EUSeaMap

Technical Report No. X

Bathymetry and thresholds

Contents

1 Introduction

Bathymetry is one of the key deliverables for EUSeaMap from the EMODNET hydrography project. The DEM being developed by the EMODNET Hydrography consortium is of a minimum quarter minute resolution, with the latest half minute resolution GEBCO (General Bathymetric Chart of the Oceans) release incorporated for areas where sufficient data cannot be made available. The EMODNET Hydrography project covers the North and Celtic Seas and the Western Mediterranean. An initial draft of this dataset for the North and Celtic Seas was received in May 2010. The preparation of this North Sea and Celtic Seas DEM is described in more detail in the Hydrography project Interim Report[1]. In the Western Mediterranean, EUSeaMap partners are also partners in the EMODNET Hydrography project. The projects have elaborated a Mediterranean global DEM with a resolution of 0.0027 decimal degrees.

2 Data layer preparation

2.1 Baltic Sea

The Baltic Sea bathymetry map was compiled from four regional bathymetry maps (Figure 1), these are:

- The Swedish 1:500,000 scale map
- The Swedish 1:50,000 scale map
- The Finnish 1:50,000 scale map
- The Danish 1:500,000 scale map

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[1] https://webgate.ec.europa.eu/fpfis/iwt/sites/default/files/Hydrography-1st-Interim-Report.pdf

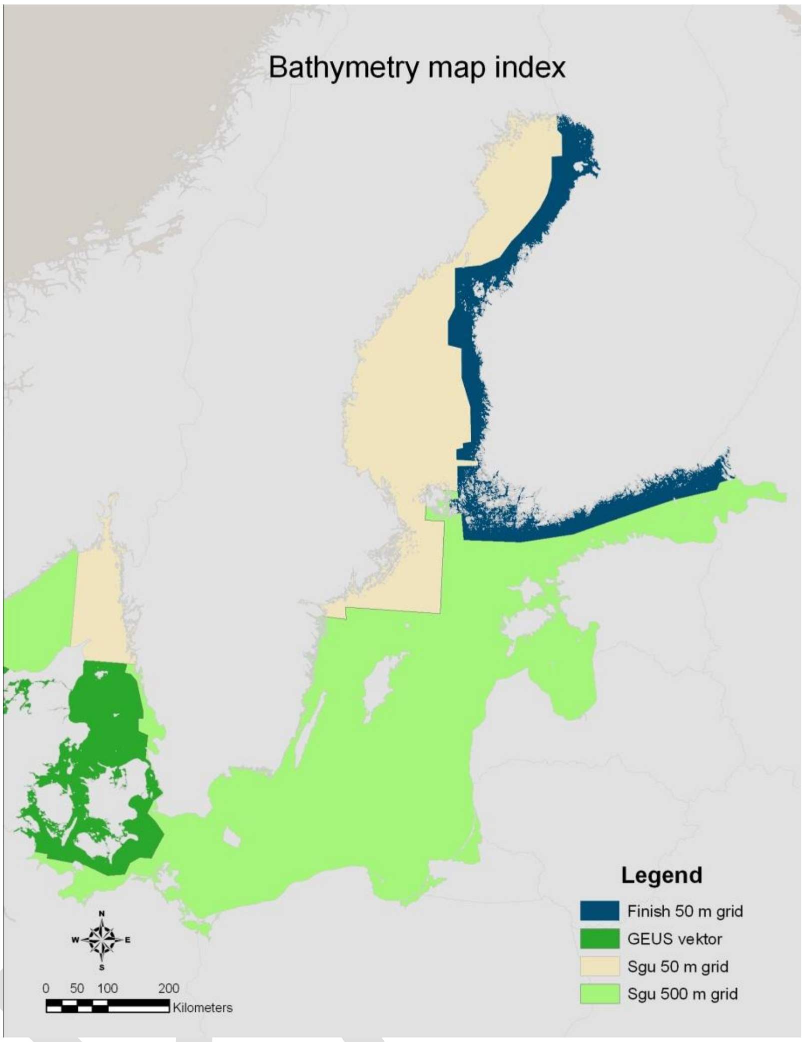

Figure 1 Baltic Sea bathymetry map index, showing coverage of four regional sources.

Joining bathymetry maps from different sources is not a straightforward task. Differences in bathymetry values at the boarder lines are readily shown in the merged map. It is also difficult to produce a reasonable and flawless slope values out of such maps. Therefore care was taken to inspect the boarder zone of each two different maps and try to merge them by finding the average value at the overlap if they do not match.

Another problem was to join maps of different resolution; this immediately appears at the joint boarder so at some area it was decided to under sample the high resolution map to match it with the neighbouring low resolution one. In other occasions the high resolution map was used as it is, and others it was replaced by a lower resolution map. The final Baltic bathymetry map used in EUSeaMap is shown in Figure 2.

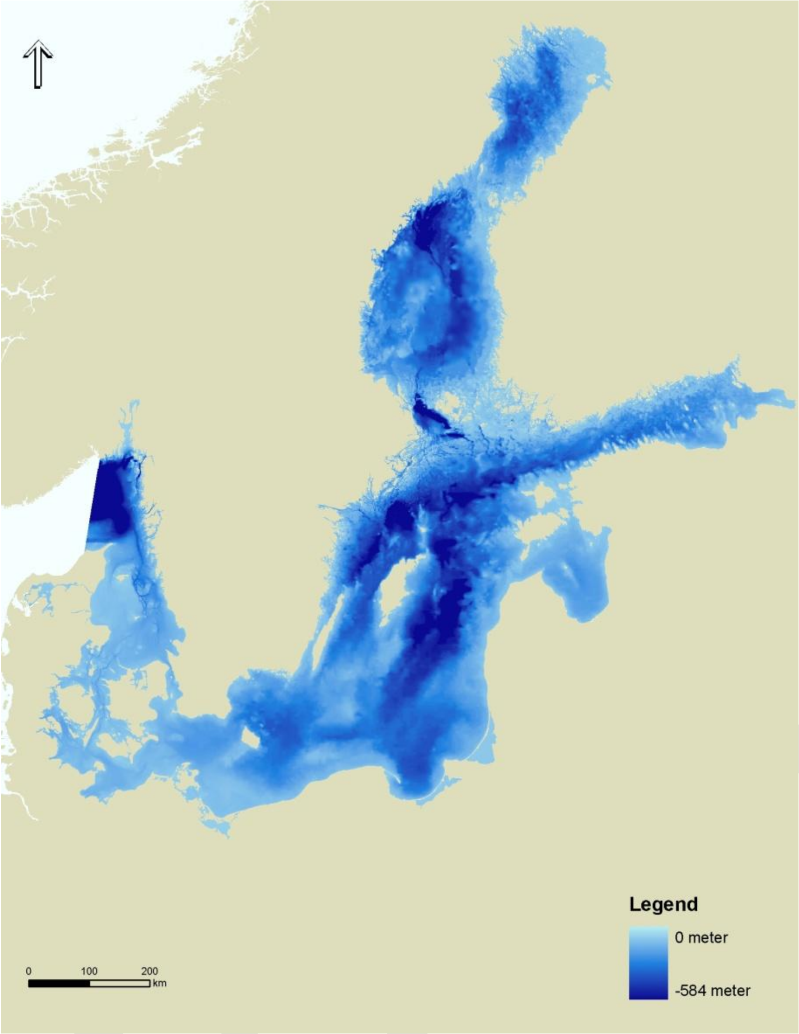

Figure 2 Baltic bathymetry map used in EUSeaMap, sourced from BALANCE project.

2.2 North and Celtic Seas

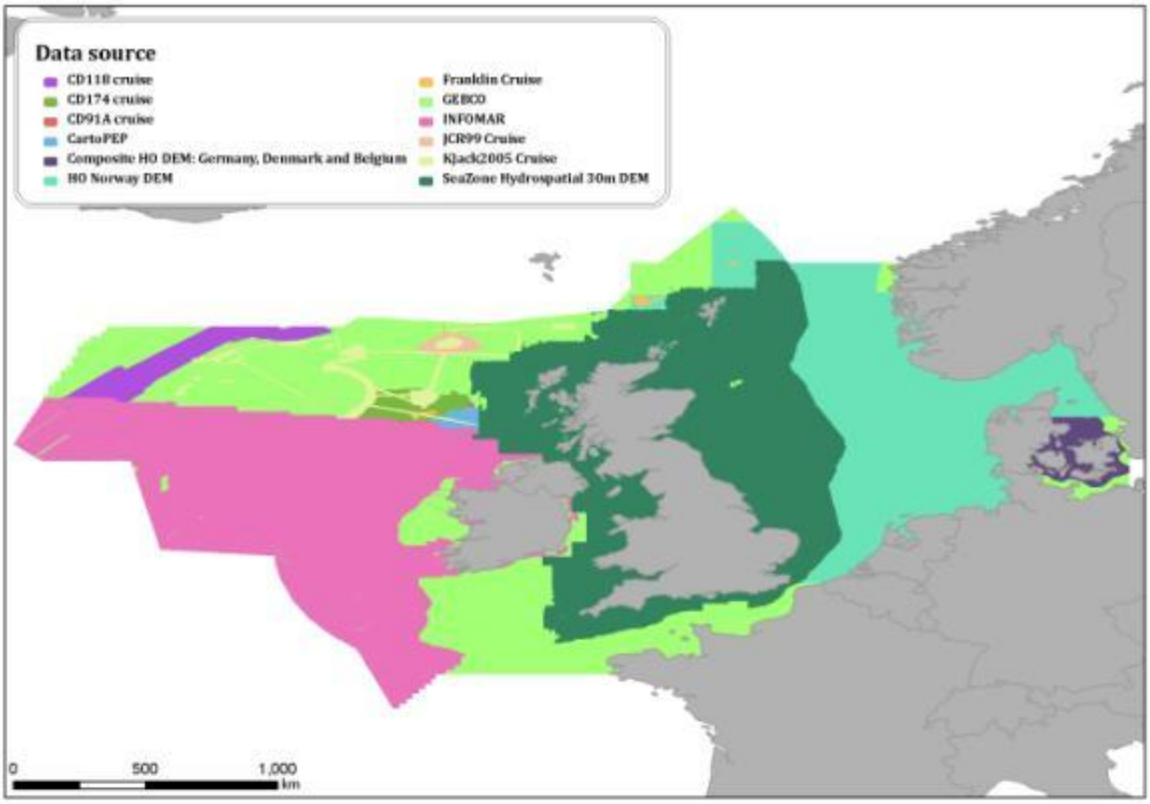

Figure 3 Data sources for the North and Celtic Seas. All data sources contributed to the EMODNET DEM except the SeaZone hydrospatial 30m DEM. This licenced product was included within this project to improve the modelled habitats for coastal and shelf regions of UK waters, and in lieu of access to UKHO data.

Due to difficulties encountered by EMODNET Hydrography group in obtaining data from the UK Hydrographic Office (UKHO), the EUSeaMap group used UKHO depth data obtained through a licensed SeaZone product (the 'SeaZone dataset' hereafter) for much of the UK shelf waters: these data cover a large part of the UK shelf area, but do not extend as far as the deep sea. EMODNET has since obtained data from the UKHO and is in the process for incorporating it into an update of the DEM, due in March 2011. There are some gaps in the SeaZone dataset, which were filled as follows:

a. Use EXTRACT BY MASK to select GEBCO data for the area, in order to cover the 'large gaps'
b. Convert extracted GEBCO data to points then apply Inverse Distance Weighting (IDW) function to interpolate to the resolution of EMODnet hydrography project (0.0020833333)
c. Mosaic a 0.0025 'resample mosaic'* of SeaZone (all) and their Seazone IDW interpolation (the 'small gaps')
d. Resample the above (c.) to 0.0020833333
e. Mosaic (d.) and (b.), giving precedence to (d.)

**SeaZone data were provided as a set of raster tiles at 30m resolution. A script was written which converted all the tiles to points, interpolated them to 0.0025 (IDW) and then mosaiced them together.*

In order to join the EMODnet hydrography GRID and SeaZone dataset, the following steps were carried out:

a. Multiply EMODNET bathymetry by (-1)
b. Mosaic output (e.) above and the EMODnet bathymetry

The final North and Celtic Seas bathymetry map used in EUSeaMap is shown in **Figure 4**.

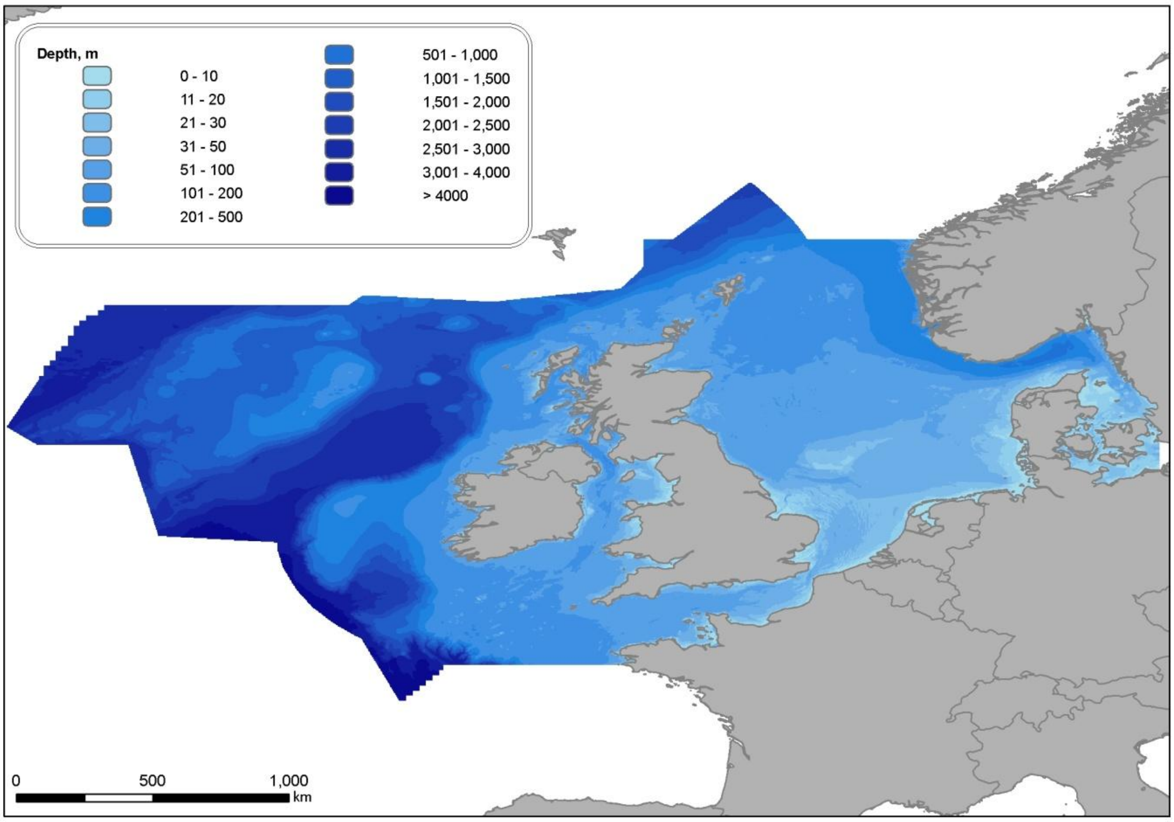

Figure 4 Bathymetry map for the North and Celtic Seas.

2.3 Western Mediterranean Sea

2.3.1 Introduction

A Digital Terrain Model (DTM) for the Western Mediterranean was produced with a resolution of 0.0027 decimal degrees. This DTM was made from DTMs covering different parts of the area (Figure 5).

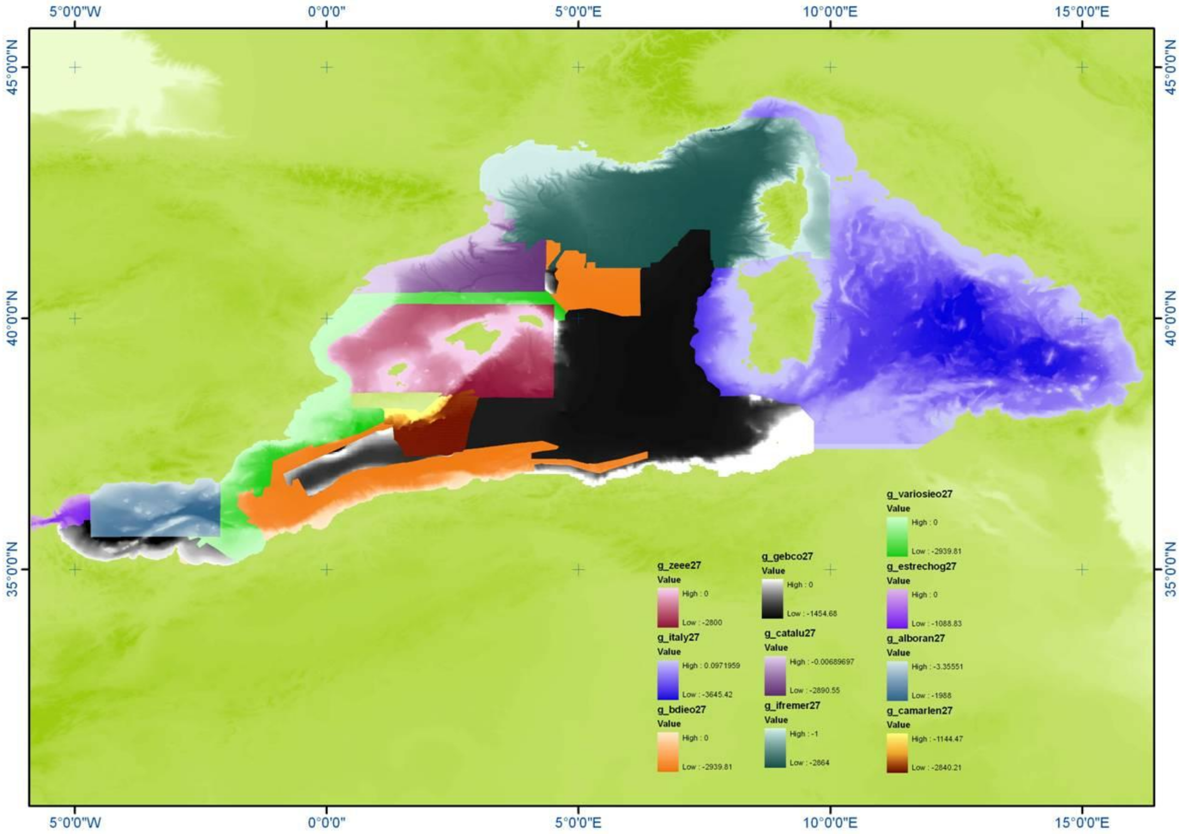

Figure 5 DTMs covering parts of the Western Mediterranean.

Nine DTMs were available for the Spanish margin and deep zones:

1. 353_291001 (Alborán Sea)
2. 353_291002 (Catalan Continental Margin)
3. 353_291003 (South of the Ibiza Island – Balearic Islands)
4. 353_291004 (South of the Formentera Island – Balearic Islands)
5. 353_291005 (Strait of Gibraltar)
6. 353_291006 (East Mediterranean Margin)
7. 353_291007 (ZEEE: Spainish Exclusive Economic Zone – Balearic Islands)
8. 353_291008 (IBCM: South Alborán Sea)
9. 353_291009 (IBCM: Deep zone of Mediterranean Sea)

One DTM covered the French margin:

10. 353_291010 (IFREMER)

Two DTMs for the Italian margin:

11. 353_291011 (Shallow water Tyrrhenian Sea)
12. 353_291012 (Deep water Tyrrhenian Sea)

The data processing has been different for each DTM, with the type of processing required determined by the data source and format of the original data.

2.3.2 Processing for the Spanish margin data

Data have been collected from several sources to prepare these DTMs. The data owners have provided data in two formats.

In most the data source was a DTM in GRID format (raster format ArcGIS, structured in a regular matrix), with the depth value associated in the centre of the cell. These DTMs have different resolutions. The process executed in this case has been:

a) From each GRID, and ESRI™ Shapefile of points has been exported, with each point corresponding to the centre of the cell on the original GRID and having the associated the depth value of each cell.
b) With each point Shapefile the standard ArcGIS Inverse Distance Weighting (IDW) interpolation command was applied to interpolate between the points.
c) Several tests were made, changing the search radius and the number of points used to interpolate the new value. The number of points that produced the least error in each case was used.

In other cases the data sources were ISOBATHS with variable equidistance, in which case the process was as follows:

a) From the polyline Shapefiles, a GRID was interpolated with the algorithms used by ArcGIS Software in the TOPOGRID command.
b) The results depend on the distance between the ISOBATHS.

A small overlap zone occurs where different datasets meet, to avoid areas of 'no data'. Further information is given below about the data source for each grid:

1. 353_291001 – Alborán Sea
   This DTM was elaborated from two GRIDs, both interpolated with the IDW method:

   1.1 A GRID of 25 x 25 metres resolution with information about the continental shelf and slope. The depths vary between 5 and 160 metres. This information has been obtained using multibeam echo-sounder: ESPACE Project; 2000-2005; Spanish Institute of Oceanography (IEO) and Spanish Sea Secretary General (SGM).
   1.2 A GRID of 100 x 100 metres resolution with information for depths greater than 160 metres, for the whole Alborán sea. This information has been obtained using multibeam echo-sounder: CARPEMA Project; 2002-2007; IEO-SGM.

2. 353_291002 – Catalan Continental Margin
   This DTM was elaborated from three GRIDs:

   2.1 Two GRIDS of 25 x 25 metres resolution with information about the continental shelf and slope. The depths vary between 5 and 160 metres. This information has been obtained using multibeam echo-sounder: ESPACE project; 2000-2005; IEO-SGM.

   2.2 A GRID of 250 x 250 metres resolution provided by the University of Barcelona (Spain), Dr Miquel Canals. The GRID was interpolated from information obtained using multibeam echo-sounder.

3. 353_291003 – South of the Ibiza Island – Balearic Islands
   This DTM is formed only by a GRID, interpolated with the IDW method:

   3.1 This 200 x 200 metre resolution GRID is derived from to the multibeam information obtained in the SBAL-DEEP Project: 2005; OGS (Italy).

4. 353_291004 - South of the Formentera Island – Balearic Islands
   This DTM is composed of one GRID interpolated with the IDW method:

   4.1 The grid corresponds to the information provided for the Secretary General of Sea (Ministry of Environment of Spain), with a resolution of 100 x 100 metres, obtained using multibeam echo-sounder: Balcom Project; 2002.

5. 353_291005- Strait of Gibraltar
   This DTM was elaborated from three data sources:

   5.1 Information obtained in the TARIK surveys using single-beam echo-sounder: 1980-1992; IEO. The data source has been ISOBATHS with an equidistance of 2 metres. The grid has been obtained by the TOPOGRID command of ArcGIS.
   5.2 Information obtained in the HERCULES survey Single Beam (1983; IEO). The data source was ISOBATHS. The GRID has been obtained by the TOPOGRID command of ArcGIS.
   5.3 Information collected with multibeam echo-sounder during several surveys (EZA survey; LE SUROIT – 91 survey; MARGUAL survey; MARSIBAL Project) was used to produce a grid for each survey. The composite grid was interpolated with the IDW method.

6. 353_291006 – East Mediterranean Margin
   This DTM was elaborated from several data source:

   6.1 Six grids corresponding to the information obtained from isobaths with variable equidistance depending on the zone of study. The data source of these isobaths is the MARINE GIS of Spanish Institute of Oceanography. These grids have been obtained by de TOPOGRID command of ArcGIS.
   6.2 The rest of information has been obtained with echo-sounder multibeam in several surveys, obtained a grid for each survey. The final grid has been interpolated with the IDW method.

7. 353_291007 – ZEEE: Spain Exclusive Economic Zone – Balearic Islands
   This DTM was elaborated from eight different types of data sources:

   7.1 Information obtained with multibeam echo-sounder in several surveys for the IHM (Marine Hydrographical Institute) and the IEO, concerning the EEZ in the margin of the Balearic Islands. The information used has been a grid of 100 x 100 metres resolution. The composite grid has been interpolated with the IDW method.
   7.2 The rest of the information has been obtained from isobaths (MARIEN GIS IEO) with variable equidistance of different zones. These grids have been obtained by the TOPOGRID command of ArcGIS.

8. 353_291008 – IBCM: South Alborán Sea
   8.1 This DTM is composed by one grid. The origin of this information is the IBCM database.

9. 353_291008 – IBCM: Deep zone of Mediterranean Sea
   9.1 This DTM is composed by one grid. The origin of this information is the IBCM database.

In all cases, multiple tests have been made in order to use the method which would introduce least error in the result.

2.3.3 Processing for the French margin data

10. 353_291010 – IFREMER

IFREMER provided a DTM in GRID format, referenced in Mercator projection, with a resolution of 250 metres. Therefore it was not necessary to run any process of interpolation; it only has been necessary change the projection.

To make this change the original GRID from IFREMER was transformed into a GRID format in geographic coordinates, with a resolution of 0.0027 decimal degrees, according to the technical specification of the project. Two different transformation processes were tested; the method selected was the one associated with least error produced:

Method 1

- Transform the GRID data in Mercator to GRID format in geographic coordinates with the PROJECT command (ArcGIS), using as a parameter the cell size of the new raster = 0.0027 decimal degrees. PROJECT command used the nearest method to interpolate the new GRID.

Method 2

- Convert the original GRID data to a point Shapefile, where each point corresponded to the centre of each cell of the GRID. This point has the depth as the associated value.
- Next, project the point Shapefile from Mercator projection to geographic coordinates with the PROJECT command (ArcGIS).

- Finally, from the point Shapefile in geographic coordinates, an interpolation was made of new GRID with the IDW method (ArcGIS command) to obtain a resolution 0.0027. Several tests were made, and a different number of points was used to interpolate each time, which varied between 4 and 12.

After using these two methods, error estimation was made and Method 1 was shown to produce less error.

2.3.4 Italian margin data

ISPRA provided a DTM in GRID format with a resolution of 0.0027 decimal degrees, therefore was not necessary to carry out any processing. This DTM was elaborated from two different data sources.

11. 353_291011 (Shallow water Tyrrhenian Sea)

12. 353_291012 (Deep water Tyrrhenian Sea)

An error was detected in the data in the deep zone; therefore these data were replaced with the data from the morpho-bathymetry of the Mediterranean Sea: CIEMS; Medimap group; 2005.

2.3.5 Process to elaborate the DTM for the Western Mediterranean

Finally the global DTM (Figure 6) was produced from a union of all partial DTMs, with the MOSAIC command (ArcGIS Software).

- When the DTM is made from several grids with MOSAIC command of ArcGIS, the grids are adjacent with a small zone of intersection to avoid the appearance of holes.

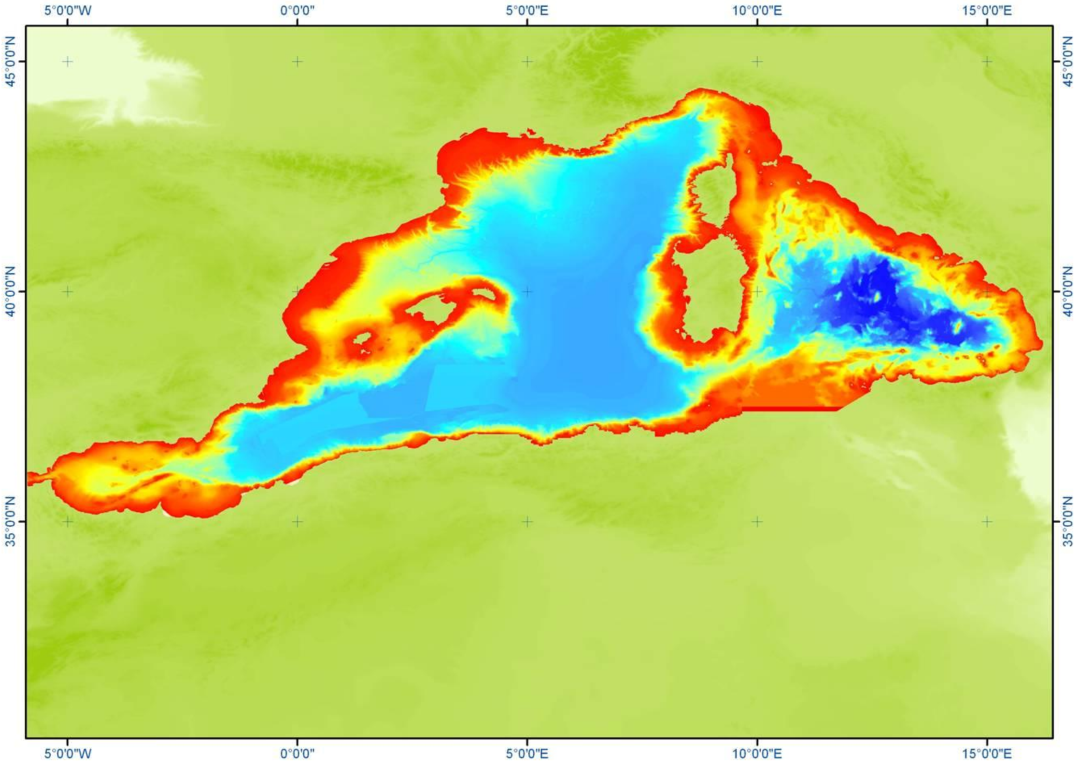

Figure 6 Final DTM for Western Mediterranean.

3 Development of thresholds

3.1 Definition of bathymetric threshold values in the North and Celtic Seas

In the current version of the EUNIS classification scheme (2007-11), the deep sea is a single biological zone, defined as areas deeper than 200m. Recent work has proposed division of the deep sea into five ecologically-relevant zones (Howell, 2010). These divisions have been applied here to increase the level of detail in the deep sea of the North and Celtic seas, towards a level of detail more comparable with that on the shelf. The zones proposed are: upper slope, upper bathyal, mid bathyal, lower bathyal, and abyssal. Howell (2010) used depth as a proxy for variation in the biological communities due to environmental conditions, such as temperature, pressure, oxygen minimum and food supply. Depth thresholds used are show in Table 1

Table 1 Depth bands applied to deep sea zones in the North and Celtic Seas.

Deep sea zones	Depth bands
Upper slope	200 – 750
Upper bathyal	750 – 1,100
Mid bathyal	1,100 – 1,800
Lower bathyal	1,800 – 2,700

Abyssal	> 2,700

3.2 Definition of bathymetric threshold values in the Western Mediterranean Sea

Bathymetry is the abiotic variable that was used to identify the threshold value to delimit the boundary between the lower circalittoral and the bathyal biological zone, and between the bathyal and the abyssal zone. In fact in both these biological zones it is the change in bottom slope angle, resulting from geological processes operating on the seafloor over time, that actually contributes to different environmental conditions influencing the formation of discreet biological communities of the bathyal and abyssal biological zones.

The deep circalittoral-bathyal boundary coincides with the margin of the continental shelf and can be identified on the basis of a change in slope angle followed by the higher slope values of the continental slope. Bibliographic information reports this break as occurring between 110-260m (Carpine, 1970) with a median value range occurring between 170-210m.

The bathyal-abyssal boundary instead coincides with a gradual change in slope angle occurring just after the base of the continental slope. Bibliographic information reports this as occurring in the depth range 2500-3000m. Given the reported heterogeneity in depth associated with both the continental shelf edge limit and the continental slope angle change, it was decided to identify these boundaries manually.

The manual identification of changes in slope angle at the seabed revealed more than one feature needing consideration for the definition of the deep circalittoral-bathyal and bathyal-abyssal boundaries. In particular, a first rupture of slope change (hereafter called ‘shelf break’) was observed at shallower depths than expected, and shallower than the continental shelf edge. The ‘shelf edge’ limit was identified for a good part of the basin but in some instances no shelf edge limit was identifiable due to the absence of a strong change in slope angle. An alternative bathyal-abyssal boundary (‘bathyal basin limit’) was identified in some areas, occurring at shallower depths than expected. The set of manually identified lines indicating slope angle changes and topographic features is displayed in Figure 7.

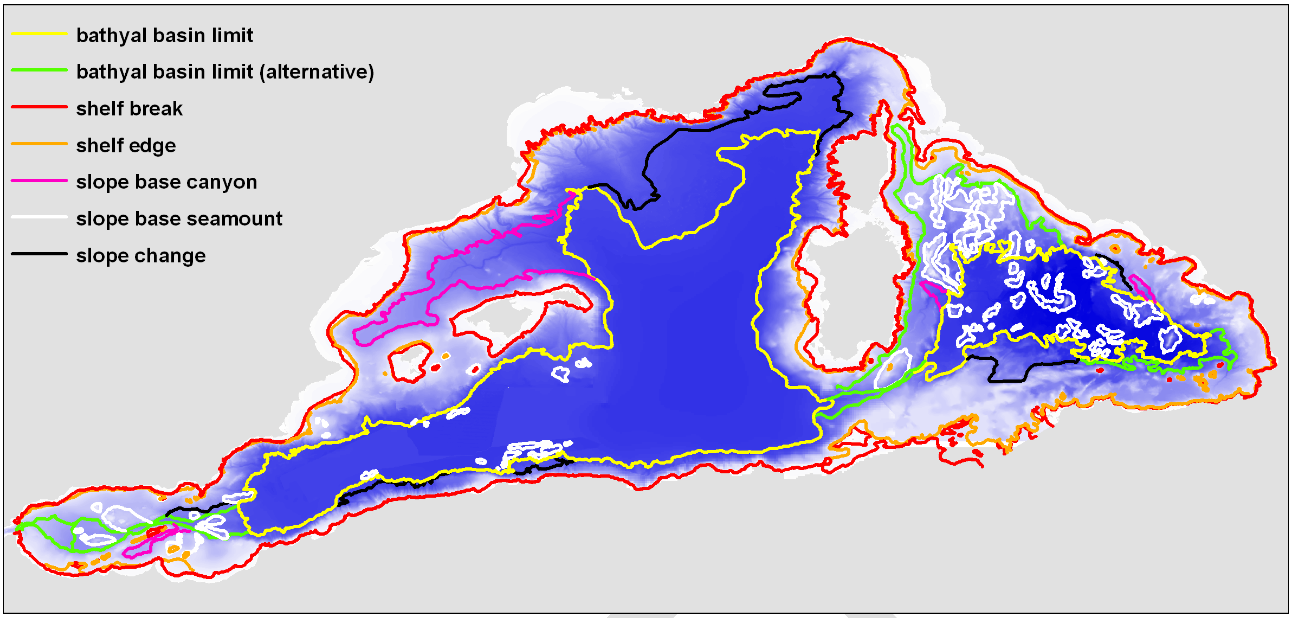

Figure 7 Seabed slope angle change observed in the western Mediterranean.

The definitions of the boundaries in Figure 7 are as follows:

Shelf break: Abrupt rupture of continental shelf.

Shelf edge: Lower limit of shelf break where the slope change is soft. Also, it can be the lower limit of a shelf with double slope rupture (this is frequent in the Tyrrhenian Sea). It usually appears around 140 to 200m.

Bathyal basin limit: Lower limit of continental margin. It is where the deepest and flat area of the basin begins. Habitually, in the sea Mediterranean Sea it is identified at 2500m (2400 to 2600m).

Bathyal basin limit (alternative): This is a limit that indicates areas where there is a strong slope change that could be the possible limit of the bathyal basin, although below this limit a part of the continental margin (very smoothed) still continues.

Slope base canyon: Lower limit of slopes of the most significant canyons or similar geomorphologic features (i.e.: Valencia Trough). It is at a shallow depth than bathyal basin limit, but it could define zones of interest for habitats.

Slope base seamount: In the Mediterranean there are a lot of seamounts and crests, especially in Tyrrhenian Sea and Alboran Sea. These features, usually, have a volcanogenic origin or they are associated with phenomena of this type. These structures appear above and below the bathyal limit. The line defines the base of geomorphologic features, which could be a single seamount or several associated seamounts.

The reason for drawing this limit is that seamounts can be areas of interest from a habitats point of view and their bathymetric ranges are not well matched to the zonation of biological zones.

Slope change: In several areas of the bathyal in the West Mediterranean basin, a change of slope has been identified that defines the border of a geomorphologic feature (scarps, accumulation of sediments, changes in lithology, slides, action of currents, etc.). This has been included as it might be of interest in the future.

The manually-drawn boundaries of the shelf break, shelf edge, and bathyal basin were analysed in order to identify the best depth values to be applied as hard thresholds for the circalittoral-bathyal and bathyal-abyssal delimitation. In order to compare the boundaries with the pixel values of the bathymetric grid it was necessary to associate an identification code to the different arcs and convert the vector feature to a raster grid having the same cell size and extension properties of the bathymetric layer. In this way a codified grid file was created. By converting this raster to points, a new shape file composed of a point for each grid cell was generated. Finally, using the spatial analyst tool “Extract Values to Points” the table associated to the point shape files was integrated with the bathymetric values. The obtained table contains both the identification code associated to the different boundaries and the relative depths.

The depth data of each limit defined by the boundaries were statistically processed in order to evaluate their distribution and to calculate the main statistical parameters which are summarised in Table 2. In a first instance, the statistical analysis was intended to compare the different depth values obtainable from each data set so as to determine a unique depth threshold value and respective fuzzy values that could be used for the creation of a biological zone confidence map. However, after various considerations and trials it was clear that the great heterogeneity observed in the depth values was indicative of the high heterogeneity of oceanographic-tectonic forces which over time have exerted their forces over the seabed morphology of the Mediterranean. It therefore became clear that the biological zone limitations should take into as much account as possible the seabed slope angle changes that were visually observable in the DTM model and that a statistical analysis of the depth range values and frequencies be used to confirm the suitability or integration of the identified boundaries. Hard limits for each of the biological zone limits were therefore sought and a decision was made to avoid using any fuzzy value for such limits.

Table 2 Main statistical parameters of the depth data.

	Count	Mean	Median	Min	Max	LQ	UQ	Pct10	Pct90	SD
Shelf edge	32960	220	212	798	0	246	187	285	154	71
Shelf break	35912	126	115	738	0	133	100	157	76	69
S. edge + S. break	46812	188	194	798	0	231	126	269	94	82
Bathyal basin	29257	2705	2675	3584	1359	2748	2544	3194	2423	285
Bathyal basin alternative	9123	1476	1260	3016	418	2080	869	2630	760	710
Bathyal + alternative	34316	2568	2638	3584	1061	2731	2450	3124	1950	440

3.2.1 Defining deep circalittoral-bathyal limit

Three different boundary datasets were analysed for the identification the deep circalittoral-bathyal boundary:

a) shelf edge

b) shelf break

c) shelf edge + shelf break (includes the shelf edge limit data integrated with the shelf break depth data for those areas where the shelf edge limit was missing)

Figure 8, Figure 9 and Figure 10 show the frequency histogram of the depth values of these respective data sets.

Figure 8 shows that the depth value distribution of the manually identified shelf edge appears relatively normal and very few occurrences can be observed for values < 100m. Even if the distribution is slightly skewed with a robust number of occurrences > 350m, the main parts of the data are included in the central part of the graph thereby indicating the suitability to use the median value in cases in which the shelf edge limit is not easily identifiable.

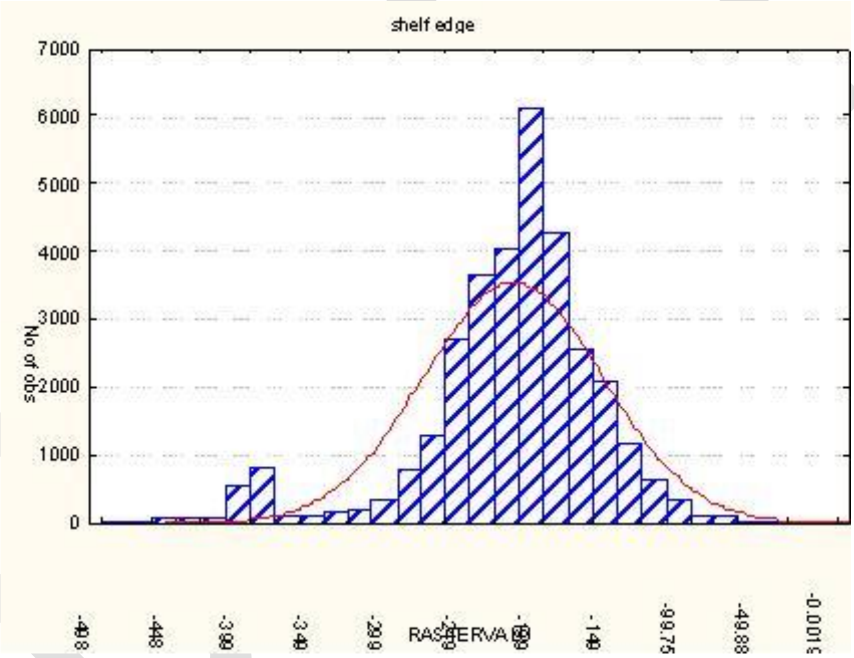

Figure 8 Frequency histogram of the shelf edge.

The frequency histogram estimated using only the depth extracted in correspondence of the shelf break limit (Figure 9) highlights the presence of a very high number of occurrences < -100 which are unusual for the definition of the deep circa /bathyal limit. A closer look at these shallow water data values indicated in fact that they are localised principally along the North African coasts and that this observed shelf break is mostly likely to be an artefact influenced by the poor bathymetric detail available for this geographic area. Nevertheless, the depth values of the principal part of the shelf break histogram (median = 115; mean =126) are also linked to areas where a sharp change in sea bottom slope creates a shelf break at shallower depths than those where a shelf edge is subsequently observed in the very same given area. These shelf break bathymetric values are in any case lower than the depth values of the circalittoral limit as defined in bibliography and as such the shelf break dataset observed is to be considered with caution with respect to its suitability to indicate the lower limit of the circalittoral zone.

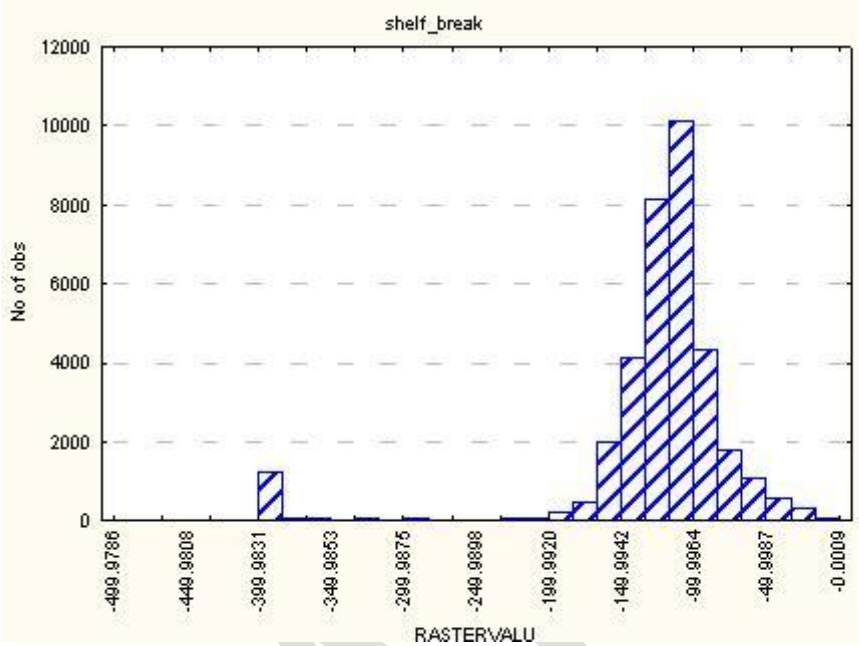

Figure 9 Frequency histogram of the shelf break.

The frequency histogram of the shelf edge + shelf break depth data (Figure 10) shows a more complex distribution in which two different frequency peaks are observed. A first peak consisting in a low depth value dataset is mainly due to the high number of pixels extracted in correspondence of the North Africans coasts where the shelf edge was not identified.

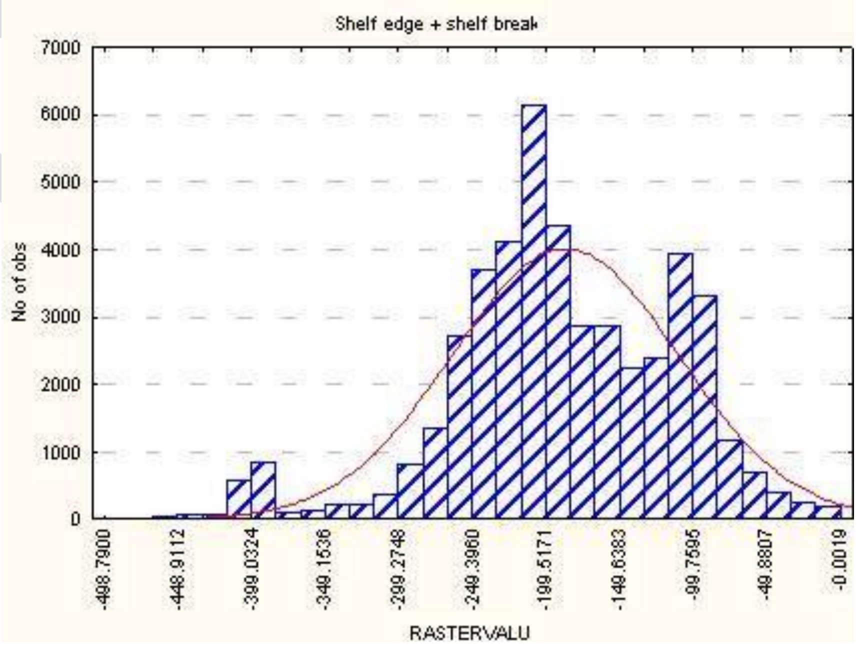

Figure 10 Frequency histogram of the shelf edge and the shelf break datasets combined.

The statistical parameters (Table 2) obtained for the shelf edge and shelf edge + shelf break depth data appear similar. In contrast, the statistical parameters of the shelf break are totally different showing values significantly lower than the other two datasets. A general comment is the unexpected maximum values observed in all three datasets as being 0. This suggests the presence of some likely artefact deriving from how the bathymetric layer was used to identify the first change in bottom slope angle (i.e. if the change in bottom slope angle is detected in cells having a bathymetric value of 0-100 this should not biologically-speaking be considered indicative of a circalittoral habitat). The error is therefore probably due to an artefact probably generated both by the interpolation and the cell size.

The depth frequency histograms and the statistical parameters suggest that the shelf break dataset could be affected by some data interpretation errors due maybe to the original quality of the bathymetry and it therefore seemed inappropriate to use the shelf break isoline or its statistical parameters as deep circa/bathyal thresholds. Moreover, when the shelf break data was integrated with the shelf edge dataset, though the statistical results of this dataset gave similar values to the statistical values of only the shelf edge dataset, the frequency histogram of both datasets combined revealed the presence of two peaks derived from a minor number of depth records indicating the presence of a shelf break at underestimated depths. In light of both the statistical parameters as well as what is known from bibliography about the depth range at which the circalittoral lower limit occurs (range 110m-260m with 170m-210m as optimum central values), the estimated statistical values derived from the analysis of the shelf edge dataset seemed to confirm the validity of the manually identified shelf edge line and its suitability to define the boundary between circalittoral and bathyal zone.

One problem needing resolution however was how to define the shelf edge limit for those areas for which the shelf edge limit was visibly not identifiable (either due to poor bathymetric data such as in the north African coasts or in cases where the shelf edge limit is marked by a slope angle change that is too soft to be picked up by manual inspection). Two possible solutions were hypothesized:

a) usage of the visually observed shelf break line
b) usage of the statistical median value (212m) obtained from the analysis of the shelf edge dataset where the shelf edge line was not visually identifiable

Both approaches were tested and the resulting circalittoral boundaries were compared to known circalittoral / bathyal habitat maps to verify which one best defined the circalittoral boundary.

The application of these two approaches produced a habitat map of the Western Mediterranean having 68776 pixels that were attributed to different biozones. The application of the approach using the shelf edge line integrated with shelf break line produced a modelled map output, for some areas, where the infralittoral merged directly into the bathyal zone in a manner that appeared too abrupt and unacceptable from a benthic zonation point of view. Moreover, if one compares sub areas modelled using the two different approaches, the passage from one biological zone to another occurs at resulting depth values that are not coherent with the depth values described in literature for the biological zones. Figure 5 clearly indicates this flaw. In particular Figure 11a shows how the first approach yielded areas in which the modelled infralittoral zone merged directly into the bathyal zone at shallow depth values of 74-97 metres whereas in Figure 11b, the usage of the median shelf edge depth value (212m) allows to model a wider zone of deep circalittoral habitat and the resulting bathyal zone begins at depth ranges >200 metres.

The circalittoral boundaries obtained with the two approaches were also tested by comparing the modelled output map with known mapped biocenotic circalittoral habitats available for the Tuscan Archipelago in Italy where the shelf edge and shelf break approach yielded 1131 pixels attributed to habitats other than the circalittoral. When these pixels were compared with the available biocenotic maps it was found that all of them belonged to habitats proper to the circalittoral (1% coastal terrigenous muds, 66 % Muddy detritic / Shelf-edge detritic bottoms, 33% coastal detritic). In light of all of the above it was therefore decided that the circalittoral / bathyal boundary utilised in the modelled habitat map be the shelf edge line integrated with the 212m median value for those areas where the shelf edge limit had not been visually identified.

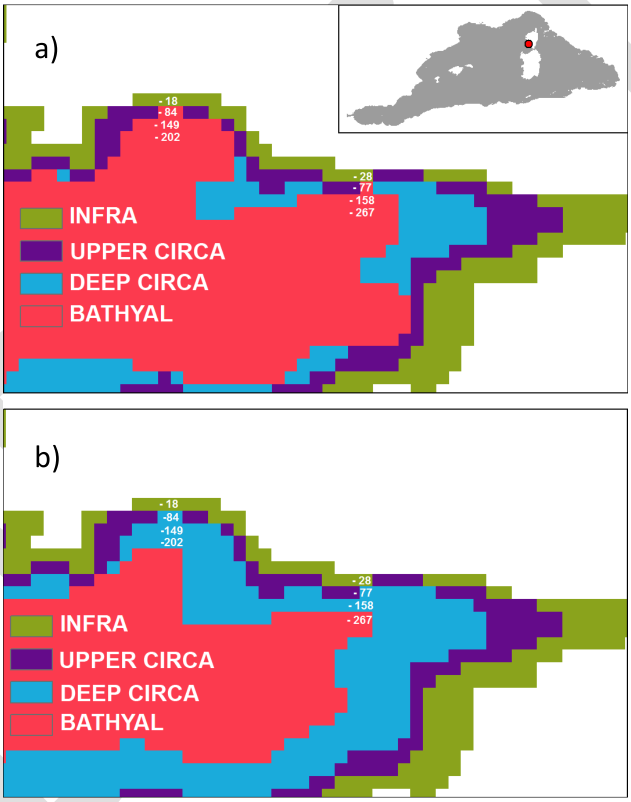

Figure 11 Comparison of the application using the shelf edge line integrated with the shelf break line(a) and the shelf edge line integrated with the median value of 212m (b) in an area of south-western Corsica.

Defining the limit between bathyal / abyssal zones

The second group of features (Bathyal basin, Bathyal basin alternative and the combined Bathyal + alternative) that define the bathyal basin were used to analyse the depth values observed in the changes in slope angle occurring at the base of the continental margin. The combined Bathyal + Bathyal alternative layer was created by adding some arcs of the original alternative bathyal to the bathyal basin for the area of the Alboran Sea and in the area lying between the southern part of Sardinia and northern Tunisia/Sicily (Figure 12).

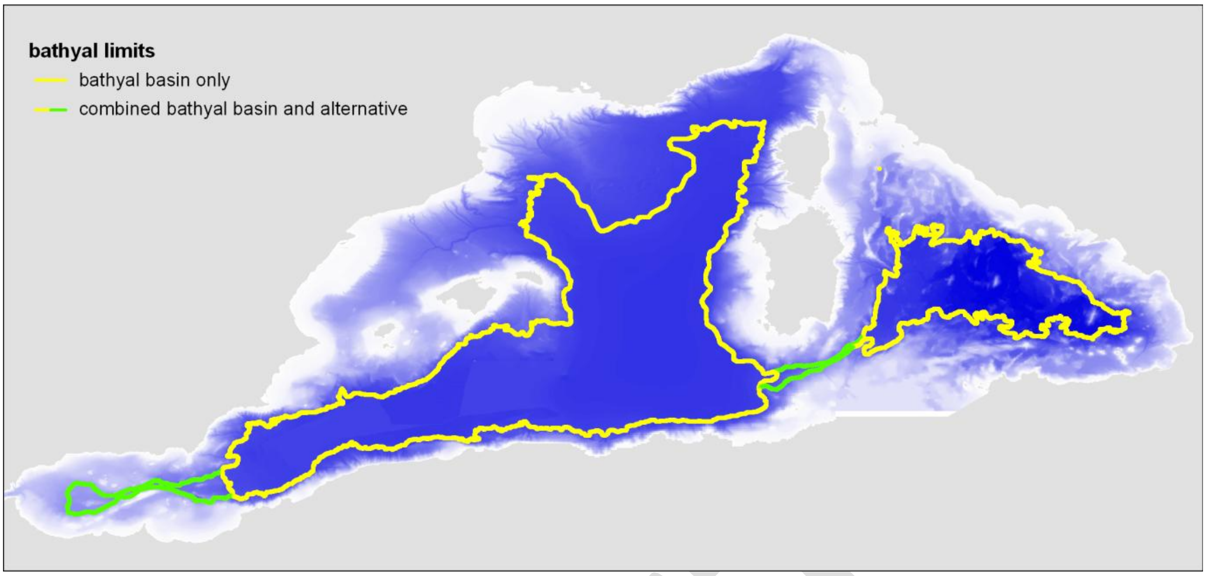

Figure 12 Identified bathyal basin limits and alternative basin limit occurring at shallower depths.

The frequency diagrams of these two datasets (Figure 13) shows a similar disperse distribution trend for the depth values between the two datasets though the bathyal basin + bathyal alternative dataset yields a more dispersed distribution in the shallower end of the bathymetric interval due to the fact that the bathyal alternative basin limit was observed in areas where the continental slope seabed angle starts changing at shallower depths than in the rest of the Mediterranean. Even though the peak depth range observed for the end of the bathyal zone lies mostly around the 2500-2600m range the histograms confirm a vast heterogeneity in depth values in which the seabed slope changes and which is a result of the different oceanographic-tectonic conditions that have operated through time on the evolution of the Mediterranean seabed. The bathyal basin alternative line identified in the Alboran sea was not considered to be effectively indicative of a real bathyal basin due to the oceanographic features of the Alboran sea. To this effect, the bathyal/abyssal limit that was used for the purpose of the modelling is that generated by the visual detection of the bathyal basin integrated with the bathyal basin alternative identified in the Sardinian – Sicilian – Tunisian area.

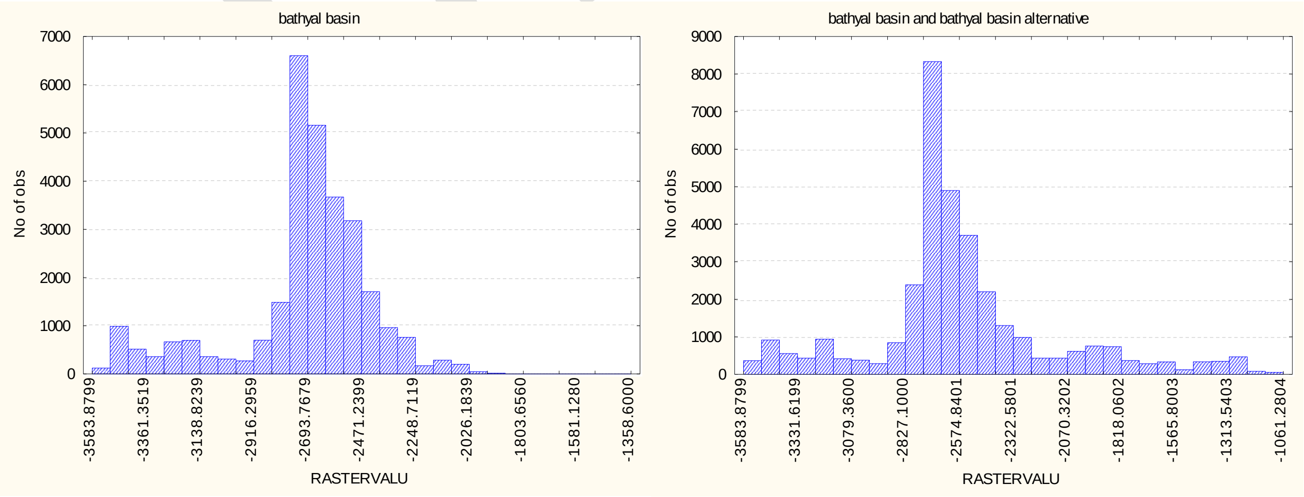

Figure 13 Frequency histogram of the bathyal basin and bathyal basin + bathyal basin alternative.

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