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Paper title:

Integrating imagery from hull mounted sidescan sonars with multibeam bathymetry

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Abstract:

Multibeam echo sounders produce high quality bathymetric data, however, for acoustic imaging their alongtrack beamwidth is much wider than what is used on conventional sidescan sonars, so the imagery produced by sidescan sonars are of a better quality and are often preferred. A hull-mounted combination instrument package that integrates both the accurate multibeam bathymetry and the high resolution sidescan imagery is an attractive and relatively low cost solution for detailed surveys of harbors, canals, rivers and other shallow areas.

Especially in these shallow water areas the sidescan sonar benefits from being hull mounted rather than towed, since this arrangement is easier and safer to handle and the sensor position is known with high accuracy.

The paper addresses how the backscatter from the hull-mounted sidescan sonar system can be radiometrically and geometrically corrected, by using the bathymetry from the multibeam echo sounder, and how the 2 data sets can be presented together in 2D and 3D.

A practical experiment is described, whereby EM 3002D multibeam echo sounder and a hull mounted EA 400 sidescan sonar system are mounted together and deployed over the bow of a small survey launch. The co-registered data sets are analyzed using the UNH GEOCODER processing scheme, and the results are presented and interpreted in terms of capability to resolve small objects. A comparison is made between the EA 400 sidescan backscatter and the EM 3002D seabed imagery.

Combining Multibeam Echo Sounder and Hull Mounted Sidescan Sonar

Several multibeam echo sounders produce acoustic imagery from the sea bottom in addition to the bathymetry. It is now most common to derive this imagery as a composite, using the signals from the different receive beams as they intersect with the sea bottom. This imagery has some nice properties, especially that it is perfectly co-registered with the bathymetry. However, in general it is not regarded to be of the same quality as the signal from a sidescan sonar, so sidescan sonars are in general preferred for such tasks as detecting small objects on the bottom.

On the other hand, it can be a problem to position sidescan sonar towfishes accurately, and unless the bottom is perfectly horizontal and flat, the image will be geometrically distorted. If the bottom has a slope, the images on the starboard and port side will have different intensities. For shallow water applications, it has become quite popular during the recent years to fit the sidescan sonars directly to the survey boat, in order to have better control of both the position and orientation of the sonar, and to avoid the practical problems of towing a towfish in confined waters.

If we make a combined installation, fitting both a multibeam echo sounder and a set of sidescan sonar transducers to the survey vessel, it would seem possible to obtain several advantages:

- Better quality acoustic imaging of the bottom, by using the sidescan sonar returns instead of the multibeam's seabed imagery
- Improved quality of the sidescan sonar dataset by using the information about the bottom topography given by the multibeam echo sounder – instead of the normal flat bottom assumption – to correct the image geometrically so that correct position determination of bottom features is obtained.
- Improved quality of the sidescan sonar dataset by being able to correct the image for radiometric effects such as a sloping bottom.
- The bathymetric dataset from the multibeam echo sounder and the imagery from the sidescan sonar are co-registered and can readily be combined, so that observations of bottom features are better described and can be made with a higher confidence level.

About the test setup

In order to find out more about the potential advantages of a combined system as well as possible problems, a small vessel was fitted with a Kongsberg EM 3002D multibeam echo sounder and 2 sidescan sonar transducers, using a Kongsberg EA 400 as the electronic topside for those. The survey vessel was MK "Pingeline", which is the hydrographic test vessel of Kongsberg. The vessel is located in Horten, and the test data was collected late February 2007.

The data was collected as 2 separate datasets, by the EM 3002D SIS and the EA 400 software. The vessel was equipped with good quality positioning and motion sensor equipment, using a Seapath 200 with a MRU5 in kinematic GPS mode for positioning, heading, and heave/roll/pitch. No attempt was made to measure the tide level changes during the test, which was conducted in water depths from 5 to 30 meters just outside Horten.



Figure 1:

”MK” Pingeline”. The EM 3002D is mounted over the bow, while the 2 sidescan sonar transducers are fitted to 2 over the side poles. The Seapath GPS antennas are seen above the roof.

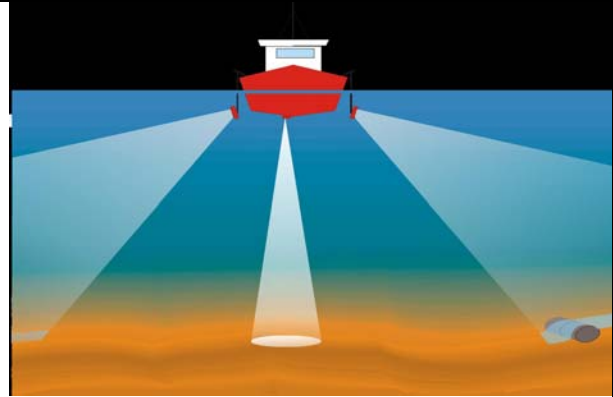


Figure 2

The basic principle of hull mounted sidescan sonar

About the EM 3002D Multibeam Echo Sounder

The Kongsberg EM 3002D is a multibeam echo sounder which uses 2 sonar heads, each being tilted some 40 degrees to each side in order to maximize the swath coverage at shallow water. The system operates at 300 kHz, and has acoustic beamwidths of 1.5 degrees both for transmission and reception. It has a maximum pingrate of 40Hz. For each ping, the system will produce 512 soundings, plus seabed imagery with 5 cm range resolution. The system will in high density mode extract several soundings from each beam in the outermost part of the swath, obtaining nearly constant spacing between neighboring soundings, and reducing the size of the acoustic footprint considerably.

The system has a total swath which covers 200 degrees. It can be used for inspection of vertical structures almost up to the water surface, but on a flat bottom the swath will seldom exceed 10 times the water depth.

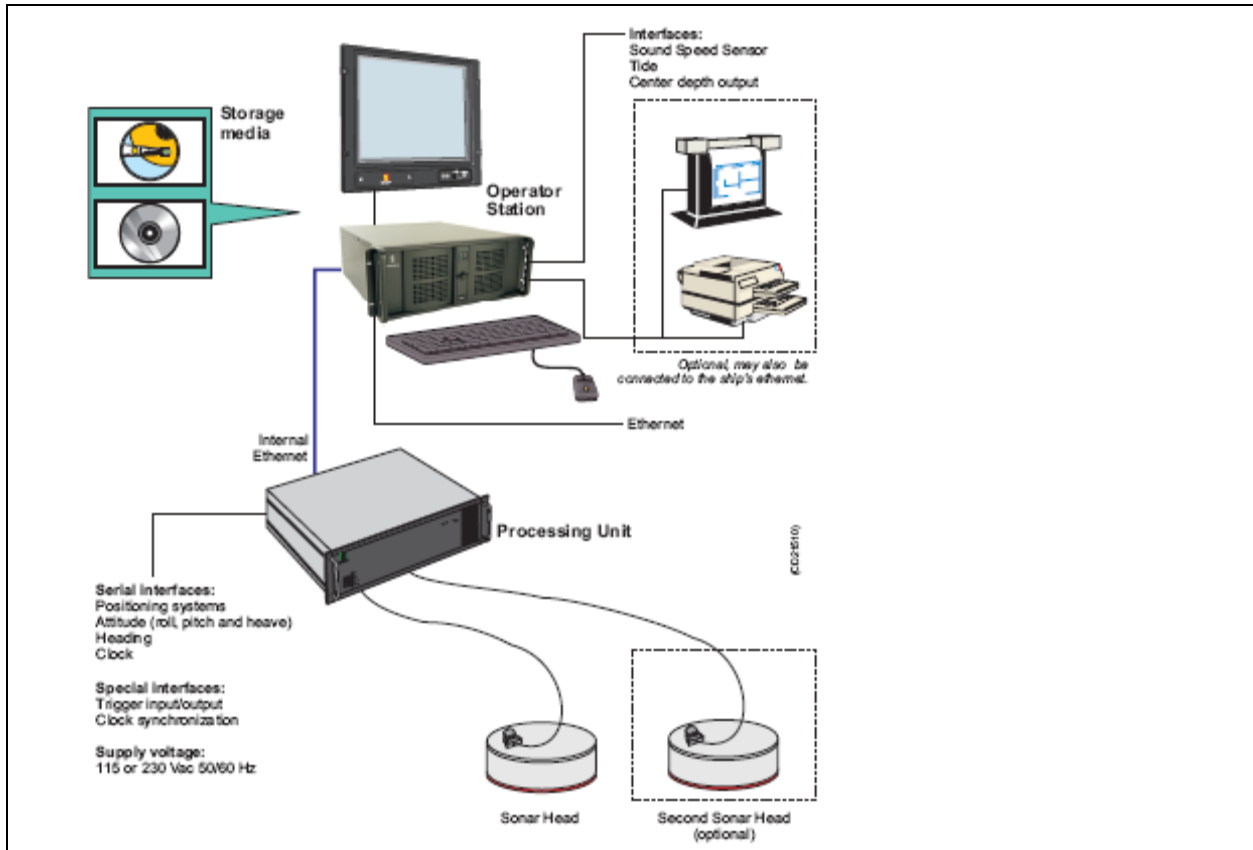


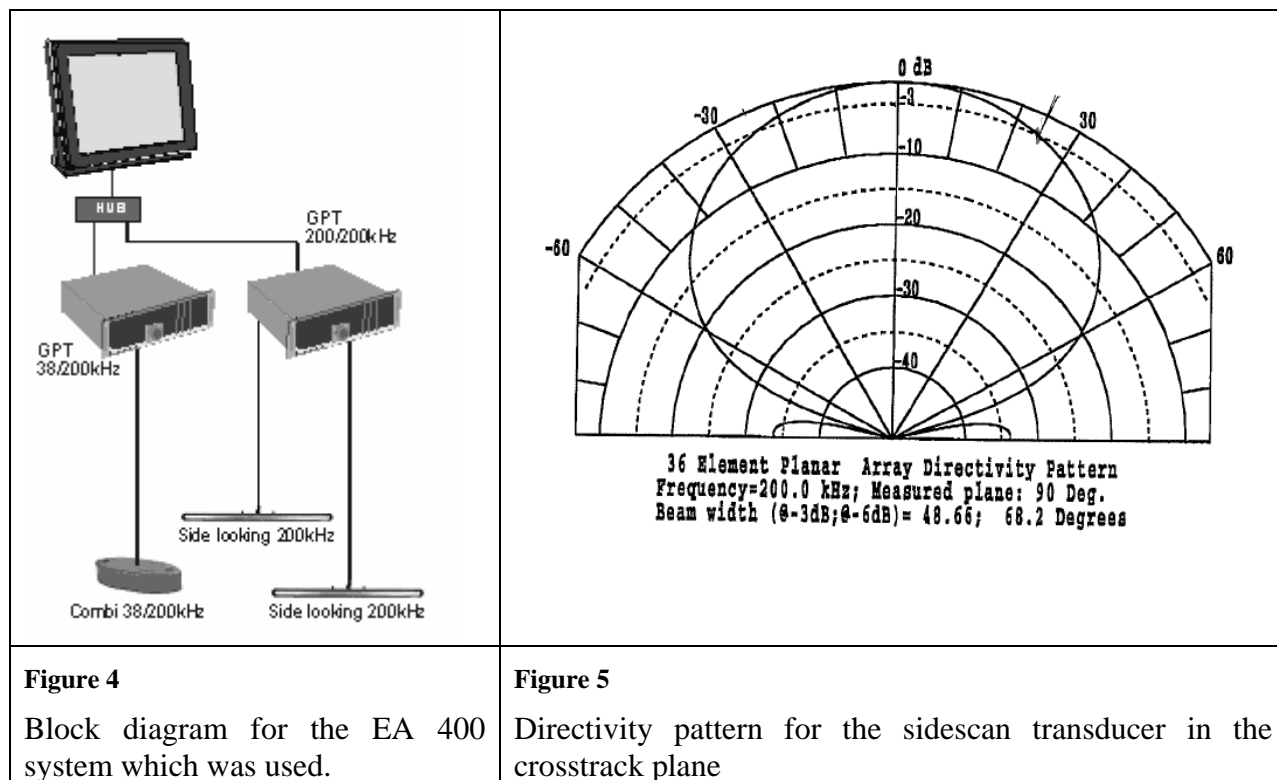
Figure 3

Block diagram for the EM 3002 multibeam echo sounder system

About the EA 400 Echo Sounder and sonar

The Kongsberg EA400 is a versatile single beam echo sounder. Using a standard PC running Windows, maximum two GPT's may be connected. The GPT (General Purpose Transducer) can be programmed to use 2 channels ranging from 12 – 700 kHz.

For this survey the setup was a vertical transducer (200 kHz, 7.2 x 7.2 degrees) and two sidescan transducers (200 kHz, 0.5 x 50 degrees) . The two sidescan transducer had a sample rate of 1.2 cm, while the vertical transducer used a sample rate of 4.8 cm. The range of the sidescan transducers was limited to 100 m. The raw data was stored for later processing.



Data processing

The data processing steps were as follows:

- The multibeam bathymetry was processed with CUBE to a digital terrain model (DTM)
- All gains and time varying gains which had been applied in real time were removed from the sidescan/seabed imagery
- The observations were corrected for the different terms of the sonar equation:
 - Transmission loss,
 - Attenuation in the water column,
 - Area of insonification,
 - Source level,
 - Transmit and receive beam patterns
- The backscatter observations were also corrected for the seafloor bathymetric slope angle

The EA 400 sidescan sonar data was not corrected for roll and pitch angles of the boat, and the course-made-good as provided by the GPS receiver was used for heading. These datasets were processed in 2 different ways: first by assuming a flat bottom and then by using the EM 3002D DTM.

Overview of results from the test

The data sets from EM 3002D and EA 400 were processed by the Geocoder sw by UNH. In addition to bathymetric plots, some different sidescan sonar mosaics were produced,

- EM 3002D seabed imagery mosaic
- EA 400 sidescan mosaic assuming flat seabed
- EA 400 sidescan, using EM 3002 bathymetry for geometric corrections.

The digital terrain model is shown in Figure 6 below. The north to south extension of the test area is close to 2000m.

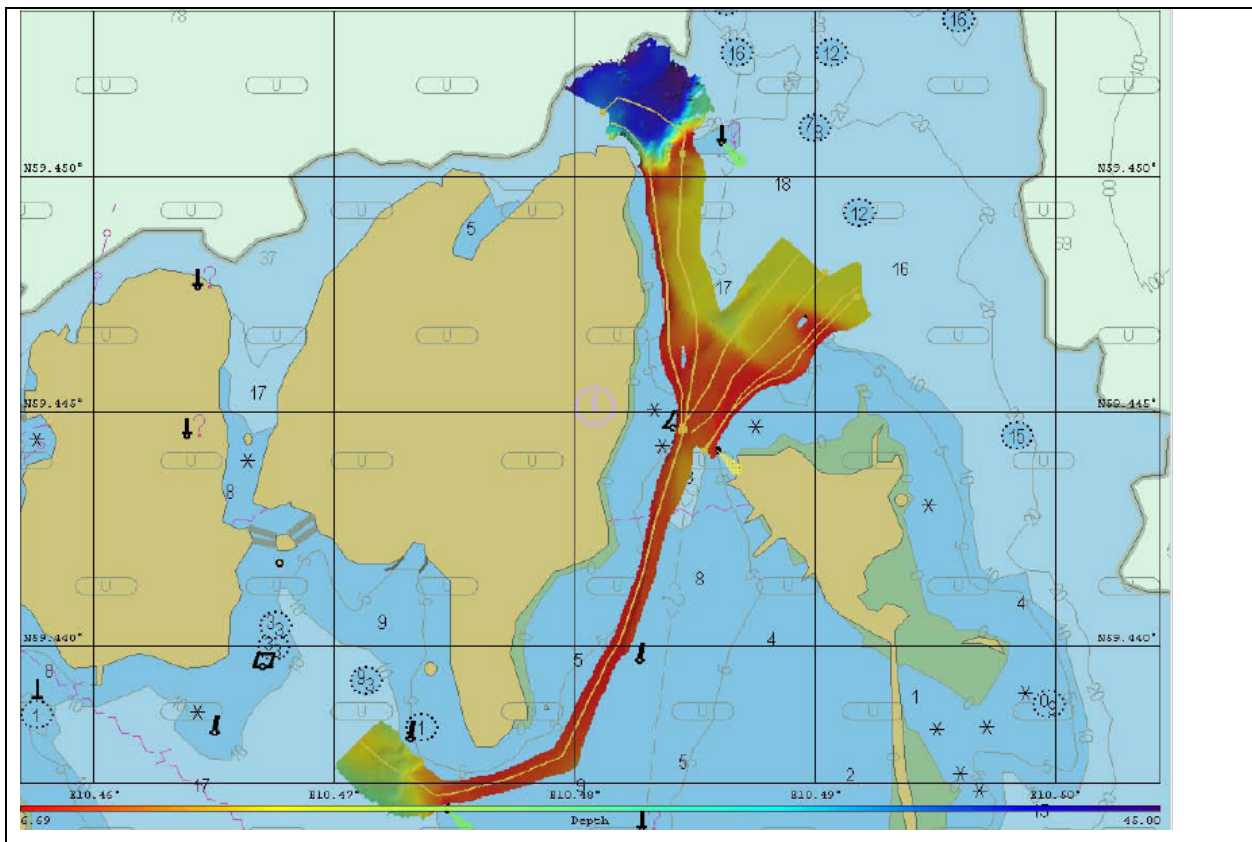


Figure 6

EM 3002D sailing pattern and bathymetry for the test area

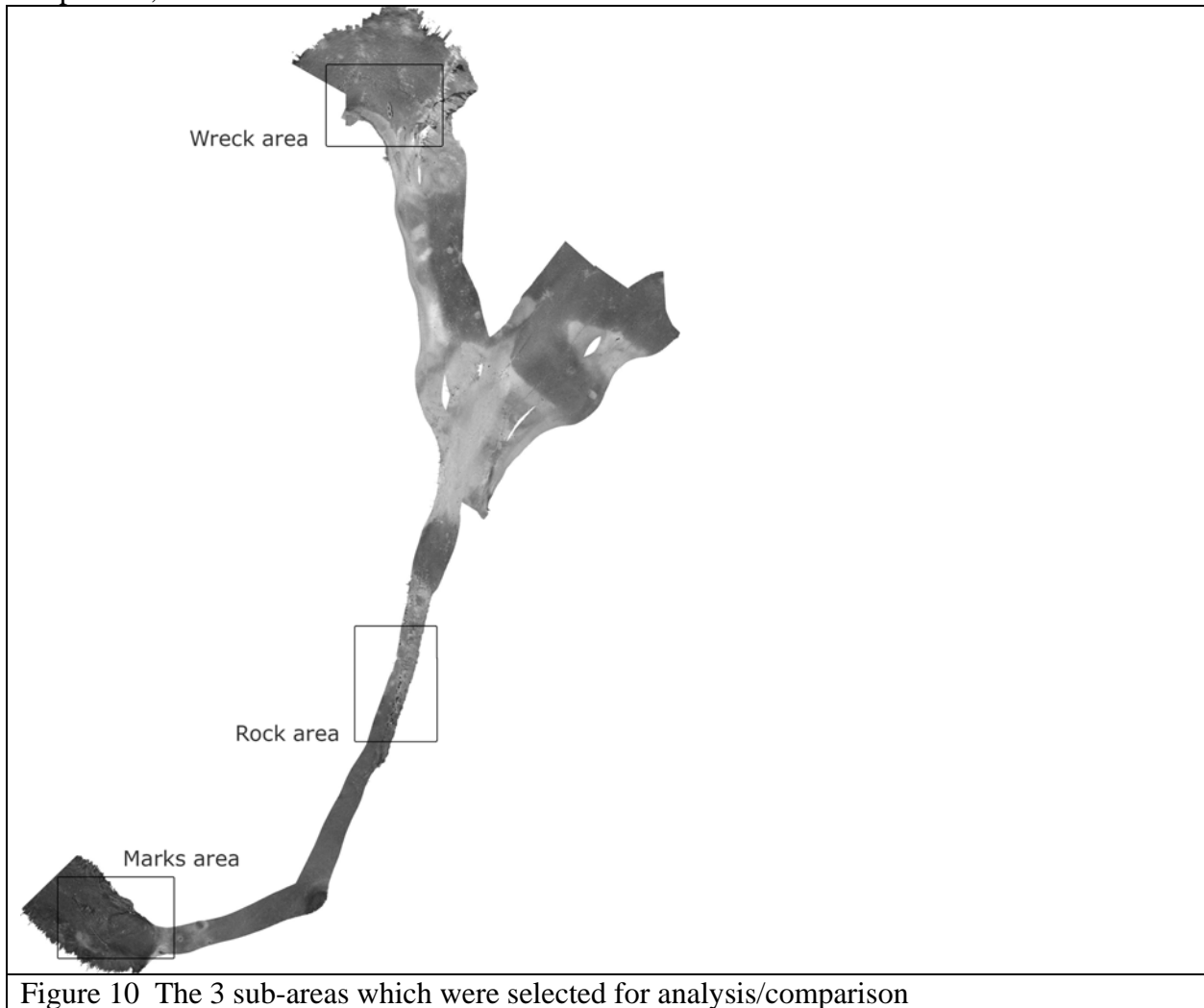
After processing the seabed imagery and the sidescan sonar data by the GEOCODER sw of University New Hampshire, we have 3 different datasets to analyse and compare. The sonar mosaicing is made with a resolution of 20cm.

<p>Figure 7 EA 400 sidescan image mosaic, flat bottom assumption</p>	<p>Figure 8 EA 400 sidescan image mosaic, DTM used</p>	<p>Figure 9 Figure 6c. Multibeam seabed imagery mosaic</p>

An immediate comment is that the swath coverage of EM 3002D is significantly less than for the EA 400 sidescan. EM 3002D stops collecting seabed imagery data as soon as there are no more soundings or if the specified max swath width has been reached. EA 400 records data until the set maximum range is reached. EM 3002D has in this case a swath width of 7 times water depth, while the EA 400 sidescan produces a swath which is 2 times wider.

Comparing some smaller areas

The datasets are too large to be practical for comparison, so we select 3 subsets for more detailed comparison, see 10.



Wreck area

The northern sub-area contains a wreck, about 30m long, lying on the bottom in 12 meters of water. We compare EM 3002D bathymetry with the different backscatter images:

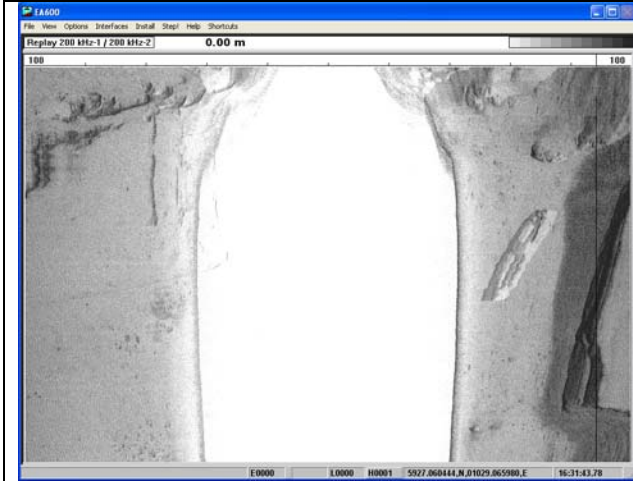


Figure 10
Raw EA 400 sidescan sonar recording from wreck

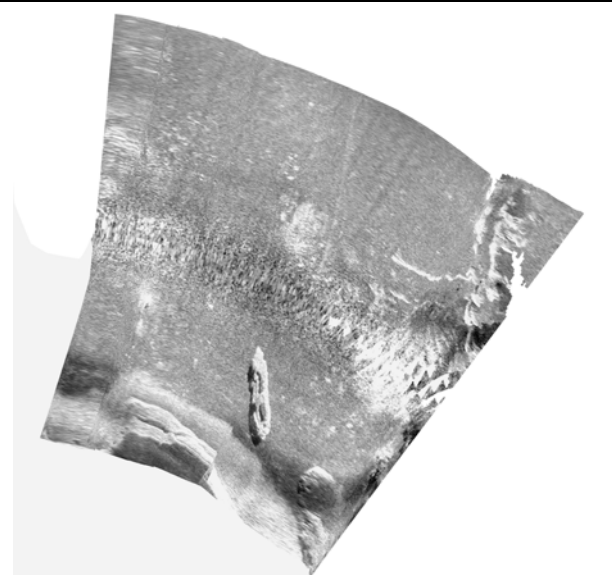


Figure 12
Sidescan image from one line in the same area, after being processed in the Geocoder SW.

Note that in the lefthand image, white is the weakest signal. The wreck is well described in this range-intensity recording, but of course not to a correct scale. In figure 12 the water column has been removed and the geometry has been corrected, using the DTM.

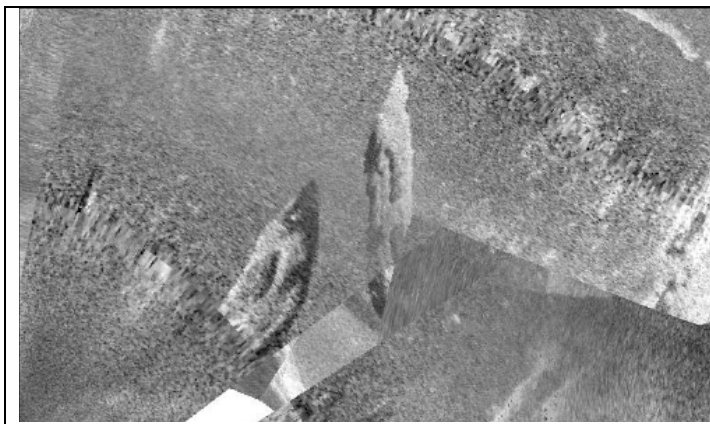


Figure 13
EA 400 Sidescan sonar mosaic, flat bottom assumption



Figure 14
EA 400 Sidescan sonar mosaic, DTM used

The obvious problem with making a sidescan sonar mosaic with an assumption of flat bottom, is that features are misplaced unless the bottom is perfectly flat (left image above). The image on

the right hand side is constructed by use of the digital terrain model for geometric corrections. Even so, the result is not perfect. Especially the heading information was uncorrect.

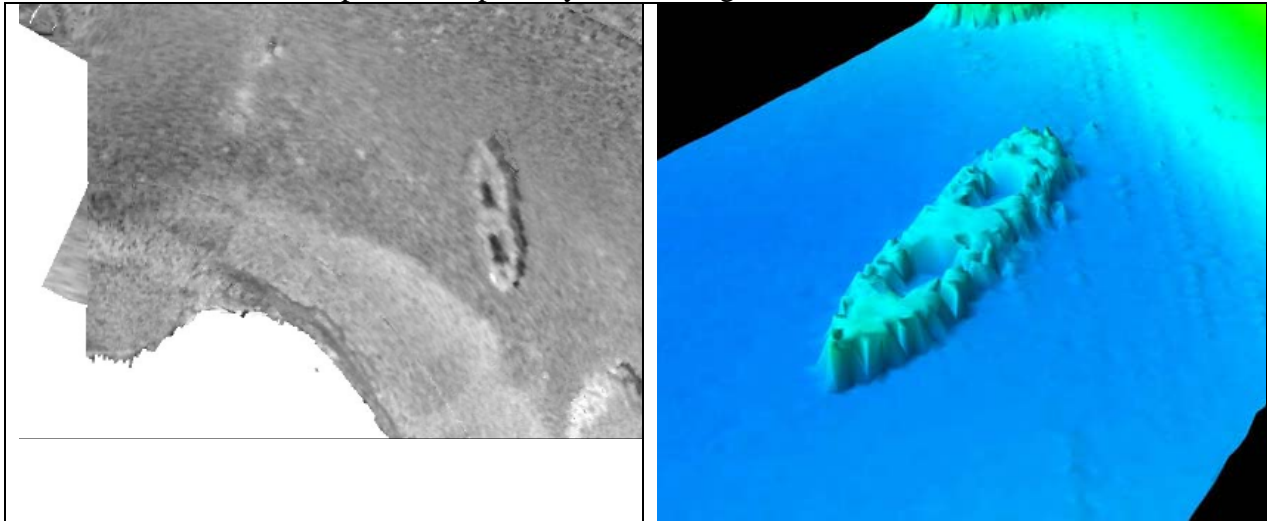


Figure 11

EM 3002D Seabed imagery mosaic

Figure 126

EM 3002D bathymetric model of wreck

The leftmost image above is the mosaic made from the EM 3002D seabed imagery. It gives a good description of the wreck, and the image is correct geometrically. The rightmost image is a 3D representation of the EM 3002D bathymetric data from the wreck, and in fact this is probably the best and most informative of the 5 different images of the wreck.

Stones and pipeline area

This is a quite shallow area in the center of the test area, with water depth of 5-8 meters and a number of rocks of different sizes.

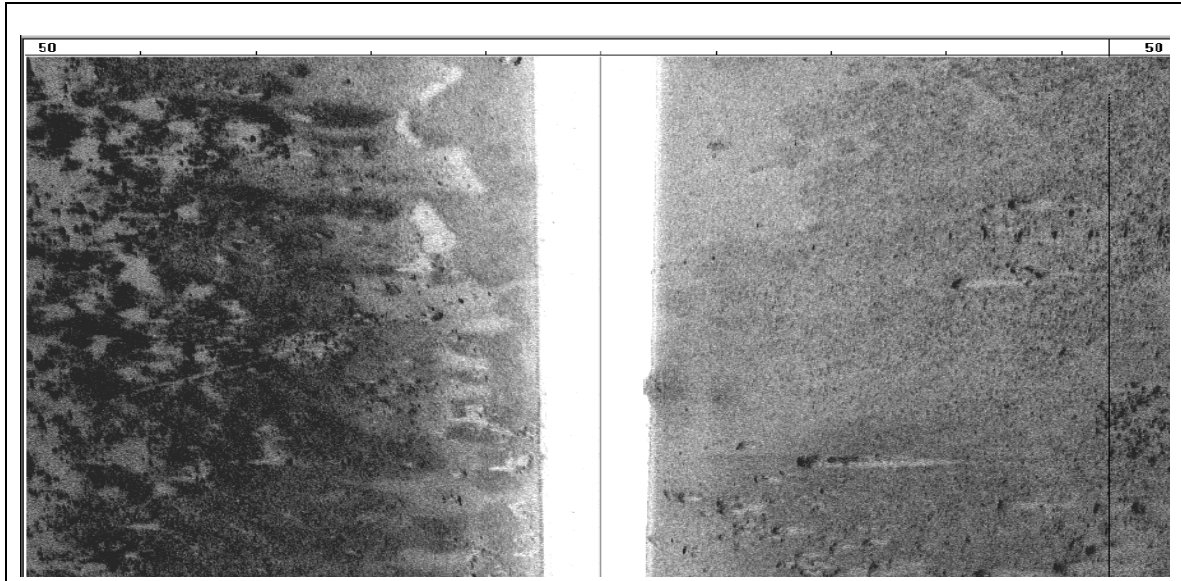


Figure 137

Raw EA 400 sidescan image of rocks plus pipeline/cable

On the raw EA 400 sidescan image the area appears much rougher, and acoustic shadows are observed behind a number of the rocks. An almost linear feature which may be a cable or a small diameter pipeline crosses the image.

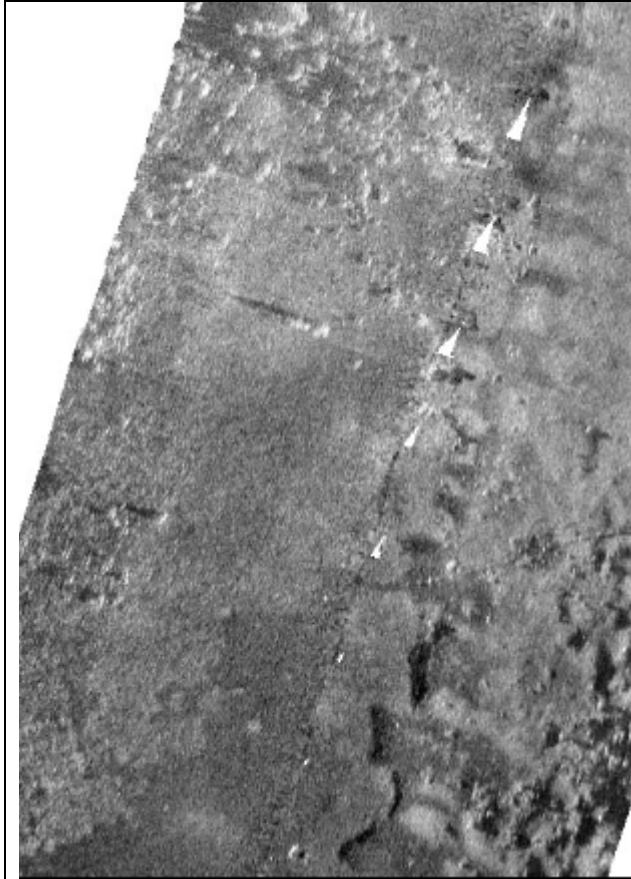


Figure 1814

EA 400 sidescan sonar mosaic (using DTM)

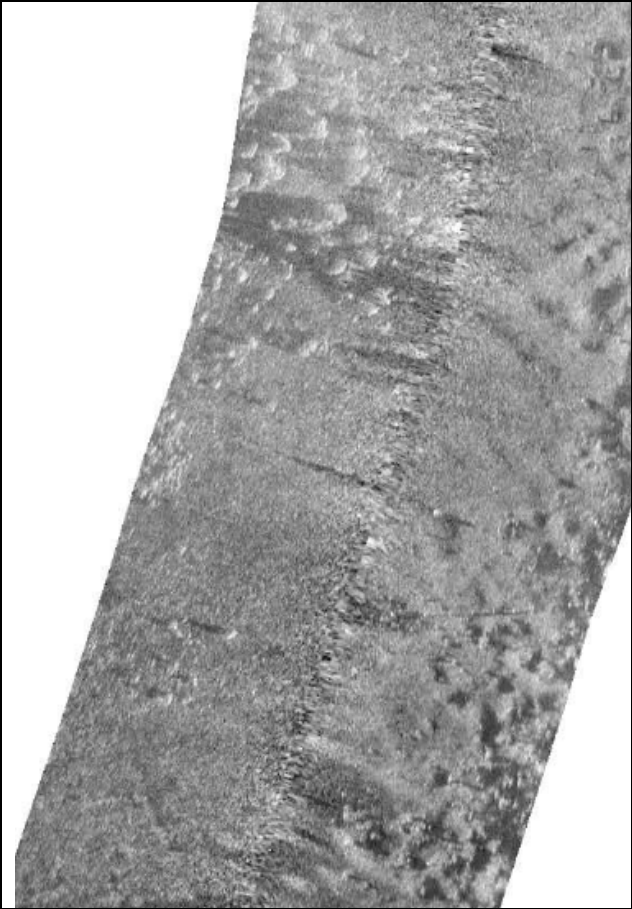


Figure 159

EA 400 sidescan sonar mosaic (assuming flat bottom)

The 2 EA 400 sonar mosaic images above are from the same area, but still quite different. Many bottom features are quite differently located. The left hand image closely resembles the multibeam bathymetry and imagery and is reasonably correct geometrically. The data mosaicing process removes some of the finer details. The pipeline/cable feature is barely observable on the image to the left.

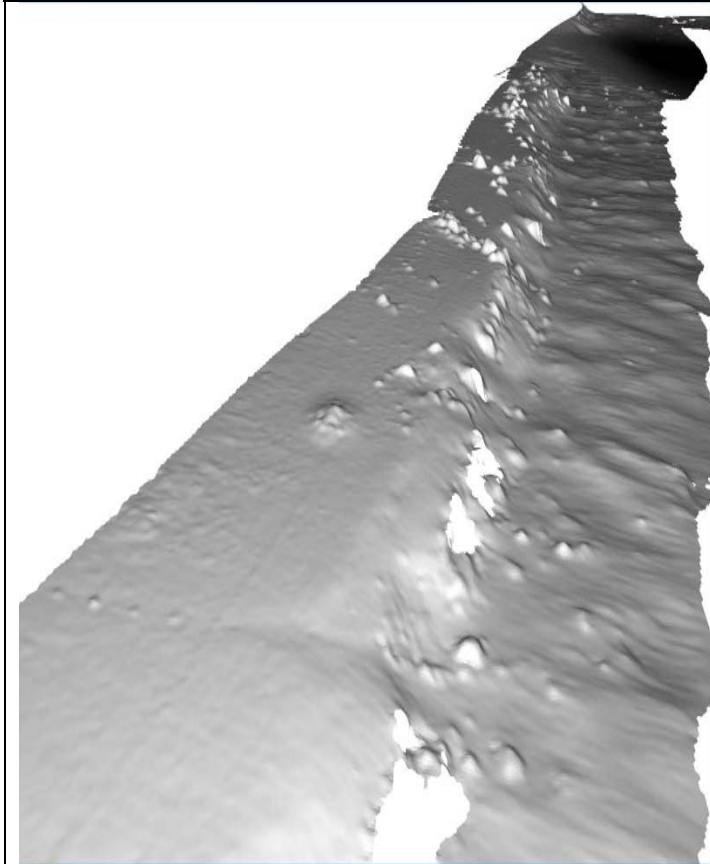


Figure 20
3D Bathymetry of area with stones

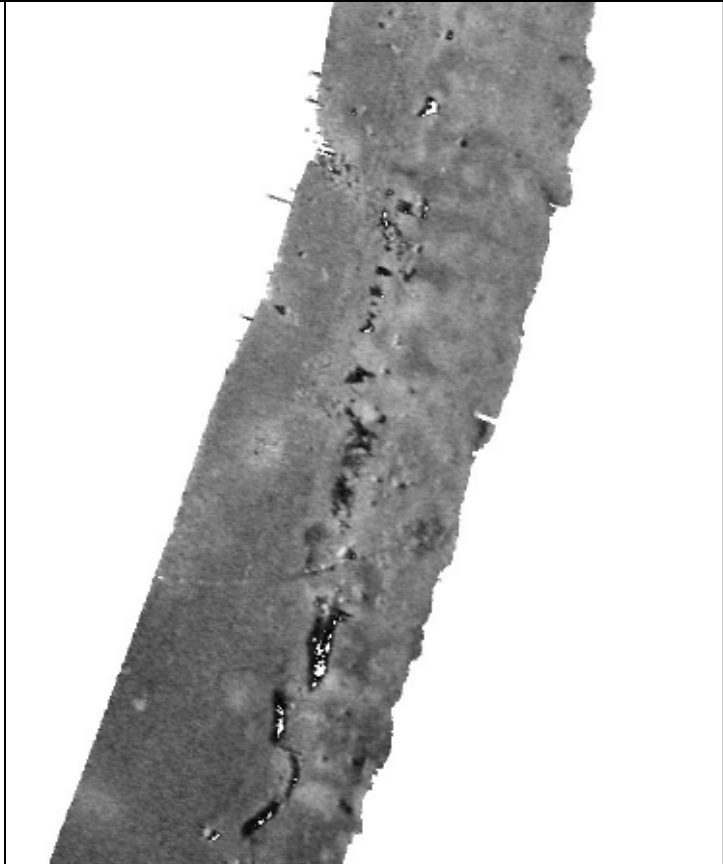


Figure 16
EM 3002D seabed imagery mosaic

The 3D bathymetric plot above gives a good description of the area, but one can notice that stones are rounded and the images has a smoother appearance than what the area is probably like. The EM 3002D seabed imagery appears smoother than the EA 400 sidescan sonar images, but still shows the pipeline/cable feature quite clearly. This imagery has no values where there are no bathymetric values; this can be observed here in some steep slopes and troughs. The multibeam data only covers about 50% of the sidescan swath.

Anchor drag marks area

This is an area south in the test area which may appear as flat, but the water depth varies between 15 and 23 meters.

The bottom is characterized by some drag marks from ships anchoring.

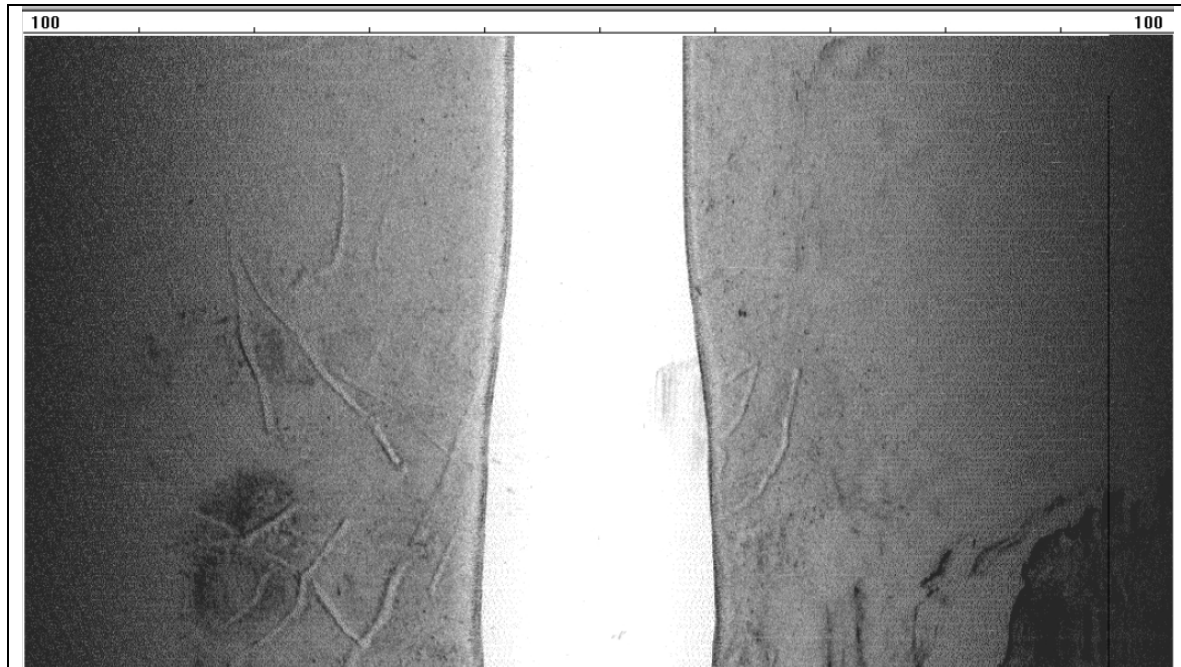


Figure 172

Raw EA 400 sidescan sonar recording from anchor drag marks

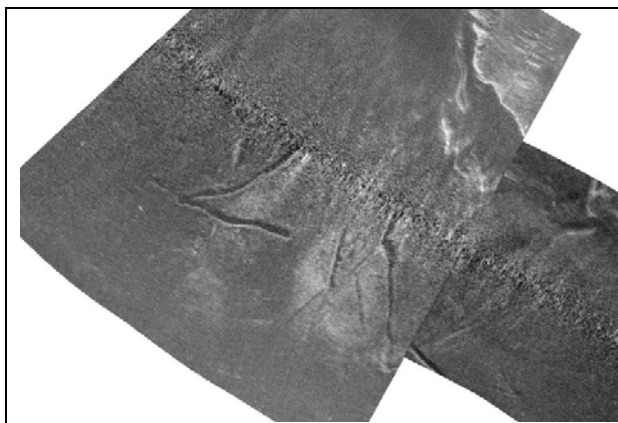


Figure 183

EA 400 sidescan sonar mosaic, Flat Bottom assumption

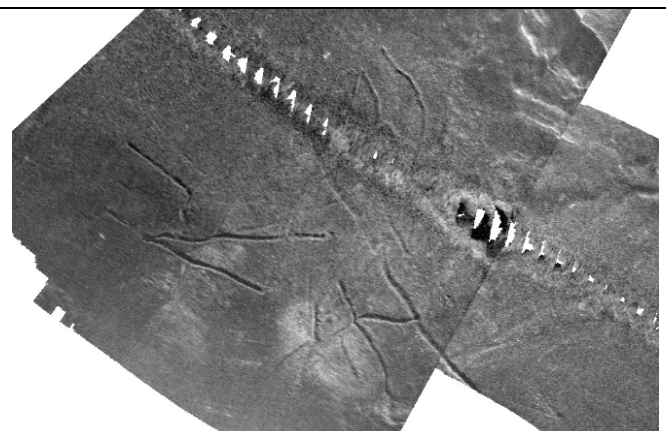
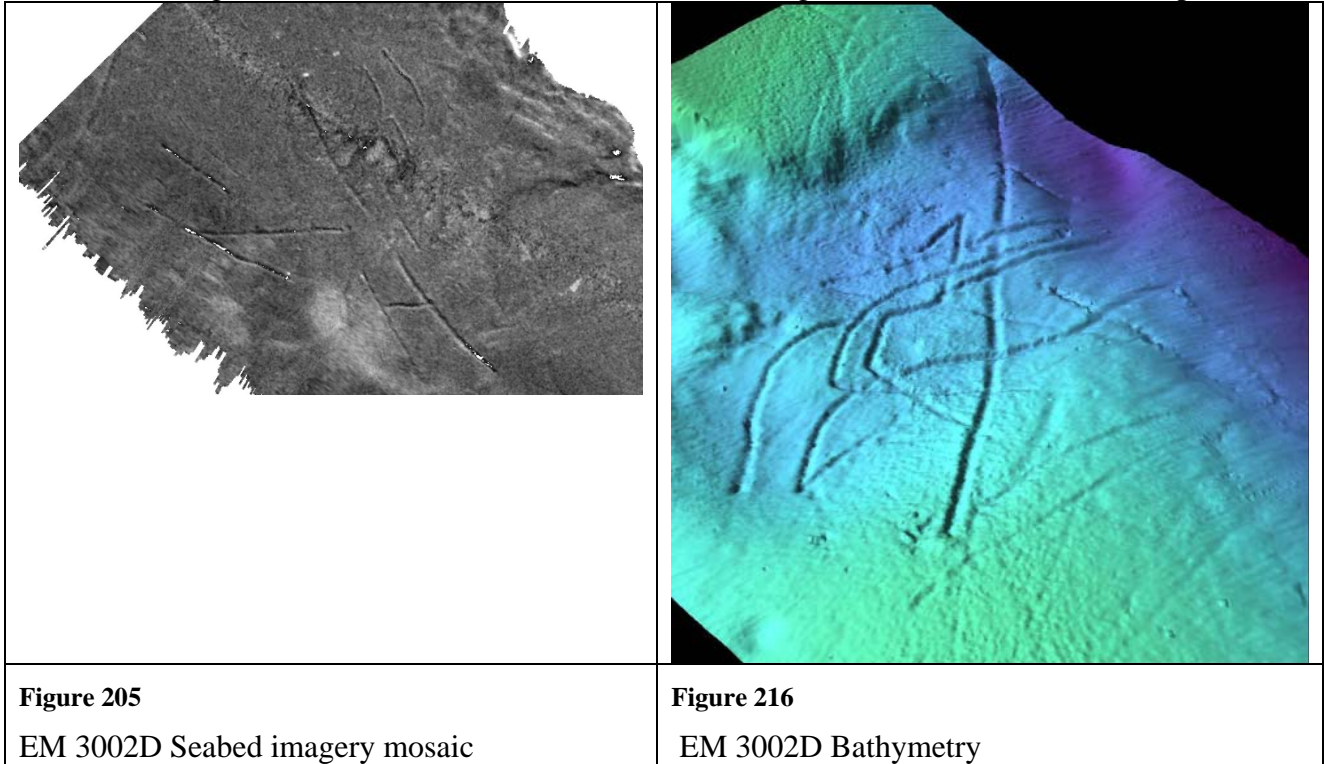


Figure 194

EA 400 sidescan sonar mosaic, DTM used

Also in this area we can see significant differences between the 2 different EA 400 image mosaics. If we compare with the EM 3002D seabed imagery, we see that most of the drag marks are in fact straight lines. The distortion is also in this case largest for the flat bottom assumption.



The multibeam seabed imagery data is geometrically correct and with good resolution, only slightly smoother than the EA 400 sidescan. Also the bathymetric data set gives a good description of the anchor drag marks.

Conclusions and future work

- The main advantages of using hull mounted sidescan sonar in addition to the multibeam echo sounder are the added swath coverage which is obtained, in addition to a somewhat better resolution. In this case the sidescan sonar swath width was the double of that of the multibeam.
- It is difficult to see that the resolution of the images is degraded by the gridding and geometric corrections of the Geocoder sw (compare the figures 11 and 12). In this case a resolution of 20cm was used for the grid.
- Using the multibeam DTM to correct the geometry of the hull mounted sidescan sonar is a major improvement, resulting in images with a more correct geometry. However, the results obtained by this experiment are still not perfect. To obtain a further improvement, one should possibly locate the transducers closer together and synchronize the transmission of the instruments, and include also corrections for the vessels rolling and pitching movements. The heading information for the hullmounted sidescan sonar should be taken from the vessels heading sensor (in this case that was a Seapath 200).

- The EM 3002D seabed imagery has some “holes”, or lack of data, in spots with no bathymetric soundings. This is quite disturbing for the eye, and it should be possible to find a solution to avoid this.

References

Fonseca. L. and B.R. Calder, Geocoder; An Efficient backscatter Map Constructor, Conference Proceedings: U.S. Hydrographic Conference, Sand Diego, CA, 2005, Conference Proceedings