SOME METHODS OF THE SEA BOTTOM RECOGNITION

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Sea bottom structure recognition nowadays is a matter of great interest due to huge spectrum of potential applications, such as a hydrography, military oceanography, marine geosciences, offshore industry, environmental protection and many others. For that reason a great variety of tools and techniques for sea bottom measurements and modeling is developed. However, each technique leads to specific bottom images and allows to determine only few characteristics of examined area. In the paper are presented experimental results collected in the Gdansk Gulf region obtained by means of three technique: wide side sonar, parametric sonar and multi-beam sonar.

INTRODUCTION

There are known a great variety of tools and techniques of sea bottom characterization. However, none of these techniques can lead to a unique characterization of the bottom. The purpose of this paper is to show that, despite their diversity, all approaches may be merged in order to lead to a global observation of the bottom and therefore to a univocal geoacoustical model. The most common used seabed measurement techniques are presented and illustrated by same experimental data sets and show the non-unique representation of the environment they individually lead to.

1. MAIN CRITERIA OF DIFFERENTIATION OF SEABED TECHNIQUES

Seabed characterization is nowadays an expression that has a large number of meanings related to a great variety of requirements. These requirements are associated with a large number of instrumental devices involving systems like corers, multi-beam echo sounders, sub-bottom profilers, sidescan sonars, seismic systems or sonar-like devices used method of the "geoacoustic inversion" that is based on long range acoustical propagation. This large quantity of techniques and systems actually provides a large variety of data that are strongly linked to their intrinsic nature. The main criteria that differentiate the seabed characterization techniques concern following parameters of them [1]:

- Geographical covering,
- Physical phenomena the technique is based on,
- Angular domain of the bottom observation,
- Frequency domain,
- Signal processing techniques.

1.1. Geographical covering

The most obvious difference is the associated geographical covering that can be obtained using one specific technique.

- single point: corings, borings or sediment grabings are the first historical seabed characterization techniques. They provide data that are point measurements by nature even if they can reach a depth penetration of several tens of meters for favorable cases. The estimation of the geoacoustical parameters of the bottom is then a matter of laboratory protocol. They can be directly measured with very high frequency acoustical probes (from a few hundreds of kHz to same MHz) or deduced from geotechnical measurements using phenomelogical relations like Hamilton's ones e.g., [2].
- linear: vertical echo sounders, sub-bottom-profilers, seismic systems and sonar like devices give an information that is located along a transect. Typically, complete geophysical surveys of a particular area are conducted following parallel tracks that can potentially be merged in order to give a surface or even a 3D representation of the bottom (e.g., 3D-seismic).
- surface: today's techniques of seafloor mapping are dominated by multi-beam echos sounders and sidescan sonars. The main interest of these systems is that they can provide a very wide acoustical picture of the bottom with a surface covering and a resolution that depend on the technical characteristics of the systems. Typical sidescan sonar ranges reach a few hundred of meters in shallow and very shallow water environments with a resolution of a few decimeters, while typical ranges for multi-beam echo sounders are around 7 times the local depth with a resolution of a few meters (shallow water equipments) to a few tens of meters (deep water systems).

1.2. Reflection or backscattering

Another main difference of seabed characterization techniques is related to the physical phenomena they are based on. Following this distinction, classical techniques can be divided into two main categories: those that exploit the coherent reflection phenomenon, and those that are based on scattering (mostly backscattering) [3].

Coherent reflection: When considering an incident acoustical wave interacting with the seabed interface, coherent reflection is related to the reflected wave in a direction symetrical to that of its direction of arrival. The reflection coefficient depends on the impedance contrast and the grazing angle at the interface. Among the techniques listed above, reflection seismic systems, sub-bottom profilers and most geoacoustic inversion techniques are based on the coherent reflection phenomenon.

Backscattering: When a sound wave interacts with an irregular interface or penetrates in an inhogeneous sediment layer, the incident energy is reflected in all angular directions. This is the scattering phenomenon. Backscattering is the physical quantity that is measured by multi-beam echo sounders or vertical echo sounders used for sediment classification.

More interestingly, the consequence of this differentiation criterion is that techniques based on different physical phenomena do not lead to the same geoacoustic representations of the bottom. For example, the use of a calibrated sub-bottom profiler can lead to the evaluation of the reflection coefficient around normal incidence. Assuming a physical model of the reflection coefficient (e.g., visco-elastic, porous or phenomenological), some geoacoustical parameters of the bottom can be inverted. The form of the assumed model obviously defines the parameters that can be estimated (e.g., compressional speeds, attenuations or densities). When using a backscattered oriented device, the physical quantity that can be assessed is the backscattering index. There again, the geoacoustical parameters that can be estimated are also linked to the physical model. Moreover, due to the complexity of real sediments (layering, inclusions, etc.) and in spite of the fact that sediment types have a strong (and visual) influence on measured reflection coefficient and backscattering strength values, no simple mapping can be found between sediment types and geoacoustical parameters. In addition, there is neither an obvious link between coherent reflection coefficient and backscattering strength, nor does there exist any obvious link with the associated models. Additional differentiation criteria can be further pointed out when considering some specific technical items of the techniques design as described in the following paragraphs.

1.3. Angular domain

One main technical difference is that of the grazing angles that are involved: indeed the techniques are generally designed to observe the sea bottom in a limited grazing angle domain. This is for example the case for echo-sounders whose angular aperture is of typical order of around 60-70 degrees from the normal incidence for multi-beam echo-sounders, while it is only a few tens of degrees for sub-bottom profilers. The techniques may also be angular limited by the environment itself: for example, classical geoacoustic inversion techniques based on long range acoustical propagation between a source and a receiver are limited by the multipath structure of horizontal propagation. The strong attenuation of reflected paths above critical grazing angles results in a measurement that is limited to low grazing angles. Obviously, one particular technique can thus only provide a representation of the bottom that is biased by its intrinsic angular aperture. For example, the bottom reflection coefficient given by a sub-bottom profiler is not the same than that given by a geoacoustic inversion technique: in the first case, the bottom reflection coefficient of the bottom is a local one for grazing angles around normal incidence, while in the second case, it is an integrated one around horizontal grazing angles. Due to the angular dependance of the reflection coefficient with grazing angle, the measured values are then different.

1.4. Frequency domain

Another fundamental difference of seabed characterization techniques is the frequency domains that they involve. The consequences of this differentiation criterion are manifold. Indeed, many different physical processes can be observed. However, their relative importance will depend on the signal frequency.

Scale of the physical processes: Basically, the seafloor may be considered as a rough interface with inhomegeneous underlying layers. The incident sound wave is scattered both by interface roughness and underlying inhomogeneities. The relative effect of every physical process has to be compared to the wavelength of the sound wave in order to estimate the scattering level.

Depth penetration: It is well known that due to an increasing attenuation of the acoustical waves with frequency, the higher the frequency, the less the penetration of the sound into the sediments. The characterization of the bottom provided by sidescan sonars (working at typical frequencies between 100 and 500 kHz) can only be superficial (i.e., it is limited to the sea-bottom interface), while law frequency seismic profiling surveys allow the characterization of the first hundreds of meters of the sediments. Even for similar techniques (e. g., involving the same principles as multi-beam echos sounders), the representation can be very different from one system to another one: the reflectivity measurements given by a Kongsberg Maritime EM950 multi-beam echosounder (95 kHz) only involve superficial sediments [1], while those of an EM120 one (12 kHz) can involve a few tens of meters [1].

Resolution: The techniques based on the use of broadband acoustical signals are directly related to the frequency band of the signals themselves (the resolution is inversely proportional to the frequency band). Physical phenomena with spatial and temporal scales below the intrinsic resolution of a particular technique can not simply be assessed by the technique. Once again, techniques based on similar principles can lead to different representations of the bottom.

1.5. Signal processing techniques

More specifically, another differentiation criterion can be pointed out. The signal processing techniques that are involved in the techniques can also directly affect the representation of the bottom that can be assessed. The improvement of signal to noise ratio is the constant aim of signal processing techniques in Underwater Acoustics. However, although the techniques may perform to theoretical limits, one still has to deal with the technical limitations of the acoustical devices, which often results from a compromise between the effective cost of the system, its physical characteristics and the performances that are looked for. Consequently, the quality of the representation that are obtainable can then be very different for systems that are based on the same principle but whose design is different.

2.SOME EXPERIMENTAL RESULTS OF DIFFERENT SEABED CHARACTERIZATION TECHNIQUES

The large diversity of seabed characterization techniques creates problems with using them in a complementary manner. The graph shown in Fig. 1 provides a synthesis of the frequency-grazing angle domains that ale involved in the available seabed characterization techniques [1]. The techniques based on backscattering measurements are represented by filled areas, while those that are based on coherent reflection are represented by the unfilled areas. This figure obviously shows that each technique provide an image of the sea-bottom that is filtered by the technique itself.

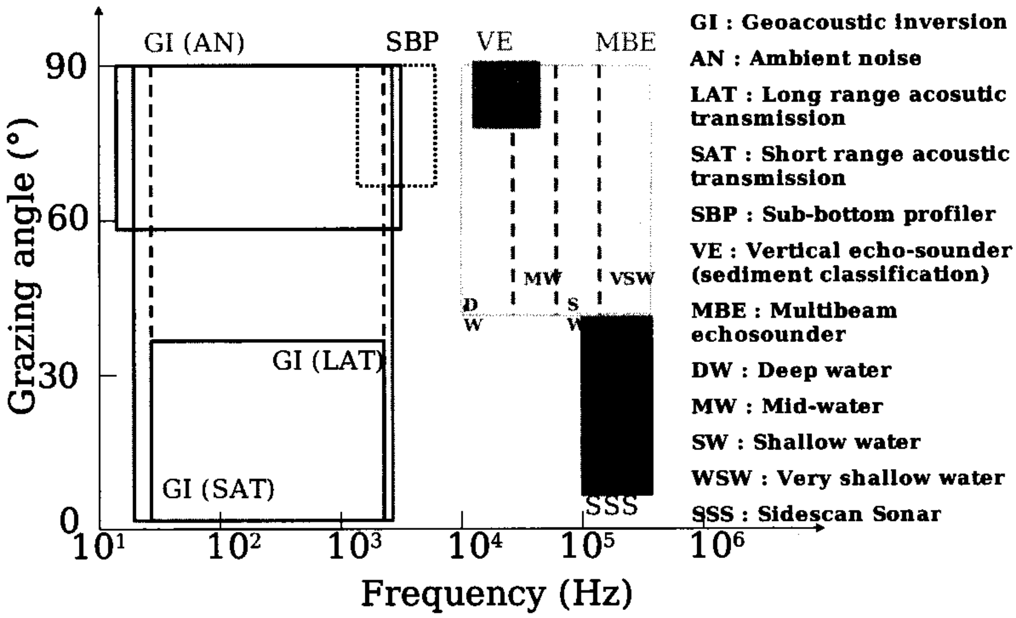

Fig.1. Areas of application of seabed characterization techniques

Several published experiments and studies have already shown that coupling different approaches may improve the understanding of seafloor geoacoustic properties and physical mechanisms.

The following figures show the characteristic features when the data on bottom properties are collected by means of three different technique. The data were obtained experimentally in the Gdansk Gulf in summer 2008. The three consecutive graphs illustrate the advantages of a side scan sonar in imaging of the shape of the bottom.

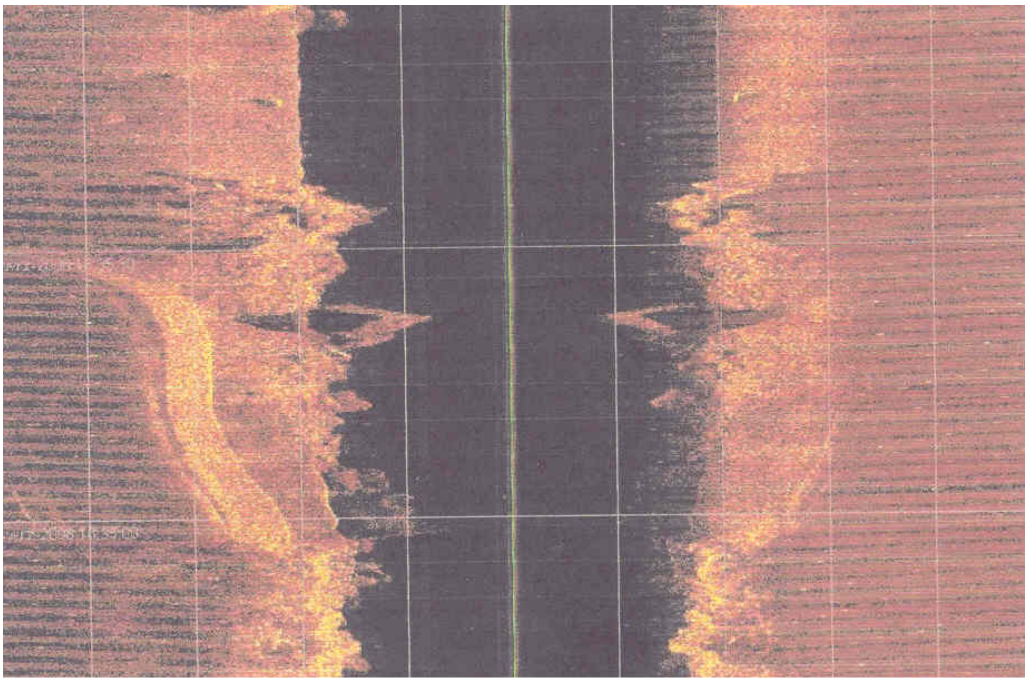

Fig.2. The image obtained directly from side scan sonar

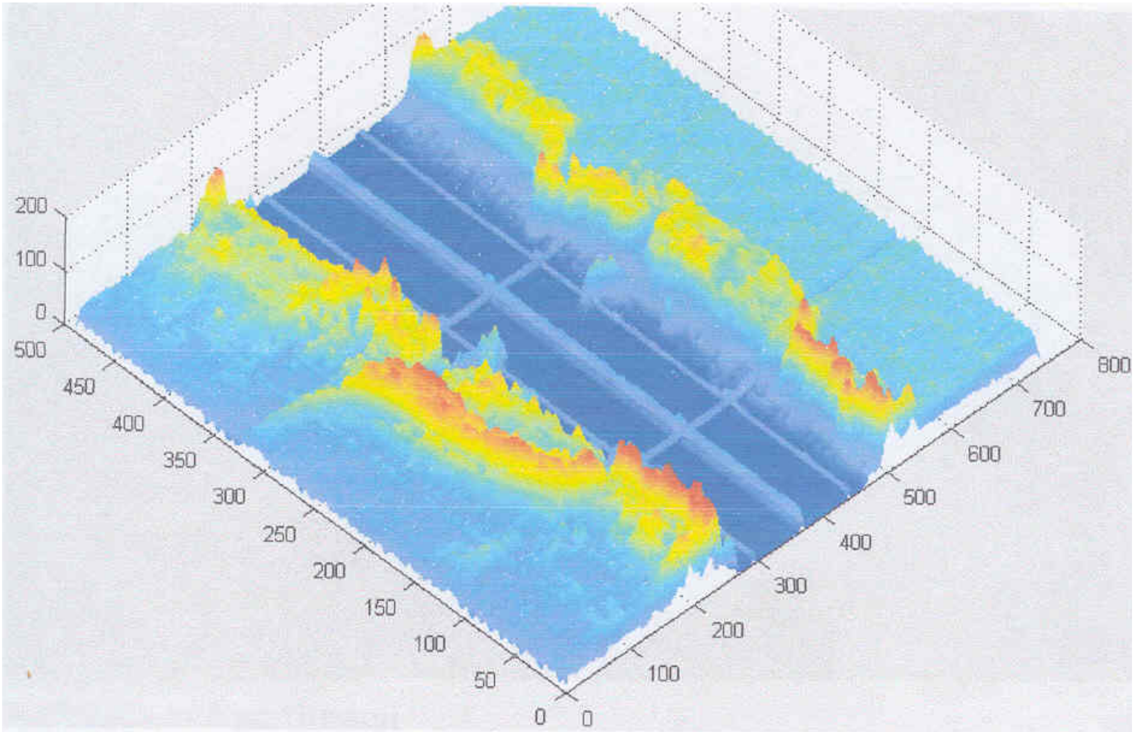

Fig.3. The same data as in Fig. 2 in 3D form

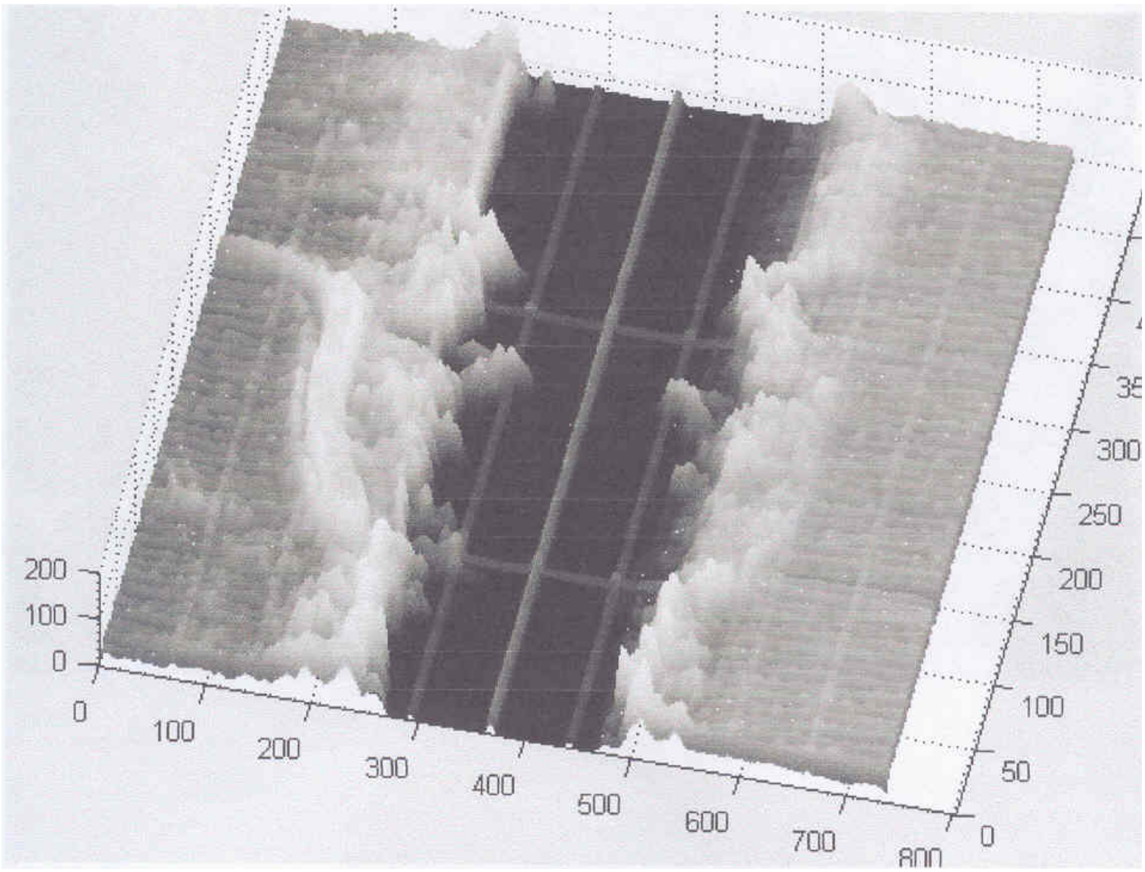

Fig.4. The same data as in Fig. 2 in 3D form in grey scale

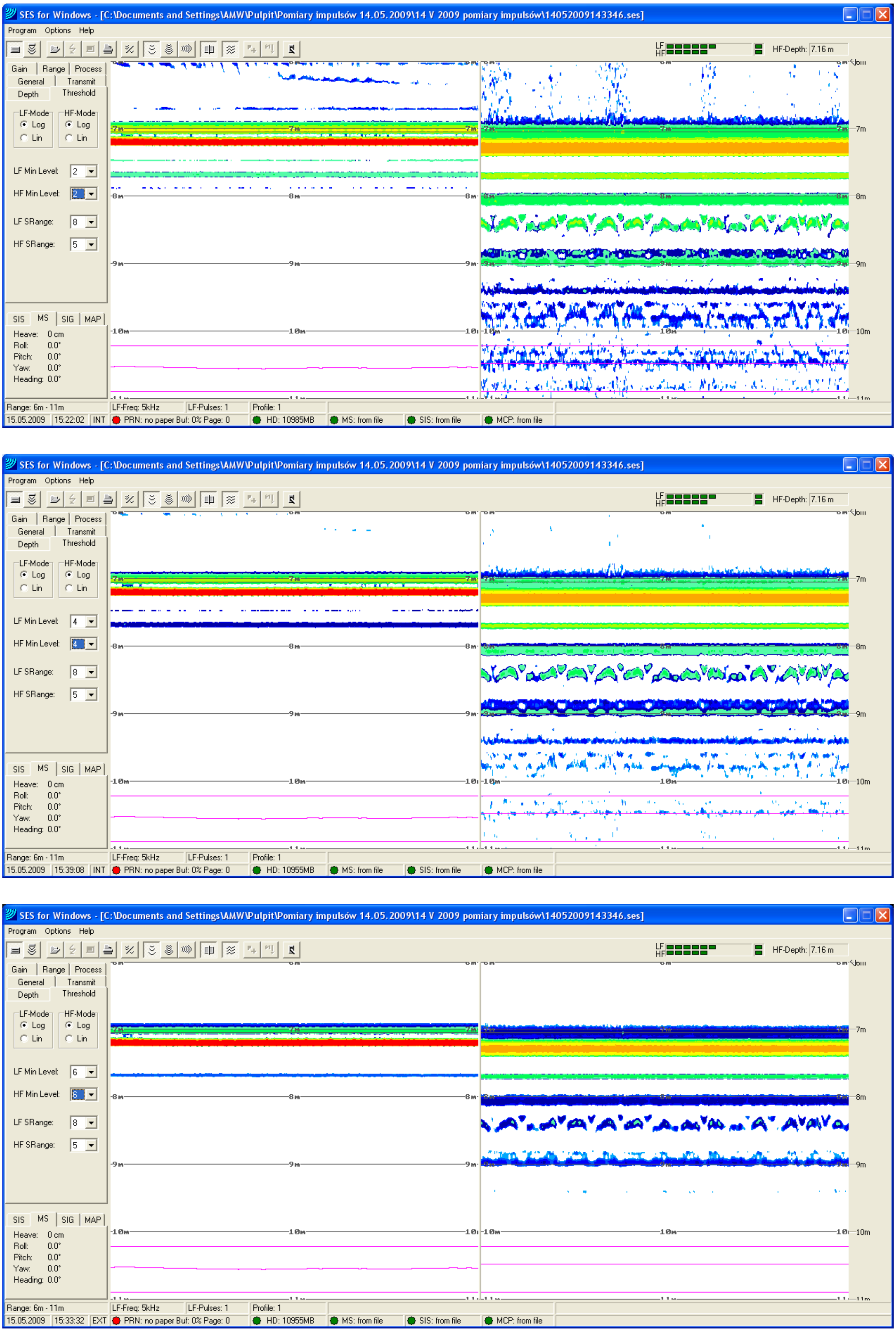

Fig.5. Parametric echosouner as a tool for sub-bottom structure imaging; left – image for primary wave of 100 kHz, right – image for secondary wave of 12 kHz

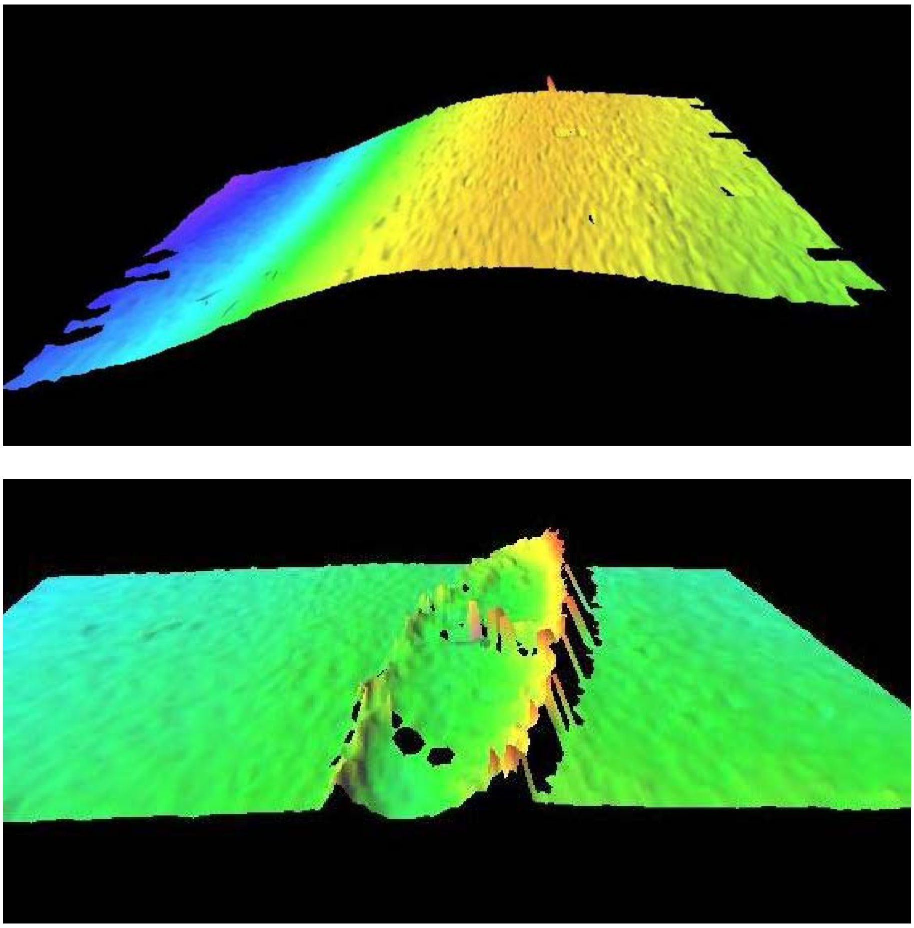

Fig.6. A multi beam echosounder as a tool for imaging shape of a great area of bottom as well as objects lying on it

3. CONCLUSIONS

The examples presented above correspond to the statements in Chapter 1 and confirm that each technique can only provide a partial picture of the bottom because of the limitation of the technique itself. Obtaining full information is possible only using few complementary technique. The examples shown that the form and accuracy of information obtained basing on the same data depends on signal processing procedures.

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