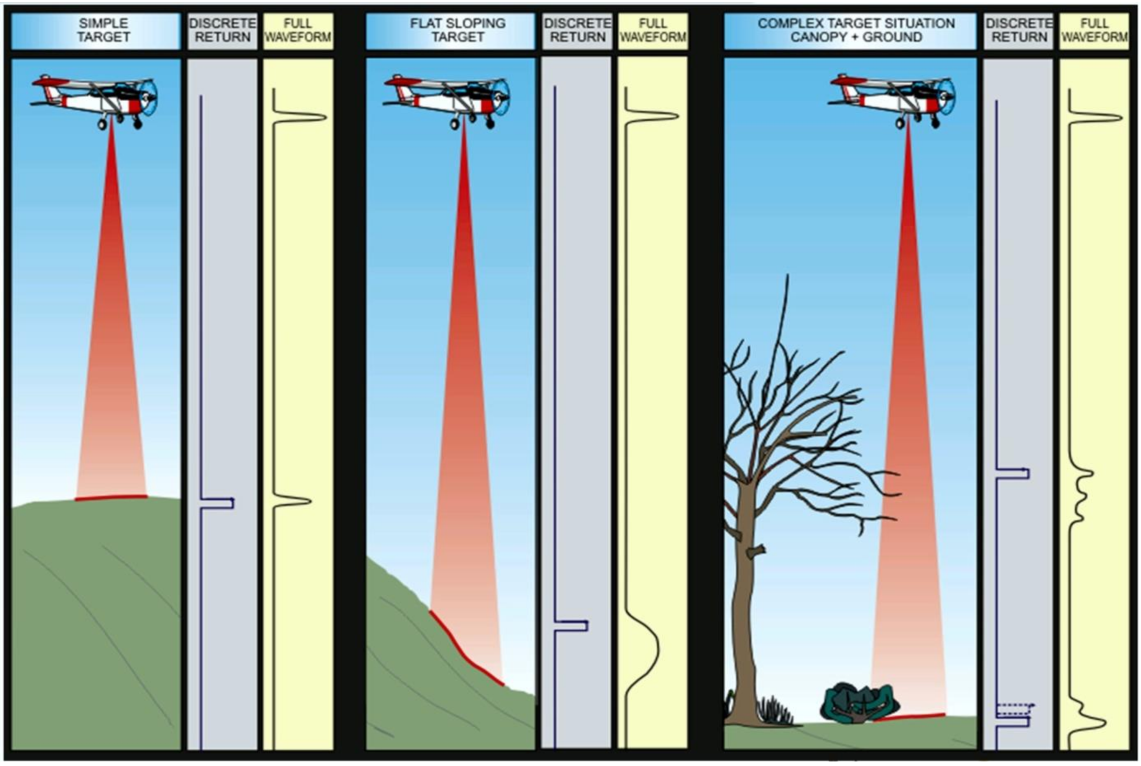


Fig. 3 A single reflected signal in comparison with one, but with a full-wave analysis

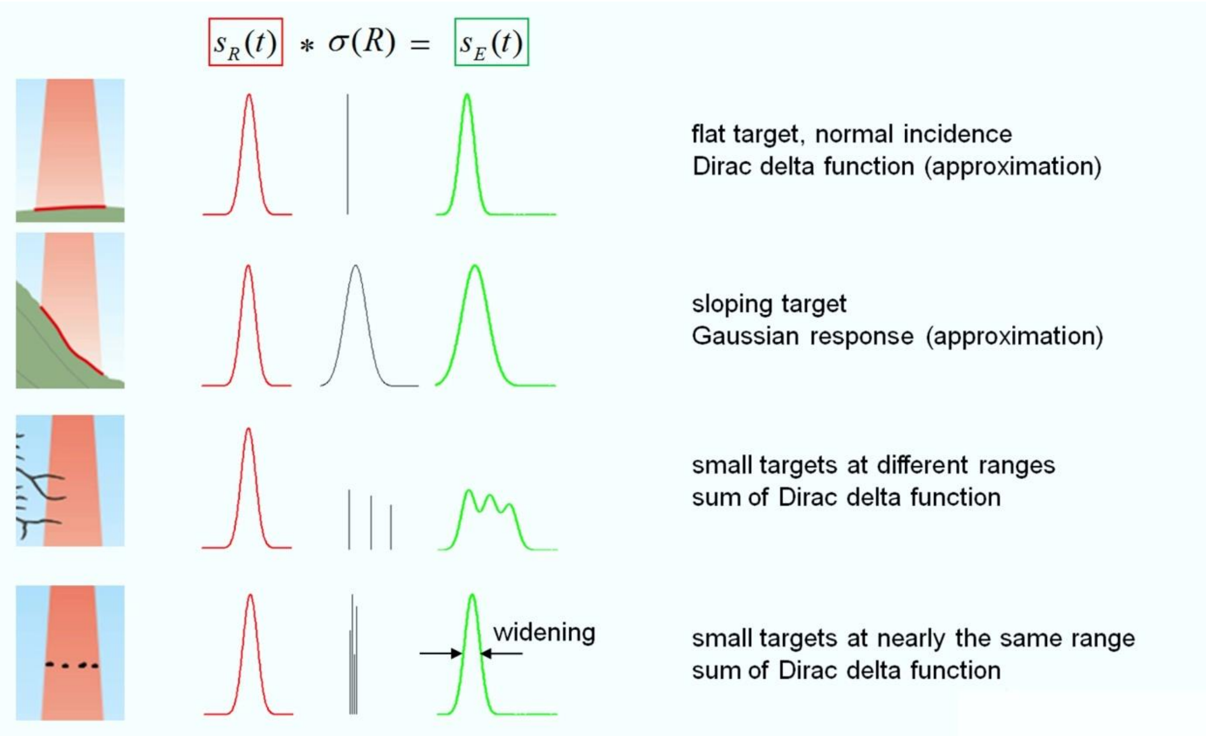


Fig. 4 Amplitude comparison received from the various objects

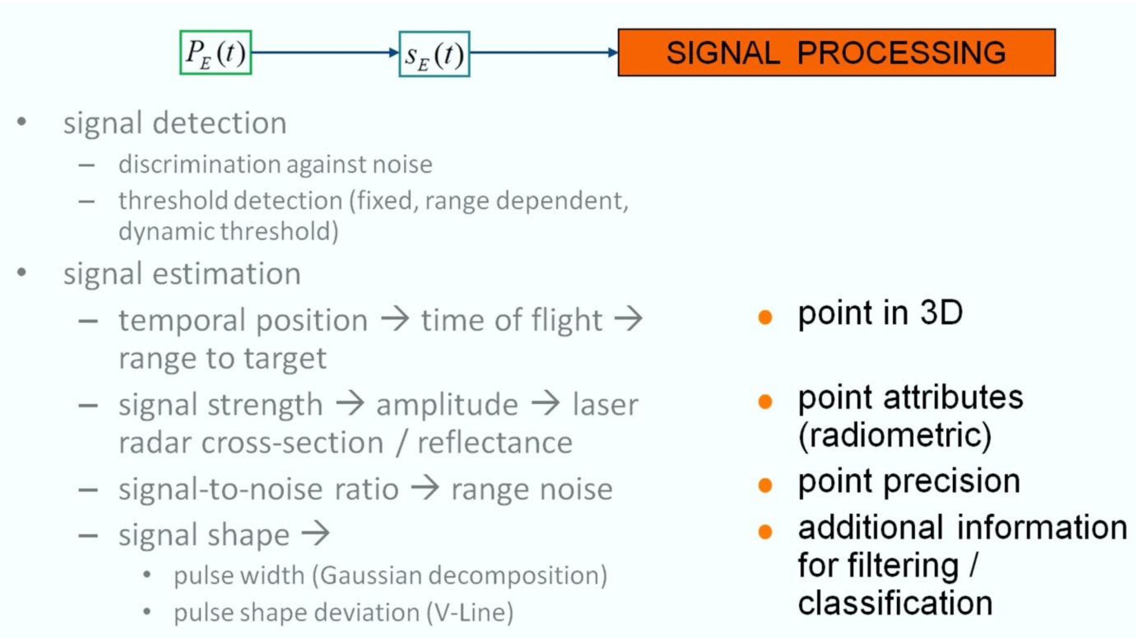


Fig. 5 Tasks and results of the waveform analysis implementation

The reflecting ability of the objects represents another important characteristic, which is directly related to the wavelength of the laser pulse fig. 2.

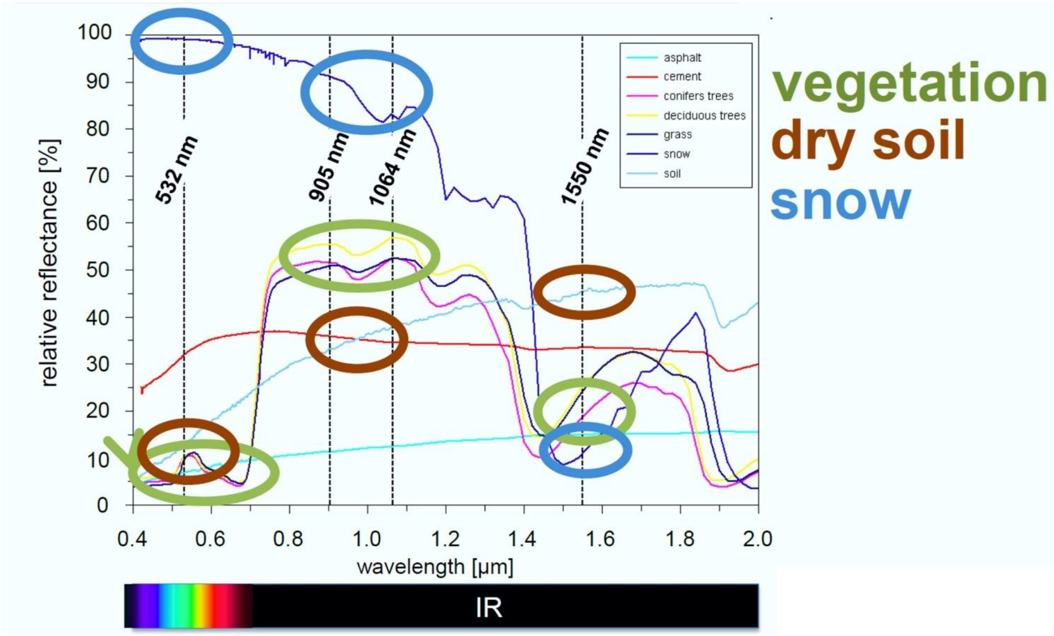


Fig.6 Reflecting ability of different objects relative to the wavelength

Here is one urban area scanned with three different laser scanners with three wavelengths of the laser pulse, namely 1550, 1064 and 532 nm.

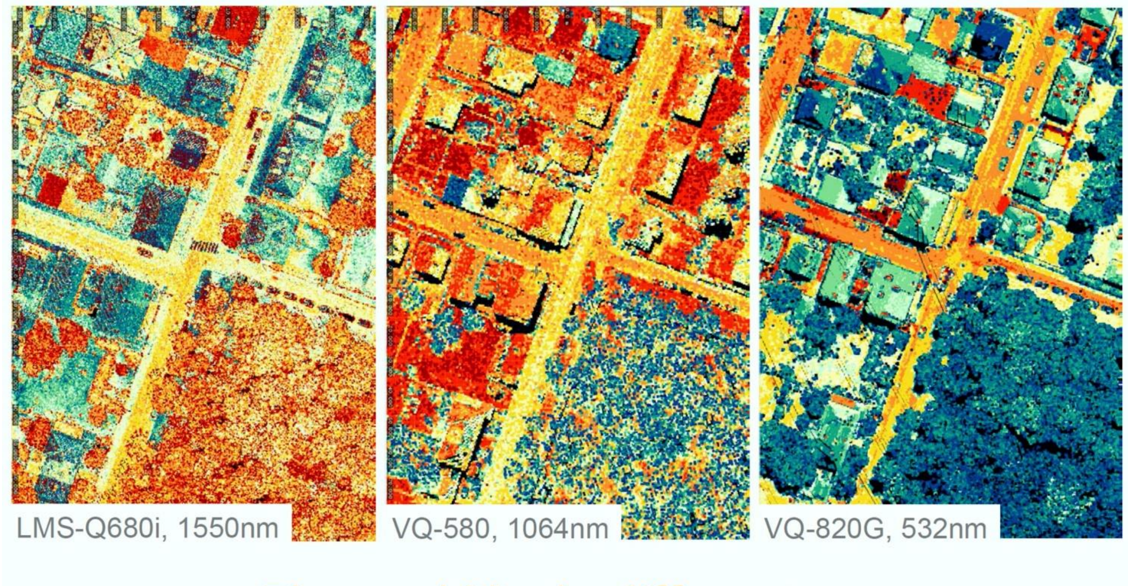
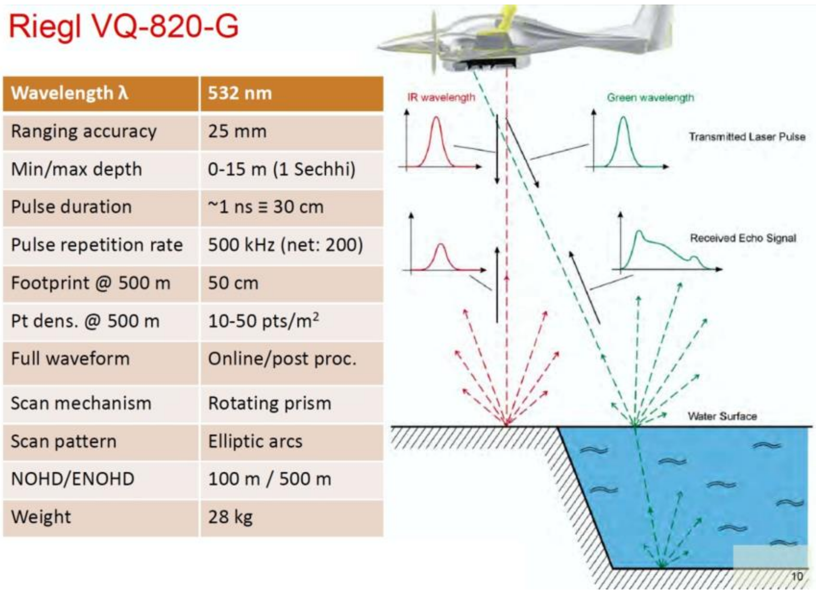


Fig.7 Views of one location scanned with three different wavelengths – indeed the world is presented in a different way

Laser pulses with a wavelength of 532 nm pass through water obstacles and are able after returning to provide spatial information about the objects located below the water surface. The extent of penetration of the laser pulses in the aquatic environment depends on the transparency of the water column, the latter is determined by the disk of Sechhi. On FIG. 4 you can see the main technical parameters of the scanner VQ-820-G.



Riegl VQ-820-G

Wavelength λ	532 nm
Ranging accuracy	25 mm
Min/max depth	0-15 m (1 Sechhi)
Pulse duration	~1 ns ≡ 30 cm
Pulse repetition rate	500 kHz (net: 200)
Footprint @ 500 m	50 cm
Pt dens. @ 500 m	10-50 pts/m²
Full waveform	Online/post proc.
Scan mechanism	Rotating prism
Scan pattern	Elliptic arcs
NOHD/ENOHD	100 m / 500 m
Weight	28 kg

Fig. 8 Technical specifications of RIEGL VQ-820-G Topo-Hydrographic Airborne Laser Scanner with a scheme of the reflecting signal from underwater ground object

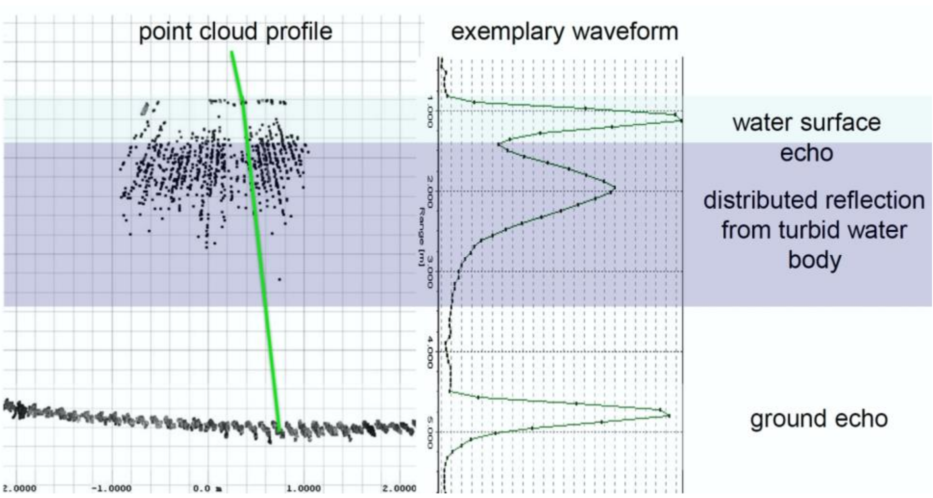


Fig. 9 Waveform derived from reflected water surface, turbulent water particles and underwater final (ground) object

The object, which lies at the heart of the practical research is small section from Ogosta river, situated immediately before inflow in "Ogosta" dam - fig.10.

Fig.10 Orthophoto of the scanned territory

The object was scanned with two scanner instruments – with 1550nm LMS-Q680i and with 532 nm VQ-820-G, with the same DSM density, namely from 9 points of m^2. From the two point DSM models are derived two DTM models, they latter are interpolated further with step 0.2 m.

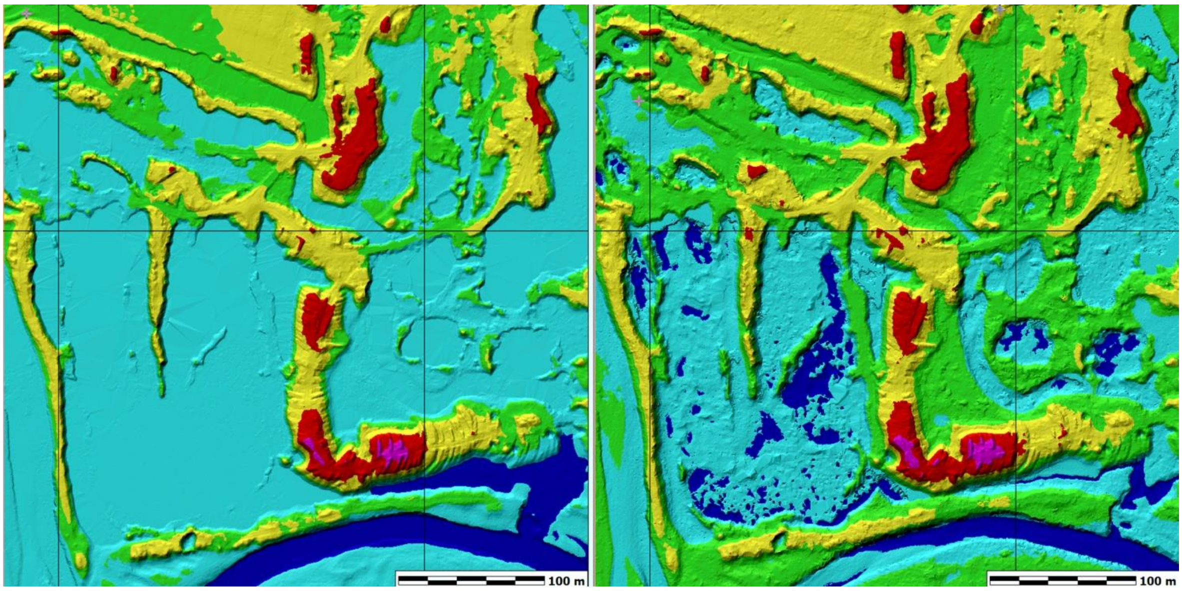


Fig.11 On the left is shown DEM by 1550nm LMS-Q680i, and in right - DEM from a scanner 532 nm VQ-820-G

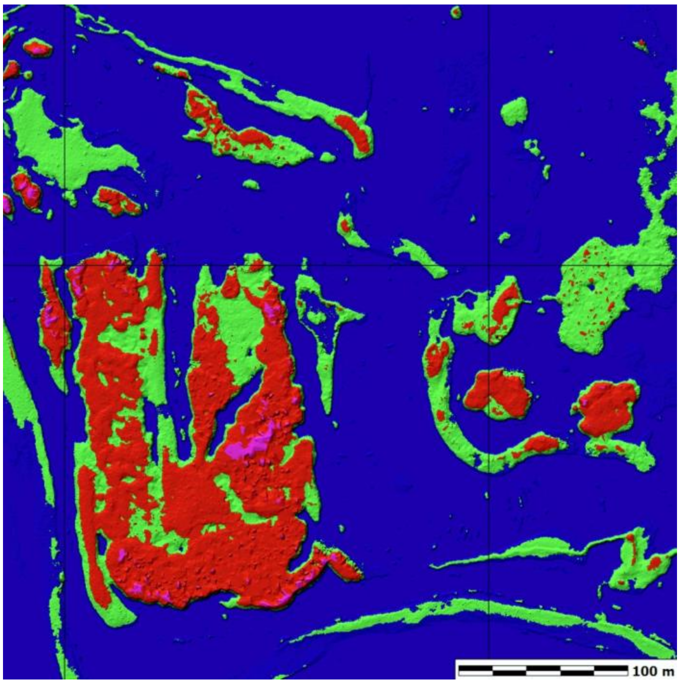


Fig.12 Absolute height difference between DEM from scanner 1550 nm LMS-Q680i and DEM from scanner 532 nm VQ-820-G - "protruding" parts visualized in practice the volume of the water table and the structure of the underwater surface

The so created two DEM models are subjected to an elevation analysis. In parallel with this were made GPS measurements of about 50 distinctive surface and underwater sub-sites for the purpose of carrying out a comparative analysis with the classic technology. The spatial differences in the measurements of the above water portions between the two scans are within +/- 1-3 cm, which in practice represents the accuracy of measurement of laser rangefinder devices. The differences in relation to GPS measurements surface and underwater parts are in the range of + 5-8 cm, that attaches to the different geoids bases for the measurements – by scanning is used the European geoid EGM08, while GPS measurements used this by Bulgarian coordinate system 2005.

The largest depth measured by scanning in the particular object and confirmed by the GPS measurement is 3.15 m. The Fig. 13 and Fig. 14 are shown two high-altitude profiles, made on the basis of the two different DEMs:

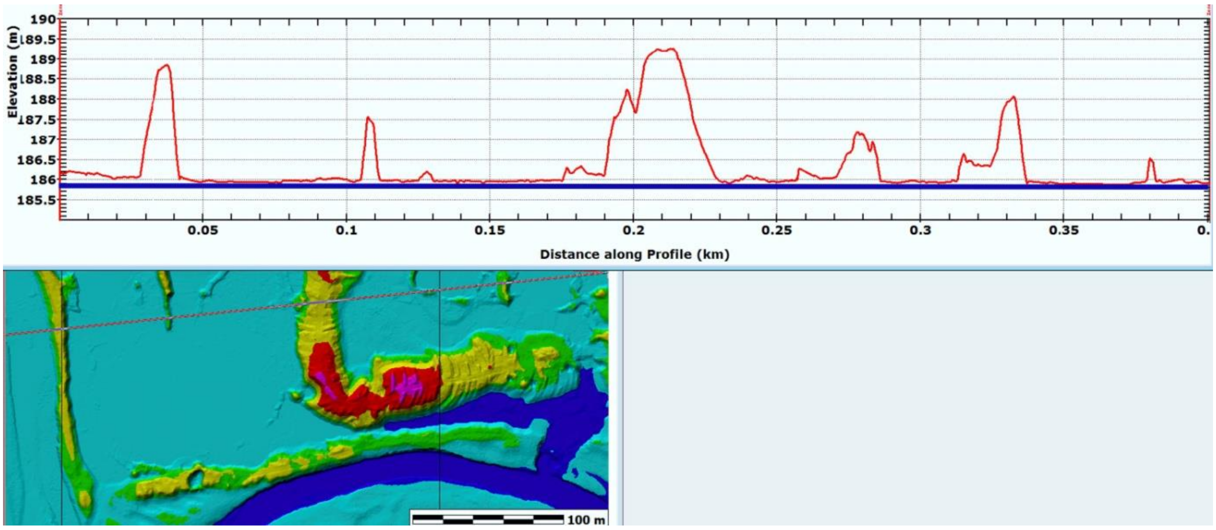


Fig. 13 Cross-section of DEM from scanner 1550 nm LMS-Q680i

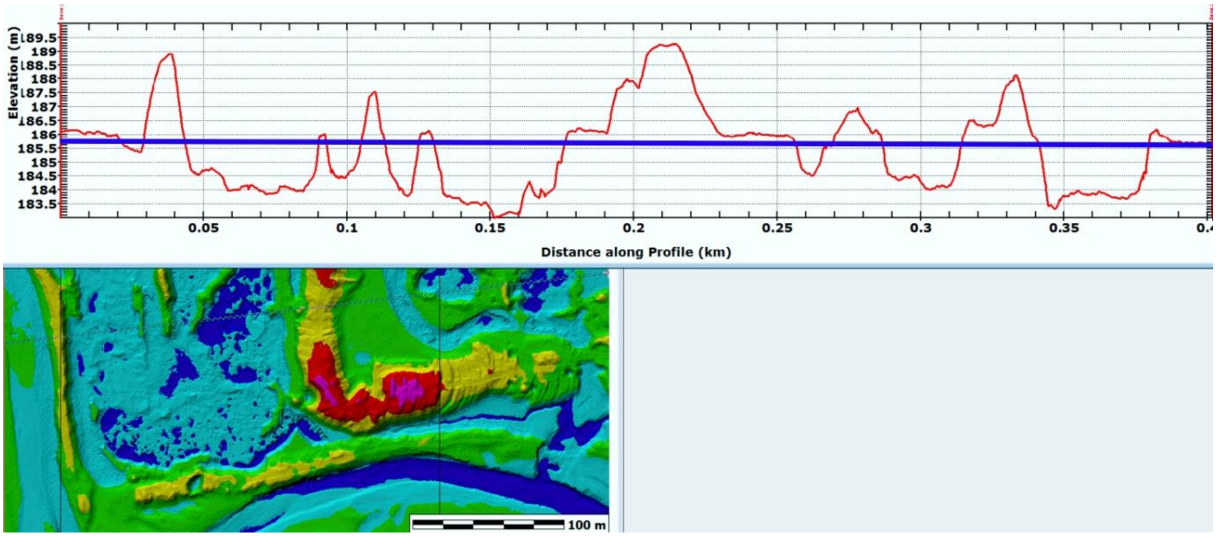


Fig. 14 Cross-section of DEM from scanner 532 nm VQ-820-G

Clearly stands out the water level height of about 186 m at the first profile and what the ground is below that level from the second profile.

The Bulgarian rivers are small in depth (shallow) and the Topo-Hydrographic (bathymetric) Airborne Laser Scanners, such as 532 nm VQ-820-G can be successfully used for the complete mapping of the river beds and bottoms in order to accurately calculate the dynamics of water in the prevention of floods and so on.

CONCLUSIONS

Deployment of airborne laser (LiDAR) bathymetry for the overall and detailed 3D surveying and exploration of watercourses and other shallow-water sites and facilities certainly enables to save time, labor and economic-technical means and provides a unique opportunity to be consigned to history traditional to date methods and tools for measuring the water basin - Fig. 15.

Fig. 15 To avoid this already dangerous work

The role and importance of that discussed innovative technology for airborne laser (LiDAR) bathymetry is expressed in several aspects, namely:

- Economic
- Scientific and Research
- Political
- Humane

This technology on the one hand greatly improves the quality and efficiency of learning of complexity and dynamics of hydraulic, geo-morphological and environmental processes by rivers, lakes and dams, on the other hand helps to revise and reform motivation and business decisions related to the facilities and management of water resources to optimize and refine measures in terms of prevention and protection of the population from floods and gives practically unlimited possibilities for reliable monitoring required by the EU, in accordance with Framework Directive (WFD).

Can make confident recommendations for the use of technology that discussed in the practice. It is to achieve close cooperation and partnership between research bodies, businesses and social-managment field for the full and multilateral use of the big potential of these laser sensor instruments. It is important to optimize methods to transform data information systems and improvement of the mere use of water resources and provide reliable protection of the population in case of accidents and disasters. Of great importance for the whole society - both of scientific research and the socio-economic level is the implementation and optimal relationship between customers and contractors - making applications for study Water systems recovery of information about customer needs.

Scientific and economic benefits of that discussed application of technology are significant, both at national and at European and international level. Successful implementation of the airborne laser bathymetry concerns the resolution of such colossal problems like energy and the work of national and international hydroelectric companies, monitoring rivers and reservoirs, specialized hydro studies, consultations and other engineering services.

In this respect, dense spatial data supplied by airborne laser (LiDAR) bathymetry will undoubtedly contribute greatly to better study the eco-hydro-morphological processes, as are innovative methods and tools, combined with appropriate software and service packages. Deservedly can be seen as an important prerequisite for cost effective and sustainable implementation of the WFD. They contributed significantly to the recovery of damaged eco-systems, and waning and limit future potential adverse impacts associated with climate change and water in Europe.

OUTLOOK

Today, people often seem to forget that the Earth is a living organism with its immutable crises and whims. Nature has an arsenal of disasters including floods. We can not eliminate them completely, but we can study them, modeling, analyze, predict, to minimize the damage caused by them. Research and practical achievements in this area are higher IQ test and humanity of all mankind in the struggle to tame the wrath of nature for the benefit of all mankind. The challenges are before us, the fate of Earth is in our hands and we have no choice - we must act properly and in time for the sake of our children, because it is our responsibility - to beat and humanity to survive ... Even today we have to start we are late ... Let us not forget that the Earth is our common mother - she bore us and feed us. Let us not be ungrateful her children. We modern people have to realize it in time and that the spaceship "Earth" no VIP, nor third class passengers, we are crew all accountable and responsible to take care of our only planet and its population. We ought not to destroy, but to multiply its natural resources. And until it was hopelessly late to tap the wisdom of the ages and to deal with the challenges of our time each of us gives his own, albeit very modest contribution to the preservation of the harmony of nature to continue the Earth to rotate , lit by the life-giving sunlight, and donate air, water and food for our children and their descendants ....

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BIOGRAPHICAL NOTES

Nelly Zdravchev graduated "Geodesy, Photogrammetry and Cartography" as leader of graduates in VIAS - now UACG. Also graduated with honors and in "Methodology of teaching technical subjects" at the Medical University. Specialized and Applied Mathematics at the Technical University - TU. Longtime professor and assistant professor in the Department "Photogrammetry and Cartography". Doctor of Photogrammetry and Remote Sensing (GMF) and has authored more than 25 scientific papers and scientific reports, exported mainly to international conferences. Lectures. exercises and teaching practices GMF, architectural photogrammetry, and so on.. with the students of Faculty of Geodesy of the University. Its scientific interests are in the field of GMF, architectural photogrammetry, preservation of cultural heritage, pedagogy and education, philosophy, ecology, literature, poetry and design.

Peter Todorov – TU Sofia, CEO "Innovation Optic Electron Systems - IOES" since1990, implementation and system maintenance of classical, analytical and digital photogrammetric systems of Carl Zeiss, Intergraph, Z/I till 2001, laser (LiDAR) scanning systems RIEGL 2008, author of more than 30 application-scientific reports, interests in the field of remote sensing instruments for Earth exploration

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