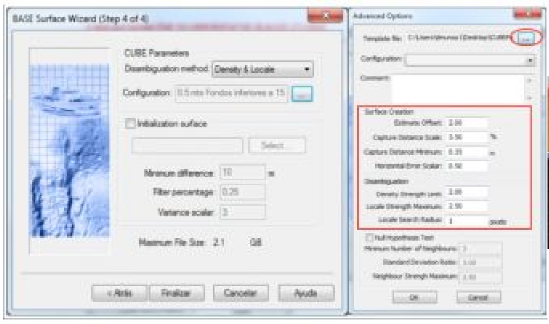
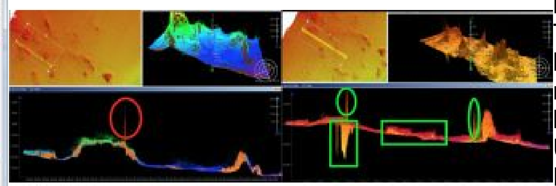
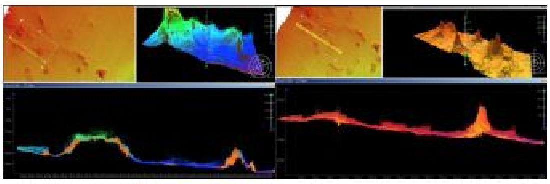
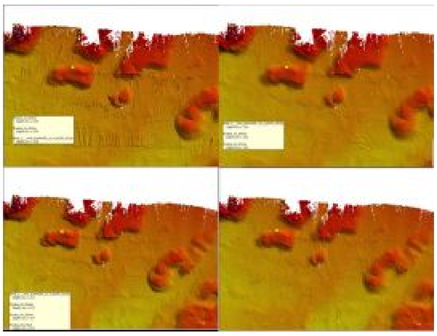
TO PROCESS DATA FROM A SURVEY WITH CARIS HIPS

General Description of XML File CUBE Parameters

Interferometric sonars acquire millions of soundings in a hydrographic survey. The processing of this data by a hydrographer without a reliable statistical algorithm like CUBE (Combined Uncertainty and Bathymetry Estimator), to obtain a bathymetric map, would be practically impossible. *CARIS HIPS* software allows the use of the CUBE algorithm, invented by Dr Brian Calder, with an editable XML file to process the millions of soundings acquired in a survey. A good adjustment in the values â€‹â€‹of these parameters improves the outcome of the CUBE model, obtaining a seafloor as close to reality as possible. The values â€‹â€‹of these parameters mainly depend on the working depth, the roughness of the seafloor and the equipment used.

CUBE is a very complex statistical algorithm that uses all the information from acquired soundings to assign the most probable depth of the proposals with their respective uncertainty value, in accordance with the established resolution, to each position. CUBE generates hypotheses (depth values) and selects the best solution in each position, according to the values â€‹â€‹of the XML file parameters.

The CUBE model is a mathematical representation of reality. Therefore, if data from the survey is of a good quality (good sea state, high overlap between adjacent lines, high updating of sound velocity in the water column, adequate speed of the boat/vessel, etc.) and CUBE parameters of the XML file have a good adjustment, the bathymetric model will give efficient results, resembling the seafloor. Otherwise, the bathymetric model will be less similar to the real seafloor, and the hydrographer will spend more time processing acquired data.

Generation of Hypotheses in CUBE

Generally speaking, it is possible to wonder which soundings have greater weight than others in a node, and how CUBE generates hypotheses. The weight assumptions are:

- Soundings with a low vertical uncertainty have greater weight than those with higher vertical uncertainty.
- Soundings with a low horizontal uncertainty have greater weight than those with higher horizontal uncertainty.
- The closest soundings to the centre of the node have greater weight than those that are far away.

It is important to highlight that from these assumptions the importance of knowing all uncertainties of the equipment used in the system are deduced because the CUBE algorithm depends on them.

Hypotheses are generated at each node. There may be more than one hypothesis per node. If the value of a sounding does not vary from the previous soundings significantly, the value of the hypothesis is maintained. However, if the value of the sounding varies with respect to the previous soundings, a new hypothesis will be generated. All this is related to the survey quality. If the data are of poor quality there will be a greater dispersion of data and more hypotheses will be generated.

Disambiguation Methods to Determine the best Hypothesis

Starting from the premise that acquired data is of high quality, it is only necessary to analyse which values â€‹â€‹are the best to use in the XML file. For this, it is necessary to know, in general terms, how the CUBE algorithm works.

CUBE parameters are set in accordance with two methods of disambiguation, density and local.

- The 'density' method selects the hypothesis that presents the largest number of soundings at the same depth in the node (in according with the established resolution).
- The *'local'* method selects the hypothesis that is more consistent with the neighbouring nodes, in compliance with a set of constraints. This method, which is more difficult to understand, works as follows:

A radius of influence is established around the node of interest, controlled by the parameter 'locale radius'. Only the nodes within this radius are used to determine the robust average depth, according to the values of parameters 'density strength cut-off' and 'locale strength max' *(*minimum and maximum thresholds of this method respectively), which have the same scale as the hypothesis strength.

For each node, in its radius of influence, is determined if the hypothesis strength (which is 5 x [1 - (number of consistent soundings / number of soundings per node]). The lower the hypothesis strength value, the better) is acceptable. If so, the best hypothesis (i.e. the lowest hypothesis) is used in each node of the radius of influence. Otherwise, that node is omitted in the calculation.

With the best hypothesis of the nodes that influence the radius of influence of the node of interest, an arithmetic mean of soundings is computed, discarding the extreme soundings of the nodes in the radius of influence, i.e. the average value of depth of adjacent nodes that influence the radius of influence of the node of interest without considering the depth of the adjacent nodes with the highest and lowest value. Finally, the algorithm in the node of interest selects the hypothesis with the closest depth to this robust average value.

Therefore, it is recommended to use a combination of both methods. At first, each node selects the hypothesis containing the largest number of soundings at the same depth (density method), and when the value of the hypothesis strength of a node is greater than the cut-off value of the parameter 'Density strength cut-off' and lower than the value of the parameter 'local strength max', the local method is used to select the closest hypothesis to the robust average depth (see Figure 1).

CUBE Parameters of the XML file

After modifying CUBE parameters one by one, and generating more than 40 XML files to analyse the results in different types of seabed, the final conclusions are:

Estimate Offset Value*:* It is the threshold to generate more or less hypotheses. It is advisable to increase its value to generate less hypotheses, when acquiring quality data.

Capture Distance Scale Value*:* It is a value (in percentage) for an estimated depth, using a radius of influence (for the soundings) to determine the data at each node. If, for example, the value 3.5 (3.5 x depth) in an area where the mean depth is 20m, the radius of influence would be 0.7m.

Capture Minimum Distance Value*:* This value (in metres) is used along with the previous parameter (Capture Distance Scale*)* to limit the minimum search radius and determine the data. The recommended value to use depends on the used resolution (it could be a value close to the value of the hypotenuse of the right-angled triangle formed by the sides that each one measures half resolution).

Horizontal Error Scalar Value*:* The value used to exaggerate or reduce the horizontal uncertainty scale of each sounding. The recommended value would be 2. However, it may be also reduced.

Density Strength Cut-off Value*:* It is the value of the hypothesis strength used to change the disambiguation method, from 'density' to 'local'. The default value to use is 2. However, it may be reduced to 1.5.

Locale Strength Maximum Value*:* It is the maximum value of hypothesis strength allowed in the local method so that weaker hypotheses do not influence the calculation. The default value is 2.5. However, it may be increased up to 3.0, giving good results.

Locale Radius Value*:* It is the search radius for the calculation of the average value of neighbouring nodes. The value is in nodes and its default value is 1. However, it is recommended to increase this value.

Conclusions and Recommendations

On the condition that all data is of good quality, the use of CUBE algorithm in *CARIS HIPS* with an effective adjustment of its parameters in the XML file allows the hydrographer to reduce processing time to obtain a bathymetric map that resembles the real ocean floor (Figures 2 and 3).

The study and analysis conducted on the statistical model CUBE and the wide variety of tests performed in different survey areas, at different resolutions, has given rise to convincing conclusions in different types of ocean floor, with data from an interferometric sonar (Figure 4).

CUBE parameters/Type of seafloor at 1 metre resolution	**Flat Seafloor**	**Varied rocky seafloor**	**High gradient seafloor**
Estimate Offset Value	8	7	6
Capture Distance Scale Value	7	5	5
Capture Distance Minimum Value	0.6	0.5	0.5
Horizontal Error Scalar Value	2.0	1.5	1.5
Density Strength Cut-off Value	1.5	1.5	2.0
Locale Strength Maximum Value	3.0	3.0	2.5
Locale Radius Value	8	2	2
CUBE parameters/Type of seafloor at 2 metre resolution	**Flat Seafloor**	**Varied rocky seafloor**	**High gradient seafloor**
Estimate Offset Value	9	5	5
Capture Distance Scale Value	6	6	6
Capture Distance Minimum Value	1.2	1.2	1.2
Horizontal Error Scalar Value	2.0	2.0	1.5
Density Strength Cut-off Value	1.5	1.5	2.0
Locale Strength Maximum Value	3.0	3.0	2.5
Locale Radius Value	5	2	2

Table 1: Possible values â€‹â€‹to use in CUBE parameters XML file with an interferometric sonar, at resolution 1 and 2 metres, depending on type of seafloor.

Therefore, it is advisable to generate CUBE parameters for each system, depending on type of seafloor, the depth and the desired resolution.

More Information

CUBE User's manual v. 1.13 (2007), Brian Calder, David Wells, University of New Hampshire.