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Comparison of coastal marine vegetation mapping methods

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Abstract:
This article presents the results of comparisons of DIVA method (French acronym for Vertical Acoustic Detection and Inspection) developed by SEMANTIC TS with optical (towed video systems MOBIDIC and MOOGLI) and acoustic (side scan sonar) methods deployed by IFREMER in three different areas: (i) Les Embiez (Western Toulon), (ii) Saint Raphael (data collected during the INTERREG IIIB / POSIDONIA program, web site) and (iii) Le Bassin d'Arcachon for Zostera meadows cartography. The DIVA method is particularly efficient when it completes the usual methods performed by IFREMER.

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1. Introduction

Submarine vegetation mapping methods consist in using acoustic and optical methods as well as diving. Concerning optical methods, IFREMER has developed a towed video system dedicated to submarine vegetation cartography called « MOBIDIC » (Module d'Observation des Biocénoses par Imagerie Digitale pour le Côtier). This system is complementary of the acoustic method (side scan sonar) usually used by IFREMER (EDGETECH 110 kHz side scan sonar).

For its part, SEMANTIC TS company has been conducting research works since 2004 in the particular field of acoustic cartography of Posidonia seabeds. SEMANTIC TS developed an acoustic detection method at the vertical of the ship which is particularly groundbreaking. This method is called DIVA (French acronym for Vertical Acoustic Detection and Inspection). The first step of this work consisted in transferring visual observation of an acoustic response of the vegetation on the echo sounder screen, as well as fish on the water column (LURTON, 2002), to an automatic method of sea grass detection (NOEL *et al.*, 2005). This was done through the analysis of the acoustic response of the sea floor and studies of its acoustic signature characterisation (VIALA *et al.*, 2006) which demonstrated the pertinence of the DIVA method for the side scan mosaic interpretation and an optimized classification of the sea floor covered with vegetation (VIALA *et al.*, 2006 ; VIALA *et al.*, 2007). The operational results make comparisons possible with methods usually conducted by the IFREMER.

In the field of acoustic characterisation of the sea floor, several systems are available; one of the most well known is the RoxAnn system developed by the Scottish company Stenmar Micro Systems Ltd. This system, which is onboard of the IFREMER' ship « Haliotis », is essentially focused on the seabed characterisation. It processes in real time the part of the acoustic signal after the bottom detection and gives two indexes (E1 for the roughness and E2 for the hardness) which allows an automatic classification of the seabed nature according to its roughness (smooth and muddy sediment vs. rough and coarse sediment) (GUYOMARD, 1994 ; SHOM, 1997). As for the DIVA method, it has been specially developed to work on vegetation coverage and particularly on the Posidonia meadow in the Mediterranean Sea. It processes part of the acoustic signal recorded before the bottom detection. A specific modular processing signal has been developed using echo-integration and discriminant analysis algorithms, allowing a better characterisation of the received signal.

In order to improve its performance in benthic cartography, SEMANTIC TS deploys simultaneously the DIVA method and several acoustic sensors: side scan sonar and multi beam echo sounder (KLEIN 5000 and GEOSWATH) and a single beam echo sounder (SIMRAD ES60). SEMANTIC TS worked in collaboration with the GESMA/DGA (Groupe d'Etudes Sous-Marines de l'Atlantique de la Direction Générale de l'Armement) on acoustic data fusion methods coming from several sensors so called a multi-sensor fusion method (VIALA *et al.*, 2008), which is particularly attractive for sea floor vegetation mapping. These methods were recently deployed in the Arcachon Basin in order to cartography Zostera meadow and gave very promising results (NOEL *et al.*, 2009), showing the accuracy and the rapidity of the deployment of such methods.

This article presents in a first part the comparison of the DIVA method with the towed video method developed by the IFREMER achieved on a coastal Mediterranean site, La Vaille, located near Les Embiez, Var, France. Then, it compares the results of the DIVA method with those used during the INTERREG IIIB / POSIDONIA (web site) program on two different places and species of seagrass: at Saint Raphael (Var, France) on Posidonia,) and on the Arcachon Basin (Gironde, on the French Atlantic coast) on Zostera.

2. Methods

2.1 DIVA Method (Détection & Inspection Verticale Acoustique)

The acoustic DIVA method for marine vegetation mapping operates as follows : the instrumented ship moves to the survey area (fig 1a); on board a PC records the various data coming from the different sensors i.e. :

- Position from the differential GPS (latitude, longitude, sea level elevation).
- Pulse response from the acoustic signal reflected by the sea ground from the echo sounder.

For a given position, the PC combines information on the vegetation characteristics. On board the ship, SEMANTIC TS is operating a mono frequency acoustic sounder. This echo sounder (Simrad ES60 model) is also commonly used for characterisation of fish species by acoustics (LURTON, 2002). The system processes and parses the pulse response to deduct the characteristics of the seafloor vegetation. , The acoustic response of the echo sounder is very different, depending on the density of the vegetation covering the sea floor. Figure 1b presents two echoes (sound level *vs* depth), one coming from a sandy floor and one from a vegetation covered floor. In the second case, the signal shape shows the presence of energy before the bottom detection. This energy is proportional to the extent of the biomass. This method, based on shape analysis of backscattered signal, does not require calibration of the echo sounder.

The accuracy of the DIVA method decreased with depth. Typically, if phanerogame seagrass are detected at 10 m deep, the geographical accuracy is approximately 1 meter but falls to approximately 3 meters at 25 m deep, due to the spatial diffusion of the signal. The ping rate of this system is 5 Hz, which allows a good data recovering. The acquisition speed is about 7 knots, allowing a linear survey of 100 km per day (max).

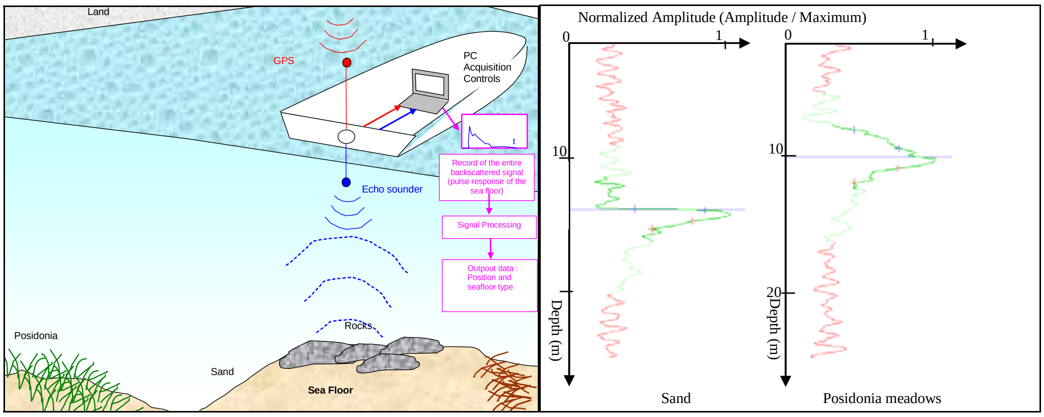


Figure 1. a) Principle of DIVA method. b) Representatives echoes.

2.2 Towed video systems of IFREMER (figure 2)

The video module MOBIDIC HD developed by IFREMER has been used in parallel with the DIVA system.

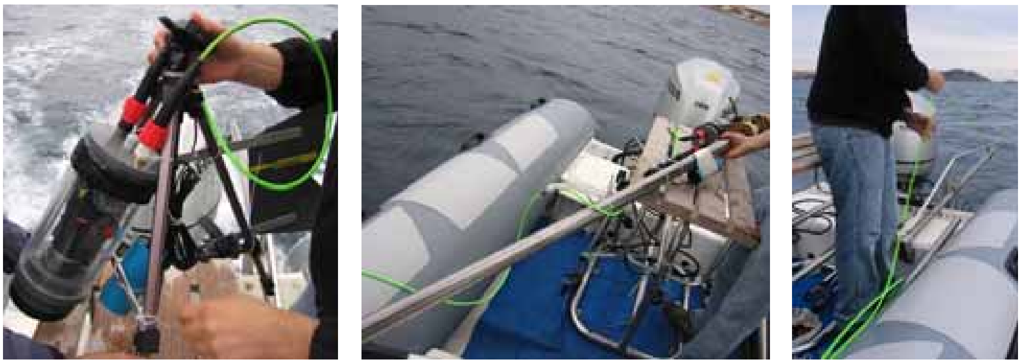


Figure 2. From left to right : MOBIDIC module – support stick – “Tangon”.

This video module is composed of a high definition numeric video camera (Sony ™ model HDR HC1) installed inside a clear waterproof cylinder closed by a spherical porthole, allowing a wide angle vision. An altimeter calculates the system altitude above the seafloor. Two methods of deployment have been tested: (i) fixed at the end of a metal pole and immerged just under the ship and (ii) towed using a 30 meter or 100 meter cable, according to the survey area depth.

The geographical accuracy of data collected is about 5 meters (which is the accuracy of a fixed GPS) at the typical towing speed of 1.5 knots. One image is recorded each second. The daily linear distance surveyed is practically 10 km (max).

In the Arcachon basin, IFREMER deployed a second version of the towed video system (MOOGLI). This system is constituted of a Plexiglas frame containing the video camera, the altitude sensor (Fig 3a), removable ballast and a tow cable. This system is suitable for any ship type.

Figure 3. a)Video camera frame.   b) Acquisition station.

A surface state control (Fig. 3b) composed of a mini PC is linked to the system through RS232 communication during the acquisition. A software ("Videonav") automatically records data transmitted by the sensors with a video time code. Each line is recorded in a table format which allows future processing using standard tools.

The standard sensors composing this system are: a GPS for the YY position, two single beam echo sounders for the water depth under the ship and the towed system. Two other sensors can be added:. "VideoNav" is configurable depending on the type of surveys and is provided for in situ comments and/or other field data measurements. Depending on the survey protocol, the MOOGLI system can realise cartography on a linear trajectory but also some visual punctual verification in order to calibrate acoustic methods. During the cartography of the Arcachon Basin, the MOOGLI device has been used in various locations in order to validate the results of DIVA method operated by SEMANTIC TS.

2.3 IFREMER' side scan sonar

The side scan sonar deployed by IFREMER is an EdgeTech DF1000. It is a dual frequency sonar 100 and 380 kHz. The transverse main lobe aperture is 50° and the longitudinal main lobe aperture depends on the used frequency: 1.2° at 100 kHz and 0.5° at 380 kHz. For security reasons (towed system) this system is generally deployed in area with a depth greater than 10 meters. So, the accuracy of the side scan sonar information is strongly linked to the depth, the cable length and the trajectory of the side scan sonar. The uncertainty can be estimated at 10 m for a 30 meter depth. The ping rate is 1 to 5 Hz, the towed speed is 5 knots and the swath is 100 to 200 m depending on the frequency. It allows a linear survey distance of 70 km per day.

3. Combined results on Posidonia Meadows

3.1 <u>DIVA / MOBIDIC</u>

The data acquired by the echo sounder have been processed with the acoustic method DIVA. SEMANTIC TS and IFREMER jointly analyzed the results of this experimentation in order to define the performances of acoustic imagery on homogeneous and discontinuous seabed. Images from Fig. 4 show two extracts of the video corresponding to typical seabed types and surveyed both by acoustic methods (DIVA and side scan sonar). The data accuracy demonstrates the coherence of the results produced with the three methods (video camera, side scan sonar and DIVA). Sea trials have shown efficiency of a fixed video system for a better record of video in shallow water (less than 10 meters) due to a better data positioning and faster acquisition.

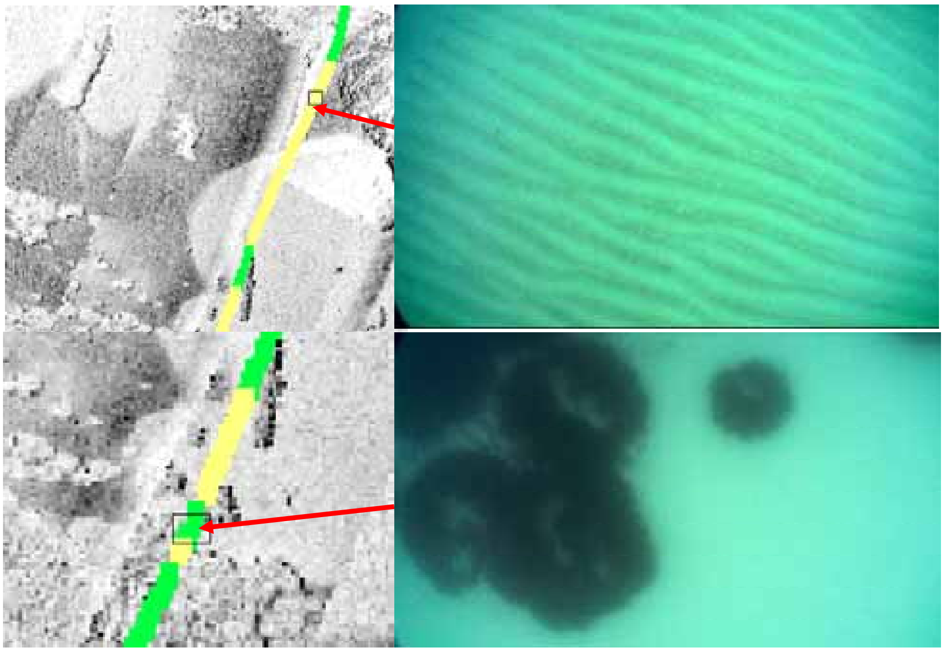


Figure 4.

Left: Side Scan Sonar Mosaic & DIVA results (Yellow/ Sand - Green/Posidonia)

Right: MOBIDIC data sample

Up: Coarse sand wave.   Down: Inhomogeneous Posidonia on fine sand

3.2 <u>DIVA / Side Scan Sonar</u>

DIVA method results are presented on Fig. 5 (side scan sonar mosaic of the EdgeTech DF1000 in the eastern part of “Rocher du Lion” near Saint Raphael).

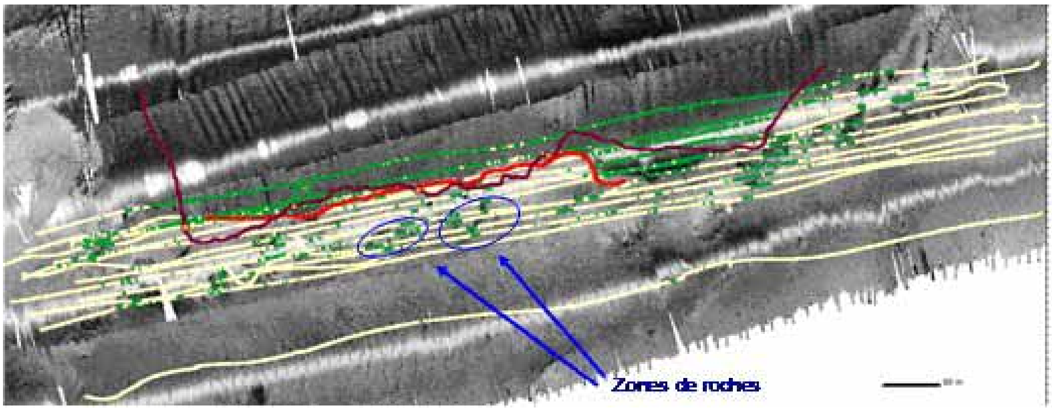


Figure 5. DIVA method results (Yellow/ Sand - Green/Posidonia) compared to diving data with GIB positioning (red) and towed videosystem (burgundy) with boundaries position reported in orange.

Data collected during several dives by the Italian team ENEA (INTERREG IIIB / POSIDONIA, web site) are positioned by the GIB system. These data are reported in red on the previous picture. Those collected by the towed video system of the IFREMER are marked in burgundy with observed boundaries between seafloor types reported in orange colour. It can be seen that the inferior boundaries derived from DIVA data is very consistent with the three others. Consequently, it demonstrates the efficiency of boundary determination using DIVA method in case of alternation of dense Posidonia meadows and sand. The DIVA method is capable of a correct discrimination between sand and Posidonia, pattern which corresponds to more than 80% of the studied cases, thus solving the problematic Posidonia detection on coastal plain. Under this limit, DIVA method finds some inhomogeneous Posidonia; however, side scan mosaic analysis has shown the presence of isolated rocks in this specific area. This difficulty of separately classifying rocks and Posidonia in DIVA method is currently under development and could be solved soon. For example, it appears that a principle based on the signal length affords to discern signals backscattered from rock from those backscattered from Posidonia as shown in figure 6.

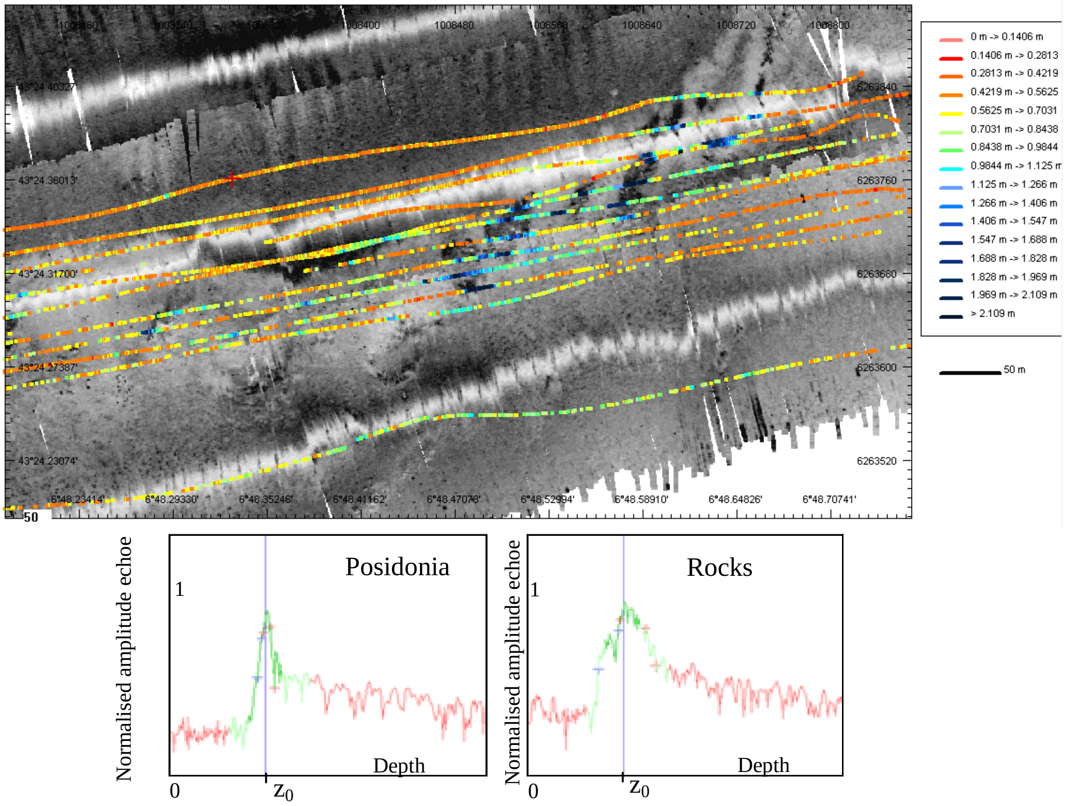


Figure 6. Up: Backscattered signal length (in m).
Down: Comparison between signal length in two different seafloor types.

Figure 7 illustrates DIVA method results in the “baie d’Agay” above the side scan sonar mosaic of the EdgeTech DF1000; it gives rise to the excellent coherence between the different methods.

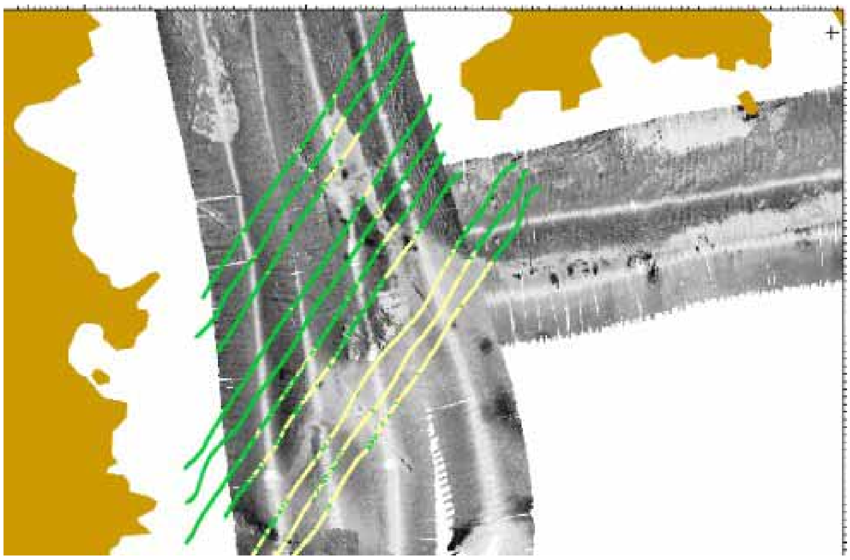


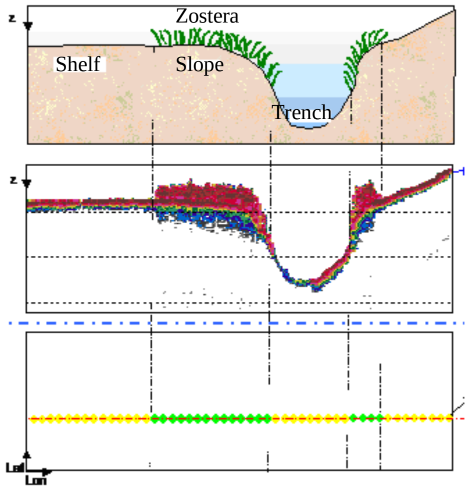
Figure 7. DIVA method results (Yellow/ Sand - Green/Posidonia) compared with side scan mosaic in the baie d’Agay (Saint Raphaël).

4. DIVA method results in Zostera detection

Figure 8 shows the application of DIVA method on Zostera meadows in the "Bassin d'Arcachon".

Figure 8. Zostera Mapping using DIVA method.

A – Environmental description
B – Replay of acoustics data:
Diva method initially developed for Posidonia detection also allows Zostera detection. The acoustic reponse of the single beam echo sounder shows clearly the Zostera.
C – DIVA methods results:
DIVA methods automatically translate the acoustic information to a localized data of presence / non presence. (Yellow : No Zostera / Green : Zostera)



As shown in figure 8, the acoustic response of *Zostera* is very characteristic in presence of this type of vegetation.

Zostera is located on the trench edges and strictly up to a certain depth. As a result, the bathymetry knowledge (through isobaths calculation) gives the inferior boundary in *Zostera* area, as shown in figure 9.

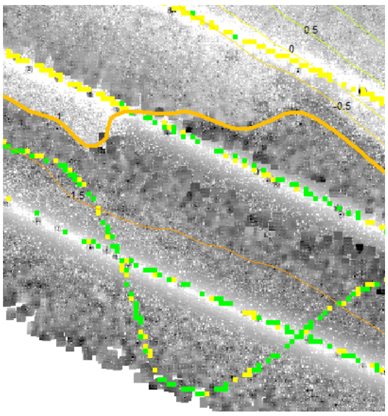


Figure 9. Side Scan mosaic extract compiled with other sensors :
- side scan data (grey level) ;
- DIVA method (yellow: sand - green : Zostera).
- In orange the -1m isobath.

Changes in the side scan grey level, DIVA method results correspond to a boundary related with bathymetry.

Data analysis from side scan sonar does not always make out a systematic acoustic signature for the *Zostera*. This can be interpreted by three different ways:

- *Zostera* is moving by current action and does not present a static behaviour like *Posidonia* where the mosaicing pattern can be different during high tide and low tide.

- *Zostera* is located on the edge of the trench' shelf: side scan sonar contrast results either from bathymetry or vegetation.
- Finally, due to tides, the incident angle of acoustic ray varies with survey time.

The DIVA method initially developed for *Posidonia* characterisation is also efficient for *Zostera* localisation and cartography. However, due to the use of a single beam echosounder, it's a low coverage method. Bathymetry knowledge of the survey area is a real advantage because it allows an easier delimitation by fusion with DIVA data (link between *Zostera* presence and area depth). Simultaneous measurement using DIVA method should 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's course.

5. Conclusions

Figure 10 sums up the main methods used for coastal marine vegetation mapping. It demonstrates that the systems deployed by the IFREMER and SEMANTIC TS are complementary (NOEL *et al.*, 2008).

The DIVA method, developed by SEMANTIC TS, leads to various accurate data, in complement with those recorded from the 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 of linear survey per day and can be use to realize a very efficient zeroing of surface images. The main inconvenience is the difficulty of finding discriminant parameters when rock and vegetation are both present in the survey area. It can be noticed that DIVA method also gives excellent results in kelp mapping (NOEL *et al.*, 2009). In addition, considering its high accuracy in data positioning (error less than 1 meter), DIVA method can easily be used to appraise the time-evolution of the various species of coastal marine vegetation.

Further more, 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 narrow but can easily detect and define boundaries of coastal marine vegetation pattern by multiplying the survey lines. It also allows localized intervention in case of doubt. In this way, the DIVA method can be a substitute for more accurate but slower methods (such as diving or towed video system) or less accurate but faster methods (such as side san sonar).

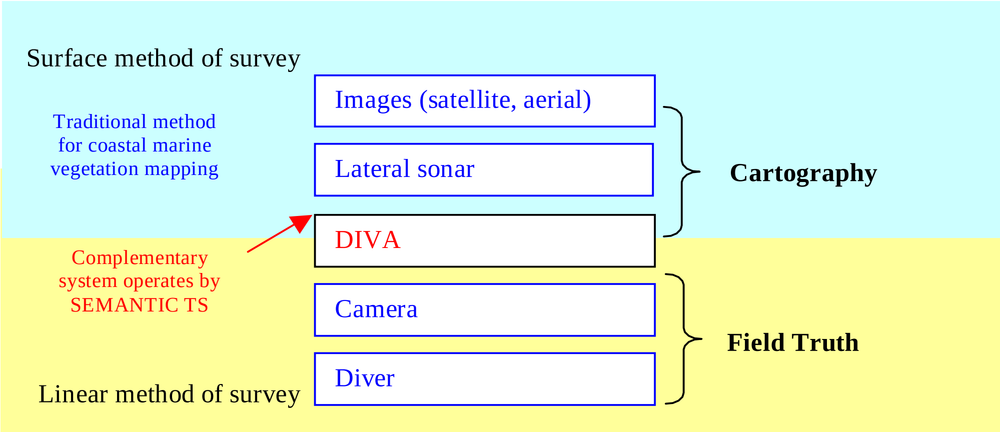


Figure 10. Positioning DIVA and traditional method for vegetation mapping.

The IFREMER methods (aerial pictures, satellite pictures and side scan sonar) allow to cover a large surface and are essential for a large-scale coastal vegetation mapping. Complementary method such as diving, towed video or DIVA should be used to validate data depending on the needs.

Acknowledgements

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