C. NOEL[1] - C. VIALA[1] - M. COQUET[1] - B. ZERR[2]
S. BLOUET[3] - R DUPUY DE LA GRANDRIVE[3]
[1] SEMANTIC TS - France - noel@semantic-ts.fr [2] ENSIETA Brest - France
[3] ADENA – Site Natura 2000 « Posidonies du Cap d'Agde » – France

MULTI-SENSORS DATA FUSION METHOD DEVOTED TO SEA BOTTOM VEGETATION MAPPING AND MONITORING

Abstract

This paper first presents multi-sensors mini-oceanographic survey unit devoted to sea bottom mapping and monitoring developed by SEMANTIC TS, which is an acoustic oceanography research and development company. Then it deals with research tasks conducted by SEMANTIC TS in collaboration with GESMA and ENSIETA, to develop a mapping method for underwater seabed. First stage is to develop methods for characterizing vegetation and sediment on the seabed using the acoustic response from a conventional single beam echo sounder. These new methods are then operated simultaneously with multi-beams sonar producing micro-relief information and side scan sonar providing gray scale levels associated with bottom reflectivity. Then fusion of these data is processed. We show efficiency of these multi-sensors survey unit and multi-sensors data fusion concepts to get very precise seabed vegetation mapping allowing monitoring, in a way optimizing truth control (video and diving investigations). Examples are given from mapping made with ADENA manager on 2000 Natural Site « Posidonies du Cap d'Agde » and in Thau lagoon. The Cap d'Agde site presents the particularity of having discontinous seagrass forming a patched meadow with frequent marine turbidity conditions that makes visual observations and aerial mapping difficult.

Key-words : Marine vegetation – Mapping - Monitoring - Multi-sensors data fusion – Acoustic classification – Natura 2000

Introduction

Research tasks presented here referred to a global project relative to development of an operational bottom mapping method devoted to underwater vegetations, from the development of a multi-sensors survey unit to data fusion of collected data. This project comes out observation of similar mapping needs in civil and military environments, because vegetation may hide bottom mines and can significantly affect the performance of acoustic sensors used for sea-mines detection.

Materials and methods

Semantic TS has begun the project by setting up a coastal survey vessel devoted to environmental submarine surveys and maps. This survey unit is a small size semi-rigid boat (6.5 m) with removable cabin, allowing moving easily on a road-trailer, boat and all its equipments and instrumentation systems (Fig. 1).

Fig. 1. Survey unit SEMANTIC : semi-rigid with removable cabin.

Professional category Useful load: 1000 kg Draught: 30 cm Length: 6,4 m
Motor: 115 CV 220 V in board. Available power 24/24: direct: 500W / spike: 800 W

This mini-survey unit is a French professional registered boat, driven by STCW professional pilots (captains 200). Objectives of this boat are to improve mapping of coastal submarine, harbors, lakes, rivers (zero state area studies and their time evolution), submarine bottom survey for structures establishment, monitoring of submarine vegetation boundaries or sediment movements. Small size is useful to move precisely in narrow sea areas or to strictly follow predefined survey lines, which is a necessary condition for monitoring purposes.

This small size survey unit presents high level of technology, both for platform positioning systems and for acoustic sensors. Boat is able to produced energy to process simultaneously all the instrumentation in 24h/24h. High speed internet aboard is process by 3G to pass on D-GPS RTK corrections, from land reference D-GPS station, in real time. Instrumentation systems are simultaneously deployed on the mini-survey vessel as shown on Fig. 2:

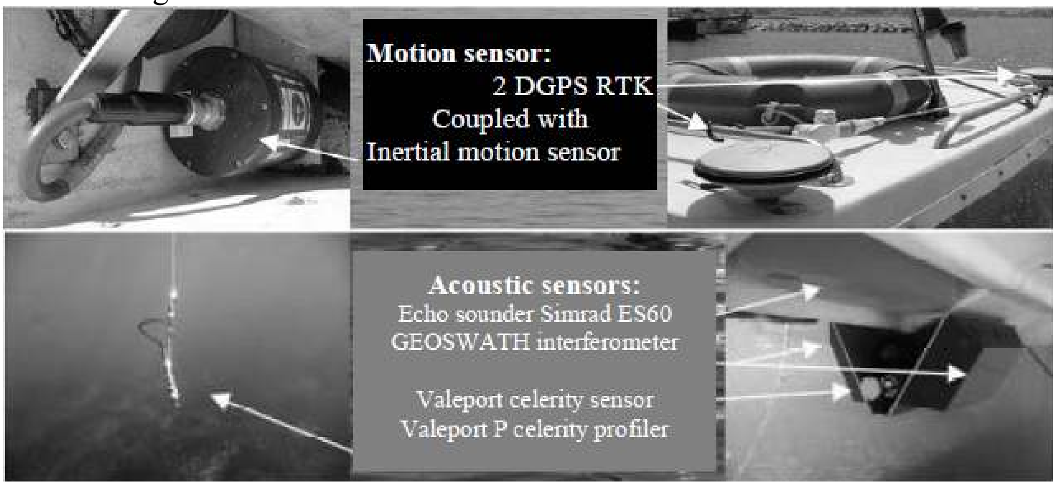


Fig. 2. Instrumentation systems. D-GPS differential RTK Leica GX1230 centimetric system - Motion sensor Coda Octopus FS185+

• Interferometric system Geoswath+ NG	Multibeam bathymetry
• Interferometric side scan sonar Geoswath+ NG	Precisely geo-located mosaic picture at 250 kHz
• Towed side scan sonar Klein 3900 / 5000	High resolution acoustic imagery
• Frequency 455 kHz / 900 kHz,	
• Resolution 20 cm at 75 meters.	
• Range max: 150 meters.	
• Echo sounding Simrad ES60 high precision (scientific)	Bathymetry/biocenoses/sedimentology
• Motion sensor Coda Octopus FS185+	Positioning and motion correction
• 2 D-GPS RTK Novatel	Location and motion correction
• 2 D-GPS RTK Leica	Land reference station and topography
• Automatic navigation and sailing system POSEIDON	Autopilot on predefined survey lines
• Data acquisition station	
• Internet and VPN high rate	Data transmission / reception
• Mini-SVS Valeport profiler	Sound velocity profiles acquisition
• Acquisition and processing data devices	
• Geographic Information System - 19” shelves available	
• Professional divers. Video camera	

Methods are operated simultaneously. Fig. 3 shows principle of multi-sensors acquisition.

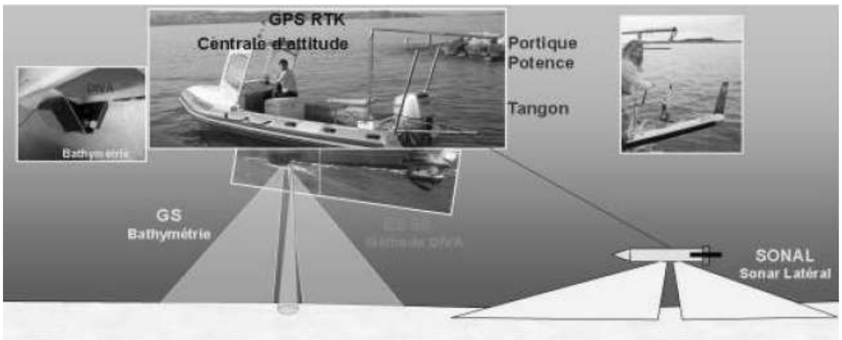


Fig. 3. Principle of multi-sensors acquisition.

To drive all these instruments we have developed a specific software, playing role of an orchestra chef, named POSEIDON. This software pilots data synchronization, acquisition, datation and positioning. As precise 3D scan pictures of sea bottom could only be obtained with very high accuracy at each step of data acquisition and processing, we have incorporated into POSEIDON, GIS functionalities, processing algorithms and data fusion process.

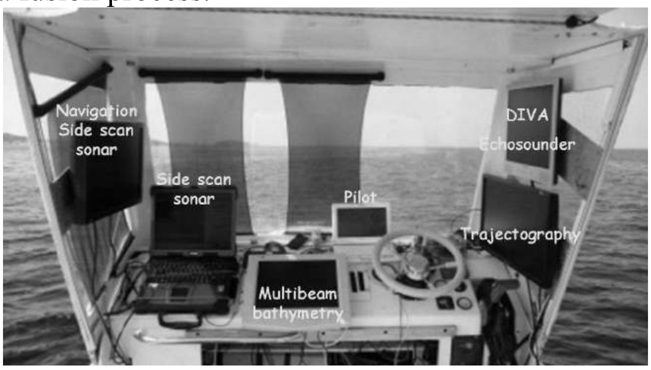
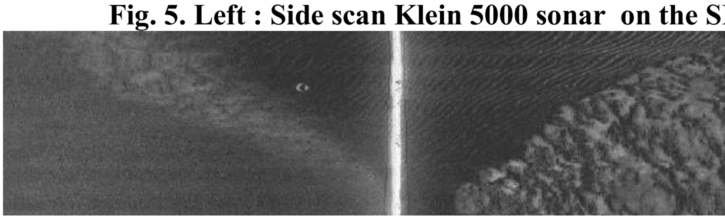


Fig. 4. Mini-survey vessel operational cockpit during multi-sensors acquisition.

Fig. 5. Left : Side scan Klein 5000 sonar on the SEMANTIC survey vessel.



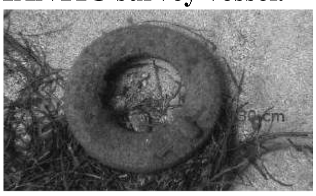


Fig 7. Example of high resolution acoustic picture by Klein 3900. picture Left : Tire on ripple sand (photo on Fig. 8). Right : posidonia meadow.

Fig 8. Submarine of Fig 7. tire.

Results

In order to produce help to acoustic imagery interpretation, we have first developed specific methods devoted to vegetation and sediment classification. Principle of DIVA method (Detection & Investigation Vertical Acoustic), devoted to vegetation, is resumed on Fig 9. The shape of acoustic bottom impulse response from a scientific echo sounder is recorded simultaneously with centimetric GPS position. As sand and vegetation have different acoustic signature shapes, we have developed a signal processing algorithm based on discriminant analysis and energy level of the bottom reflected impulse response (Viala *et al.*, 2007, Noel *et al.*, 2005, Noel *et al.*, 2006). Box in Fig 9. shows samples of sand and Zostera acoustic signature.

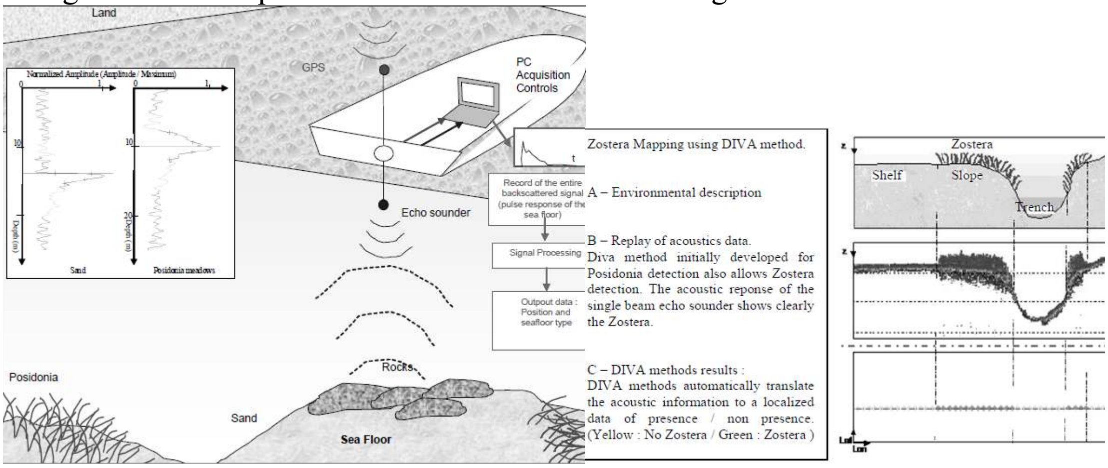


Fig 9. Left : Principle of DIVA method. In box : Representatives echoes.- Right : Illustration of DIVA approach in Zostera mapping.

The DIVA method initially developed to Posidonia characterization is also efficient for Zostera localization and cartography. But an there is only one vertical acoustic echo, it's a low coverage method. The multibeam bathymetry of the survey area is a real advantage in addition to DIVA results, because it gives help, to circle bathymetric stage (between -2 m and - 3.5 m), where zostera may be present. Simultaneous measurement using DIVA method should then increase the performance of multi sensors fusion method. We can also recommend to implement 3 to 5 DIVA sensors on a pole, perpendicularly to the ship course. The DIVA method, developed by SEMANTIC TS, leads to various data, accurate and very well localized, in complement with those recorded from a towed video system which can be considered as "field truth". It also allows a rapid mapping of the vegetation in coastal plain; it can cover about 100 km line of survey per day and can help to georeferenced surface picture. The main inconvenience is the difficulty to find discriminant parameter when rock and vegetation are both present in the survey area. It can be noticed that DIVA method also gives excellent results on kelp mapping (VIALA *et al.*, 2009). In addition, considering its high accuracy in data positioning (less than 1 meter), DIVA method can easily be used in time evolution growing surveys of various species of coastal marine vegetation. Furthermore, due to its rapid capacity of deployment and data collecting, the DIVA method can be considered as a low cost mapping method when used on its own. The effective surface covered is small but can easily detect and define boundaries of coastal marine vegetation by multiplying the survey lines. It also allows localized intervention in case of doubt. By this way, the DIVA method can be a substitute for more accurate but slower method (such as diving or towed video system) or less accurate but faster method (such as towed side san sonar which are not so well georeferenced due to underwater side scan imprecised location). (NOEL *et al.*, 2010). Moreover, we are now working to extend DIVA method into sediment classification (CLASS Method in progress), by the mean of hardness/roughness characterization, based on Chivers and al works (Chivers *et al.*, 1990).

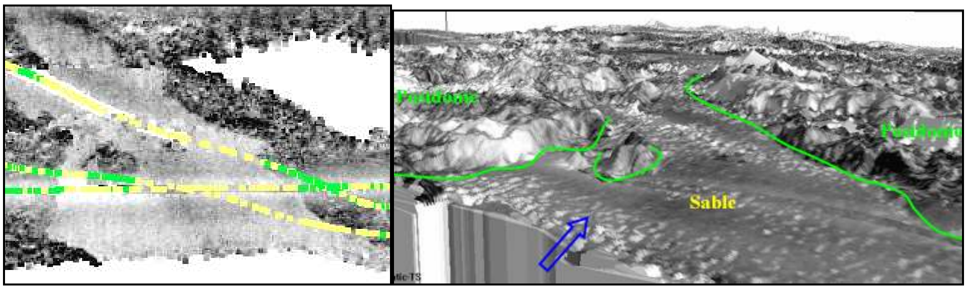


Fig. 10. Natura 2000 Site « Posidonies du Cap d'Agde » Left : view from sky : Results of DIVA method in Mediterranean area (in green : posidonia, in yellow: sand) superposed to gray scale side scan sonar mosaic from Geoswath system. Right : 3D scan picture of posidonia meadow: micro relief (from Geoswath bathymetric system) fusioned with DIVA results and side scan sonar mosaic.

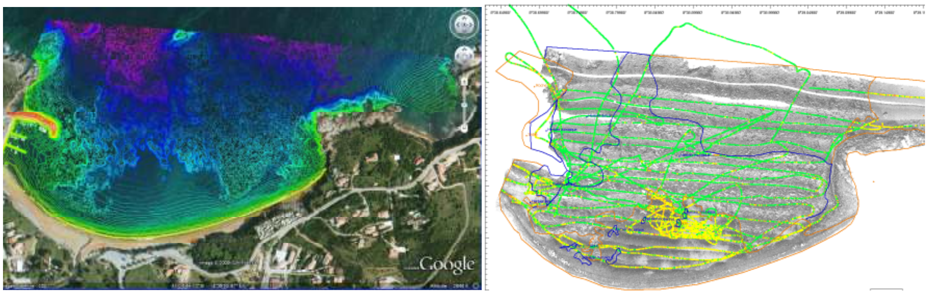


Fig. 11. Left : Micro-roughness results derived from precise bathymetry method results in posidonia/sand area may help to sonar mosaic interpretation - Right : Illustration of DIVA method results in Mediterranean area (in green : posidonia, in yellow: sand) superposed to gray scale side scan sonar mosaic from Geoswath system.

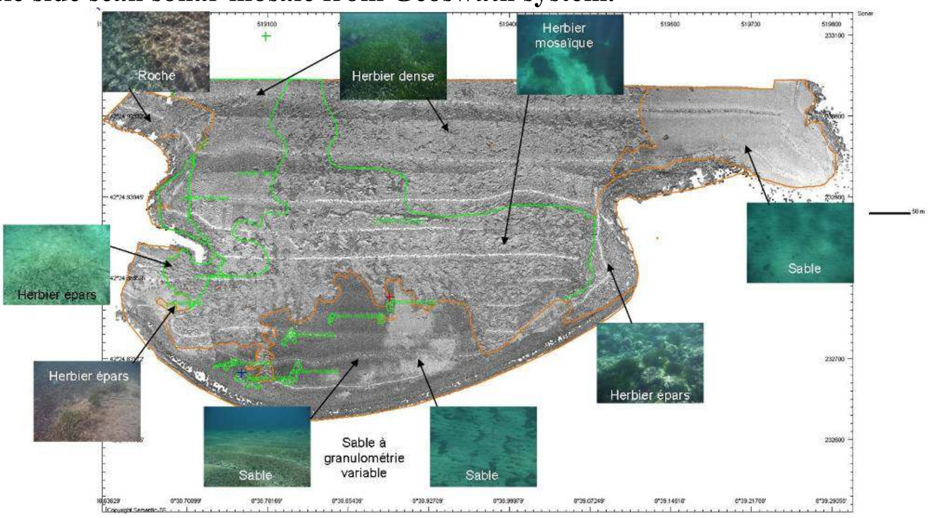


Fig. 12. Illustration of multi-sensors data fusion method results in posidonia case, allowing meadows and sand areas contouring.

So as to produce precise 3D sea bottom mapping, we have developed on a second stage **a method based on the fusion of data provided by acoustic systems** (Noel *et al.*, 2008) :

- Geoswath bathymetric system
- Side scan sonar systems (Geoswath or Klein)
- Echo sounder

Methods are operated simultaneously, and data fusion is realized by combining, after signal processing, the data collection obtained:

- 3D bathymetric data

- Side scan sonar imagery in grey levels, producing information about reflectivity, and so about bottom nature.
- Micro-roughness derived from precise bathymetry
- DIVA method information about presence and absence of vegetation.
- CLASS method (in progress) information about bottom roughness and hardness

These methods have been successfully applied in Corsica and French Riviera (see. Fig.11 & 12). It has also been especially tried with ADENA team, on the complex case of Natural 2000 site of Cap d'Agde, showing excellent mapping results in a turbid water area and typically patched meadow. Fig. 10 illustrates efficiency of boundary determination using DIVA method in case of dense posidonia meadows and sand. Right part of Fig.10 shows 3D representation of the bottom, which can be considered as a 3D echography of the bottom. Such precise and innovative 3D scan pictures of vegetation could only be obtained with very high accuracy at each step of data acquisition and processing. For this we had to develop a specific GIS software inside which, we have incorporated processing algorithms.

Discussion and/or conclusions

Data fusion concept is innovative and powerful. It allows producing like in medical applications, very accurate 3D scan pictures of seabed derived from different sources (side-scan, multi-beams, echo sounder) and information (aerian pictures, classification methods results, divers/video observations …). Power of data fusion concept remains on the quality of the data and on their complementarities. In this context such a mini-survey unit, able to operate and synchronize several complementary high resolution acoustic sensors simultaneously, and to precisely process motion and geo-positioning, appears as a very efficient tool in the crucial data collection first step of the data fusion process.

Acknowledgments

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