UPDATING THE NATIONAL COASTLINE OF PORTUGAL TO SUPPORT THE PORTUGUESE SUBMISSION UNDER ARTICLE 76 OF UNCLOS

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Abstract

The national coastline is one of the most important features when considering the delimitation of maritime zones. Its physical location might be defined by the intersection line between the foreshore and a specific tidal datum. In the 1982 UNCLOS article 5 this line is defined as the low water line along the coast, as marked on large-scale charts of the coastal state. In Portugal mainland this shoreline is fully represented in nautical charts at scale 1:150 000. The ambiguity in the definition of which “low water” to use, led the IHO to adopt the Lowest Astronomical Tides (LAT) as the world standard in 1997. The official Portuguese shoreline is divided in three major areas. These represent the Portuguese mainland and the Azores and Madeira archipelagos. Several distinct geodetic referencing frameworks are underlying those three geographic areas. Portugal is officially converting its cartography to the reference system PT-TM06/ETRS89 that use the GRS80 ellipsoid and is based on the ETRS89 (for the mainland) and to PTRA08-UTM/ITRF93 that also use the GRS80 ellipsoid but is based on the ITRF93 (Atlantic archipelagos). High spatial-resolution orthophotos and satellite imagery, together with GPS and conventional surveys, are used to infer the LAT line. However, as the remotely sensed data was already gathered, images were not taken at the same tidal level. To overcome this limitation, ancillary data, such as Digital Terrain Models and tidal data, have to be used to estimate the planimetric tidal range for each specific zone. Although the interpretation of the LAT line using this methodology and data was not the most desirable solution, it is significantly better than the one extracted from the 1:150 000 cartography.

1. Introduction

On May 11th, 2009, Portugal submitted to the Commission on the Limits of the Continental Shelf (CLCS), in accordance with Article 76, paragraph 8, of the United

Nations Convention on the Law of the Sea, information on the limits of the continental shelf beyond 200 nautical miles from the baselines from which the breadth of the territorial sea is measured. Later, on April 13th, 2010, Portugal officially presented the submission to the CLCS.

The coastline solution adopted within the Continental shelf submission of Portugal fully observes the recommendations of the Scientific and Technical Guidelines of the Commission on the Limits of the Continental Shelf (CLCS/11, 1999).
Considering the workload of the CLCS a wide temporal gap is expected up to the moment of effective assessment of the Portuguese submission. New and improved quality data, from the public agencies in Portugal, became recently available which may assist to improve the accuracy of the coastline and constitutes also an opportunity for further improvement of the information contained within the Portuguese submission. An additional goal was also considered for undertaking the task described here: the updating of the obsolete geographic referencing systems used for Portugal into the new official ones.

Along this project several methodologies were considered to achieve the final results based on a low-cost solution. Although several authors consider that this mapping process is an expensive task, mainly due to the cost of the data (Carleton, 2010), we tried to find out an alternative approach to access the required data, but maintaining the costs at a lower level.

2. Representing the National Coastline

Although it appears at first glance a trivial matter, the National Coastline definition is not a straightforward topic. There are several different factors that contribute to this reality. These are the inherent wording that describes the object, such as coastline, shoreline, baseline, the spatial location of the feature, which depends on the adopted vertical datum, and the technical complexity to locate and delineate such spatial item.

Depending on the final purpose of the coastline, this may assume different locations as the result of the intersection of the coastal shape with the vertical reference plane. For instance, in land based cartography, the adopted vertical datum is the mean sea level. On the other hand, nautical charts normally take the adopted chart datum to derive the location of the coastline. Another type of coastline considered in Portugal to establish the public maritime domain is extracted using the highest astronomical tide as reference. Finally, and following the scope of this paper, the normal baseline takes for input the lowest astronomical tide to derive the “legal” shoreline.

2.1. UNCLOS official coastline definition

According to the Technical and Scientific Guidelines, when preparing a submission to extend the legal continental shelf, a coastal state has to provide the necessary information regarding to the baselines from which the breadth of the territorial sea is measured. As described in the UNCLOS, these can be either normal baselines, Article 5, or straight baselines, Article 7. Considering the normal baselines, these can be defined by the set of elements addressed in UNCLOS Articles 5, 6, 11, and 13, namely the low-water line along the continental shore and around islands, including the outer limits of permanent harbour works, the low-water line around certain low-tide elevations, and the seaward low-water line of atoll reefs and of fringing reefs around islands (IHO, 2006). Schematically, one can set their final baselines as represented in Figure 1.

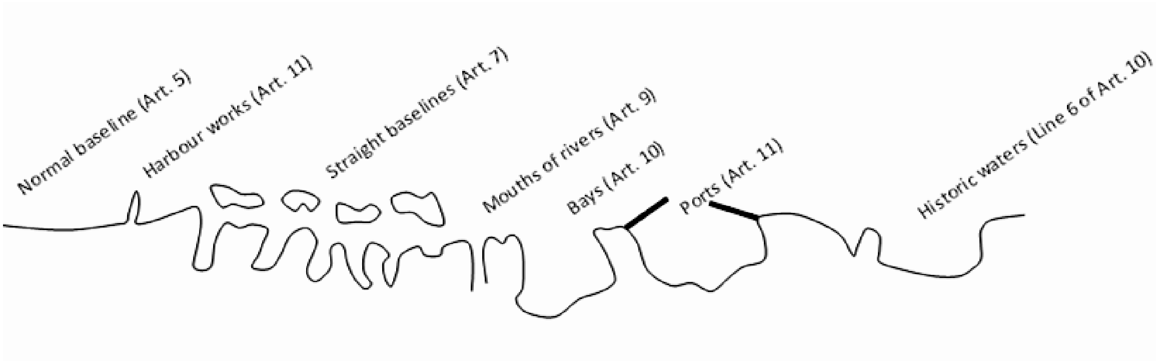

Figure 1 – Schematic representation of the baselines (Section 2 of Part II of UNCLOS).

So, at this point, it is first necessary to define the meaning of the low water line to allow the establishment of the intertidal datum and, therefore, derive such line. The ambiguity in the definition of which "low water" to use, led the IHO to adopt the Lowest Astronomical Tides (LAT) as the world standard in 1997 (IHO, 1997). These might not be necessarily the one that is represented in the official nautical charts. In fact, the coastlines represented in these documents results from the intersection of the chart datum plane with the modeled shape of the coast, which turns out to be slightly shallower that the Lowest Astronomical Tide plane.

Another important point to highlight in Article 5 of UNCLOS is the fact that *"…the normal baseline […] is the low water line along the coast as marked on large-scale charts officially recognized by the coastal State*". If we recall the chart definitions of the International Hydrographic Organization (IHO) for the large-scaled charts to fulfill this particular requirement we can easily conclude that the majority of the coastal states will not succeed in providing this level of detail. The figures for the limit of the large-scale charts is set to 1:75 000, which is the transition value from port approach/intricate or congested coastal waters to coastal navigation (see Table 1).

Medium-scale	General: passage/landfall	1:2 000 000 – 1:350 000
	Coastal: coastal navigation	1:350 000 – 1:75 000
Large-scale	Approach: port approach/intricate or congested coastal waters	1:75 000 – 1:30 000
	Harbour: harbour/anchorage/narrow straits	larger than 1:30 000
	Berthing	very large scales

Table 1 – Terms for chart scales and associated values.

To set an official coastline, based on nautical charts, it is necessary that the shoreline is continuously represented along the coastal series charts. If a coastal state provides two continuous coastal series, one on a relatively large-scale, the other slightly smaller, ships using national chart series do not necessarily use every large-scale sheet along their tracks, especially if the waters are not complex. For example, when coasting along the south coast of England British mariners often prefer the 1:150 000 second-scale cover to the 1:75 000 series, reducing the number of charts in use and hence the number of position transfers between sheets. This concept is the basis of the choice of scale 1:150 000 by France and Germany for their largest scale continuous coastal series of the south coast of England (IHO S-4, 2009). In Portugal mainland, the present coastal chart series is also represented uniquely in the 1:150 000 scale.

2.2. How the coastline is currently set in Portugal?

The Portuguese territory is divided in three main areas: (1) Portugal mainland, in continental Europe (2) Azores archipelago and (3) Madeira archipelago in the Atlantic Ocean (Figure 2).

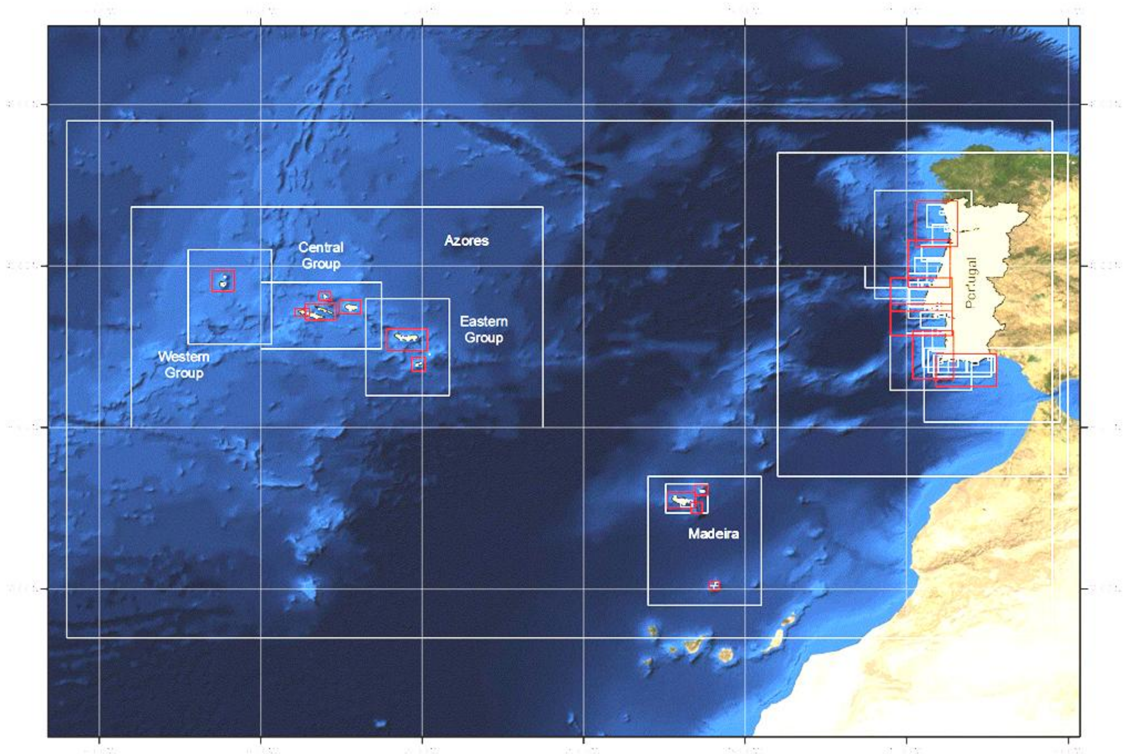

Figure 2 - Portugal (mainland and archipelagos of Azores and Madeira). The existent charts that cover the entire coastline represented in white. Charts of largest scale that continuously represent the coastline in red.

The total length of the Portuguese coastline is approximately 1 940 km, 850 km in mainland, 850 km in Azores and 240 km in Madeira. This set of coastlines is continuously represented in the present charts series published by the Portuguese Hydrographic Institute (IHPT). The associated values for charts scale are 1:150 000 in mainland, 1:50 000 and 1:100 000 in the Madeira Archipelago, and 1:50 000, 1:75 000 and 1:100 000 in the Azores Archipelago.

When defining a unique coastline as an essential feature for the extension of the continental shelf, one has not only to consider the multiple scale integration problems, which derive in different accuracies along the coastline, but also to take into account several geodetic referencing frameworks and the inherent transformation problems. The nautical charts considered for the establishment of the baselines in the Portuguese submission to the CLCS have six distinct geodetic datums. One in mainland (ED-50), two in Madeira (Porto Santo and Marco Astronómico) and three in Azores (São Braz – Eastern Group, Base SW – Central Group and Observatório – Western Group).

Presently, Portugal is officially converting its cartography to the reference systems PT-TM06/ETRS89 that use the GRS80 ellipsoid and is based on the ETRS89 (for the mainland) and to PTRA08-UTM/ITRF93 that also use the GRS80 ellipsoid but is based on the ITRF93 (Atlantic archipelagos). As far as it concerns for practical purposes, an ITRF based geodetic datum is equivalent to WGS84, with the difference between them being of the order of cms.

3. Methodology and data

To overcome the challenges presented in the previous section and to improve the quality of coastline already submitted to the CLCS, a plan, based on the present geodetic technology, was set out with the following goals:

1) Update the national coastline and rectify the straight baseline positions;
2) Migrate the original referencing systems to the new official ones;
3) Compare the accuracy of the submitted coastline with the new results.

Two types of approaches were initially considered. The first was based on a top down solution, where the project was delineated from the scratch, while the other followed a bottom up solution, where different sources and types of existing data were used. Considering the existent legacy data, with relevant accuracy and quality, that geographic and hydrographic agencies are presently providing, the choice of a bottom up solution seemed to be the obvious one. This is the best option because not only data are already existent but also because it represents a lower cost solution comparing to the alternative approach. This option is also following the present trend of reutilize data, subsequent to the European Community directive 2007/2/EC-INSPIRE (European Community, 2007). However, in a bottom up solution a significant limitation exists when dealing with the delimitation of the normal baseline (LAT line) since data was not acquired considering the tidal periods. To overcome this limitation, some alternative strategies were considered as explained in the following section.

The methodology followed was basically to compile all disparate sets of imagery data, as detailed in table 2, into a unique geographic framework. The adopted frameworks are those described in the previous chapter, the PT-TM06/ETRS89 for mainland and the PTRA08-UTM/ITRF93 for both archipelagos.

Data type	Area	Date	Spatial	Reference system
Aerial photos	Desertas	2004	1	Base SE
	Selvagens	2004	1	Base SE
Ortophotos	Mainland	2007	0.5	PT-TM06/ETRS89
	Madeira	2007	0.4	Base SE
	Porto Santo	2007/2008	0.4	Base SE
	S. Miguel	2004/2005	0.4	PTRA08-UTM/ITRF93
	Terceira	2004	0.4	PTRA08-UTM/ITRF93
	Graciosa	2006	0.4	PTRA08-UTM/ITRF93
	Corvo	2006/2008	0.4	PTRA08-UTM/ITRF93
	Pico	2006	0.4	PTRA08-UTM/ITRF93
	S. Jorge	2004/2005	0.4	Base SW
	Faial	2004/2005/2006	0.4	Base SW
	S. Maria	2005/2006	0.4	S. Braz
Satellite imagery	Madeira	2006	5	Base SE
	Flores	2004	0.6	PTRA08-UTM/ITRF93

Table 2 – Description of the imagery data used to derive the shoreline.

Beside orthorectified aerial photographs and satellite images, other types of data had been used to assess the quality of the imagery data. These were the coordinates of all national geodetic points related with the recently adopted referencing systems for mainland and archipelagos, vector data extracted from all large-scale nautical charts and in situ GPS geodetic surveys based on opportunity campaigns.

As data resolution and quality varies along the derived coastline, it was also considered to fragment this line into multiple segments, each one assigned with a specific metadata profile. This profile includes the intrinsic uncertainty allowing establishing a 5th dimensional feature (X, Y, Z, Time, and Uncertainty). The spatial representation of this measurement is established by associating an uncertainty thickness to the spatial feature.

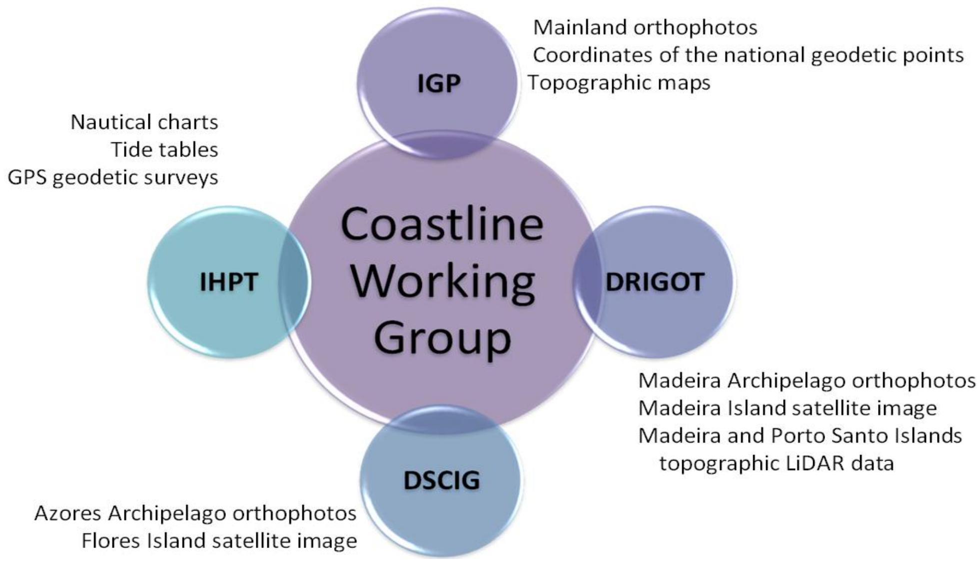

Figure 3 – Schematic model of the interactive social model to compile and collect geo-referenced data to derive the coastline.

Regarding to the data collection, it was adopted a social model that allowed to collect all data existent in public agencies, at the same time making use of the available resources in present and future works in areas where data lacks of quality (Figure 3).

4. Normal baseline delimitation and straight baseline update

The applied methodology to achieve the initial goals was assured by a precise workflow. This step-by-step procedure allowed to work in a contained approach, which made the whole process easier to accomplish (Figure 4).

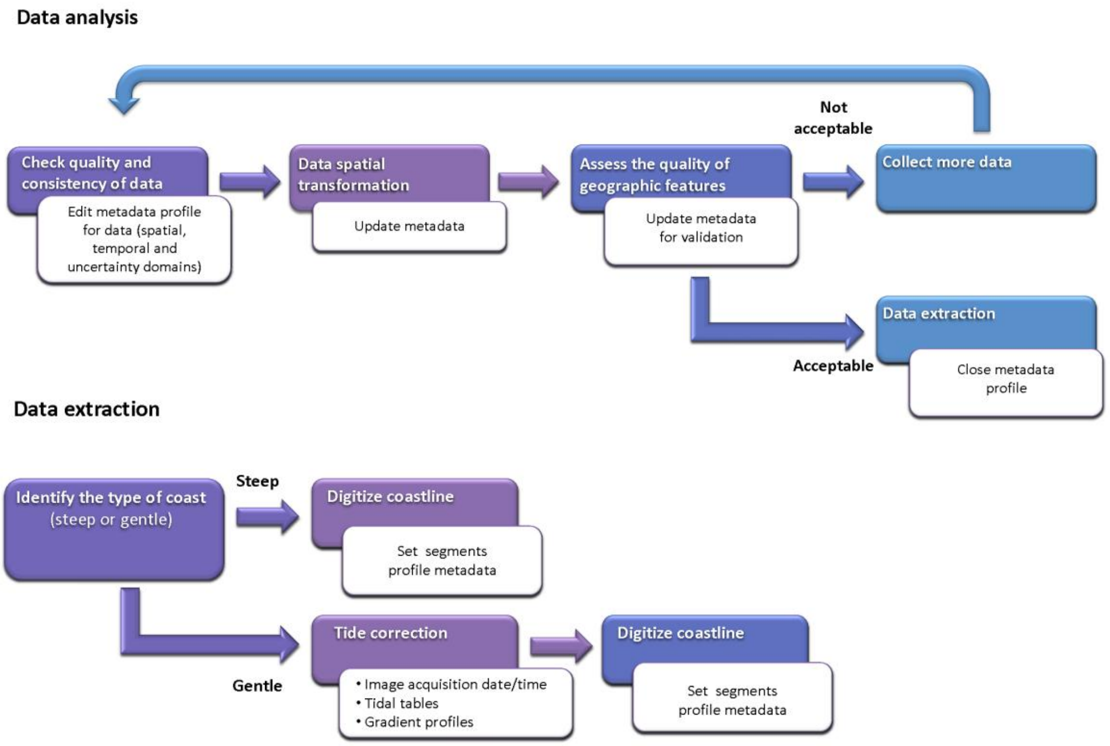

Figure 4 – Data analysis and data extraction workflows.

The first step of the workflow, after having compiled all existent data, was to check for data quality and consistency. The aim of this task was to verify the quality of the imagery coverage, especially in what concerns the fully coverage close the shoreline and also of all the islets and rocks that are to be considered for the establishment of the straight baselines. Additionally, it was verified if there was any cloudy coverage along the shoreline and at the location of the geodetic network points. Special attention was paid close to the straight baseline vertices. At this first step was also verified both temporal and spatial references provided by the data suppliers. The first is particularly useful to determine the tidal stage of each image, and the second allows to identify the correct spatial transformation to be applied to imagery data.

The second step of the analysis workflow is to effectively apply the transformation parameters to reduce all disparate sets of referencing systems into the new official ones. These parameters are provided from the national geographic agency (Portuguese

Geographic Institute - IGP) and are available at www.igeo.pt. These parameters are also integrated in two applications, also provided by IGP, namely the *mudar_sistema_tfw* and *mudar_sistema_shp* applications. The first one is applied to raster data, where a new TFW file is generated to georeference an image, and the second is applied to vector data where a spatial transformation is made. Both applications allow to transform any obsolete system into the new ones (PT-TM06/ETRS89 for mainland and PTRA08-UTM/ITRF93 for Atlantic archipelagos). At the end of this stage the metadata profile for the data is updated.

The third step for the analysis is regarded to assess the quality of the data after transforming into the new referencing systems. This was done using the coordinates of the national geodetic points and also by using large-scale nautical charts when applied (see Figure 5 for an example). If the horizontal differences between the common geodetic points, from the images and from point files, exceed the accepted tolerance then these are to be disregarded and are reported to the data providers for further examination. For instance, in two specific areas, the spatial resolution of the images disables the identification of the geodetic points. However, the local geographic agency is currently working in those sites to overcome this problem by coordinating spatial features that are perfectly identified in the image.

Figure 5 – Assessing the positioning quality of the data after applying the new referencing systems.

Considering that all steps previously described were effectively achieved then the digitizing process for the baselines may begin (see Figure 4 bottom for the workflow).

The first step of the data extraction procedure is to classify the coastal slope. Two types of magnitude were considered, one where the coast is very steep, and another for where the slope is gentle. In the first case, the process to extract the baseline is quite straightforward (IHO, 2006).

The second case is far more complex. To workaround this problem one may first to determine the value for the tidal stage based on the acquisition time of each image and the value from the tide table. Whenever the derived value for the tide is close to LAT then we assume that the interface between land and sea is the normal baseline. Otherwise, other types of data need to be used to derive the local slope. Two ways to obtain this required gradient profiles are (1) fieldwork measurements and (2) topographic LiDAR data where available (such as the case of Madeira and Porto Santo). After this step one is now able to digitize, assuming some degree of uncertainty. An alternative way to delineate the normal baseline, in particular in areas that are humanly accessible, is to collect GPS position in RTK mode, yet considering the tide level at the surveying period.

In both cases, cliffs and beaches, while digitizing the normal baseline, the metadata profiles are edited to classify each baseline segment accordingly to its accuracy. Different attributes are considered such as type of based data, imagery data resolution, date and time of the source data, type of slope (steep or gentle), tide value at the time of acquisition (close to LAT or not LAT) and type of data used to derive the slope (fieldwork or topographic LiDAR).

In areas where the Portuguese Legislation (Decree-Law 495/85, November 29th) sets the straight baselines, based on Article 7 of the UNCLOS, a special attention were considered to rectify the vertices for this type of lines (Figure 6).

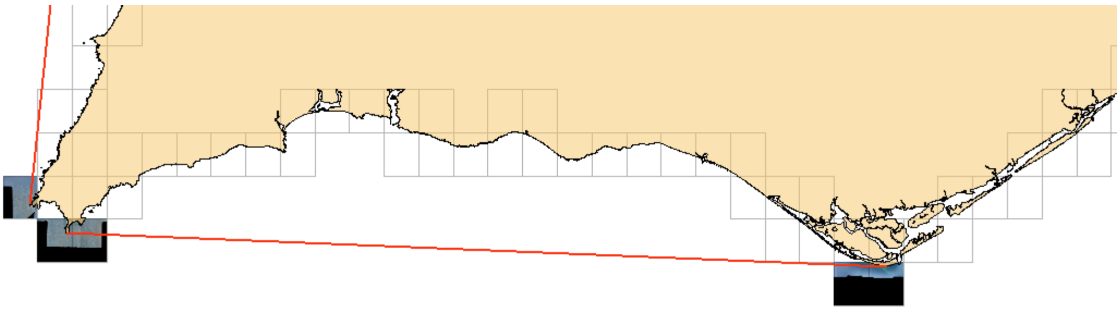

Figure 6 – Integration of vector data and imagery data to verify the location of the straight baseline vertices.

5. Conclusions and future work

Although this project is still ongoing, some conclusions can be set by now. The first is that the choice to adopt the bottom-up approach was the correct one. In the areas that are already close for the final establishment of the baselines the differences between the newly derived data to the original one, submitted to the CLCS, are in fact insignificant. This means that a considerable amount of money was saved when the top-down approach was disregarded. This solution also set a social participation among all related institutions spread all over the Portuguese territory, mainland and Atlantic archipelagos, allowing that whenever a specific hydrographic or topographic work was planned for a certain area, additional tasks might be requested to solve some specific doubts. This policy allowed to take the project budget close to zero.

In some areas it was measured a significant difference between the original data, extract from the nautical charts, and the high spatial-resolution orthophotos. Although was not the main goal of this work, the coastal erosion process can also be analyzed in a solution as this one. Fortunately, these areas have no impact in establishing any of the maritime zones measured from the baselines.

Presently, and as a result of an informal contact in a workshop, the working group end up to know that a major LiDAR survey is being carried out, by the National Institute of Water (INAG), along all the mainland shoreline. These data are obviously crucial for the quality of the present project and, therefore, the initial contacts to incorporate that information into the process are beginning at the moment.

To conclude, close to the end of the project, it might be necessary to set up a final plan to close any remaining gaps that were not solved by the present methodology. As a final solution, it might be necessary to consider a dedicated case by case top-down approach to continuously establish the normal baselines.

Acknowledgements

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