Coastal Erosion from Space

Coastal Erosion events:

in Nerja (Spain) *in Kilkee (Ireland)* *in St Laurent mouth (Canada)*

Topo-bathy morphology Verification and Quality Control

Ref:SO-TR-ARG-003-055-PVR-A5

Date: 01/05/2020

Customer: ESA

Contract Ref.: 4000126603/19/I-LG

This page is intentionally left blank

Applicable and reference documents

Id	Description	Reference
AD-1	Product validation Plan	SO-TR-ARG-003-055-PVP
AD-2	Product Validation Report	SO-TR-ARG-003-055-PVR
AD-3	SDB ATBD	SO-TR-ARG-003-055-ATBD-SDB

Contents

List of Figures

List of Tables

1. Satellite Derived Bathymetry Verification

In the case of SDB, several tests are performed to check the stability of the processor. The objective of these tests is to check how different conditions could affect the location of seabed features or the estimation of depth. The product validation document (PVP, see AD-2) detailed the possible external conditions that might affect the processor.

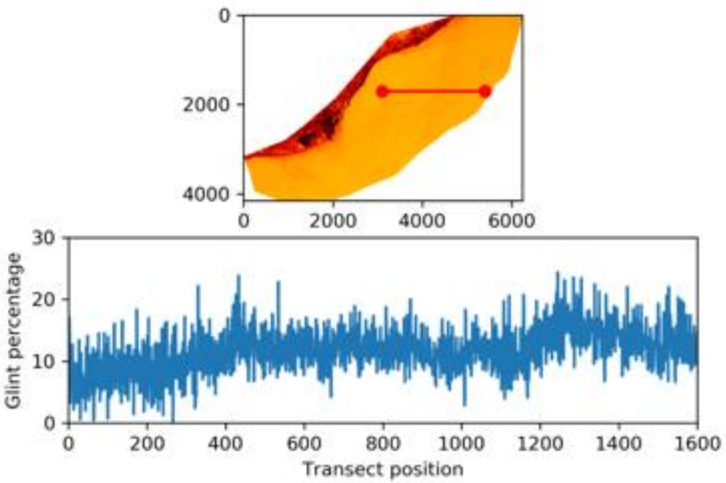
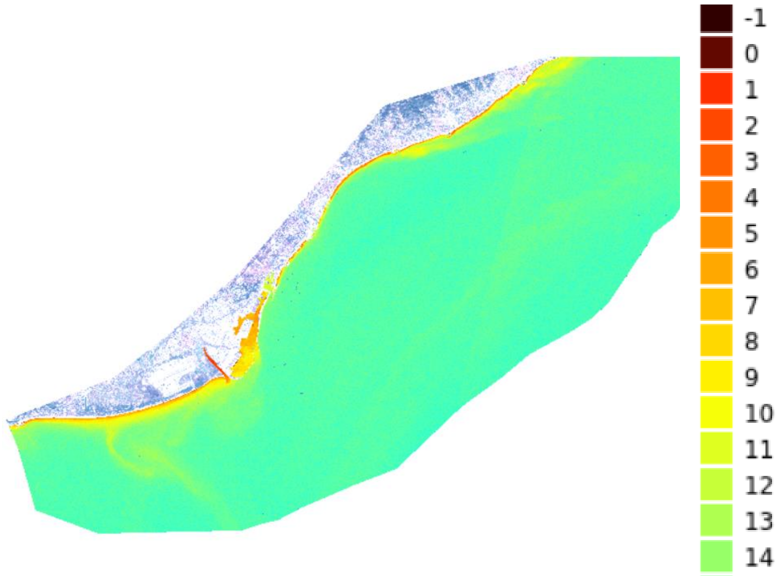
Verification tests:

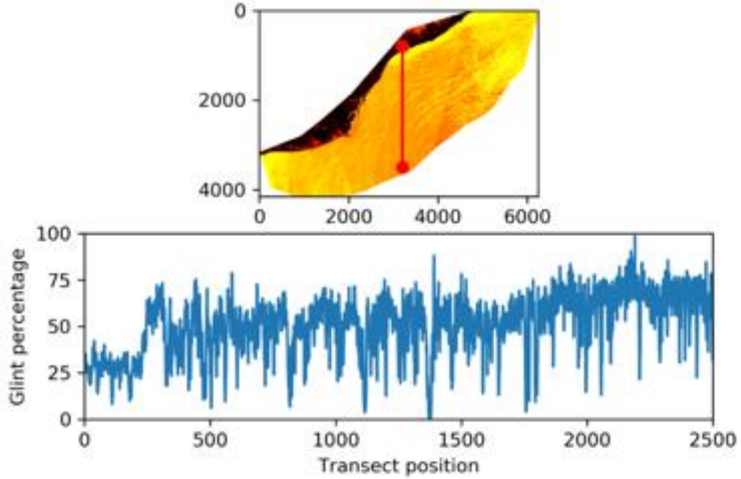
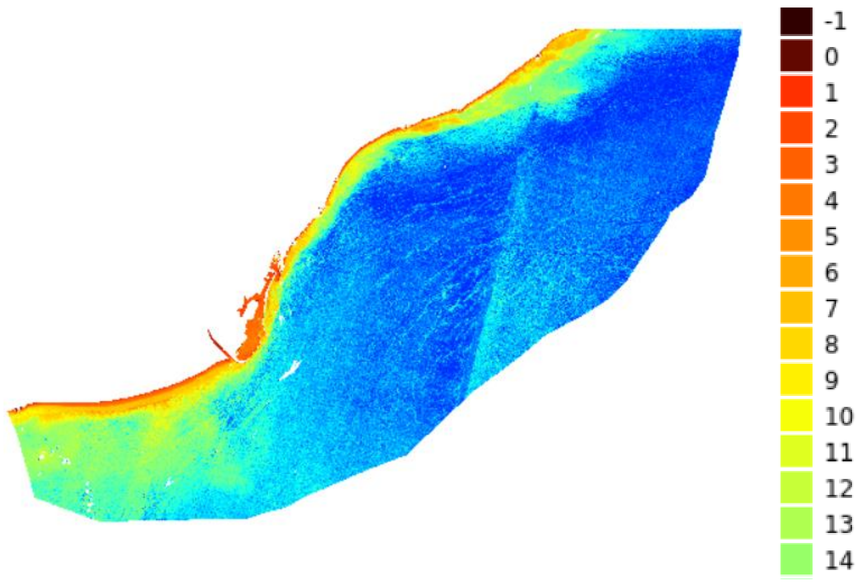
1. Levels of glint

Tests (Table 1.1) are conducted to extract bathy-morphological information using satellite imagery with different levels of glint. The glint level is evaluated usingthe NIR band, as indeed, NIR band is assumed to have zero water reflectance for waters without very high turbidity.

$$glint = \frac{NIR - \min NIR}{minNIR} \times 100$$

Table 1.1: Tests performed to verify the response of IDA to different levels of glint

Level of glint	IDA result
Glint up to 25%:	
 The image is slightly affected by glint, but it is present everywhere on the image, as a white veil.	
Glint up to 75%:	

 The image is highly affected by glint at almost all the places of the image, with exception of the east side and the near shore coastal area of the east part of the image.	

Regarding the observed results (**Error! Reference source not found.**), glint affects the estimation of SDB depth values. In the case of the first test, where the image presented areas with glint levels up to 75%, but areas with no glint were also present, SDB processor is able to retrieve SDB depth values. This is related to the glint correction integrated in the processor, as areas with minimum levels of glint can be found, thus the processor can de-glint the image. In this kind of cases, the SDB processor can be used to estimate the corresponding depth values, as even though noise is present for the areas with a depth higher than 15 m, no noise is found in the near shore coastal areas.

In the second test, were glint is present all over the image, the SDB processor is only able to recognize near shore features, providing depth values that are ~2 time higher than those ones provided with no glint (**Error! Reference source not found.**). This is due to the fact that it is not possible to find an area of the image where the NIR reflectance is minimum. Thus, the reflectance values used to estimate depth values are higher than in those images with no glint, with the consequent underestimation of depth values. Therefore, images with glint all over the image will be only able to provide the position of the bed features present in the coastal area.

2. Atmospheric characteristics

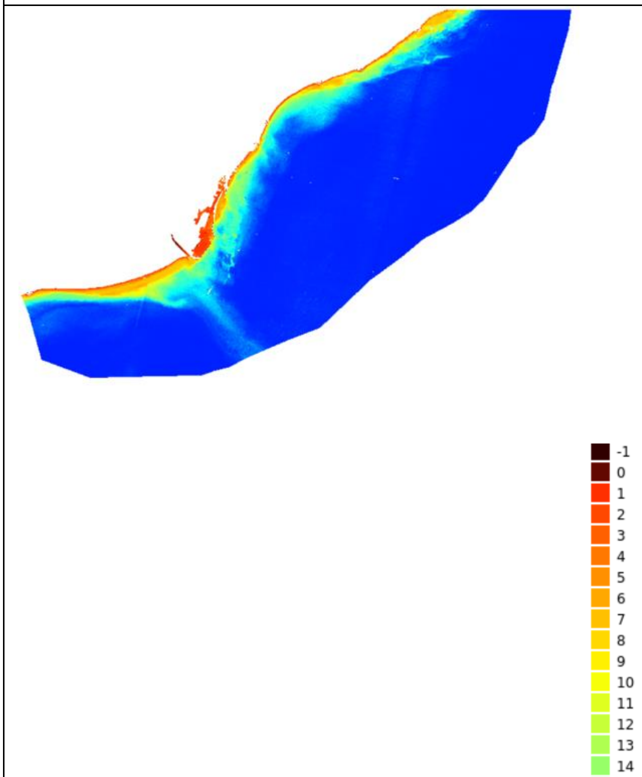
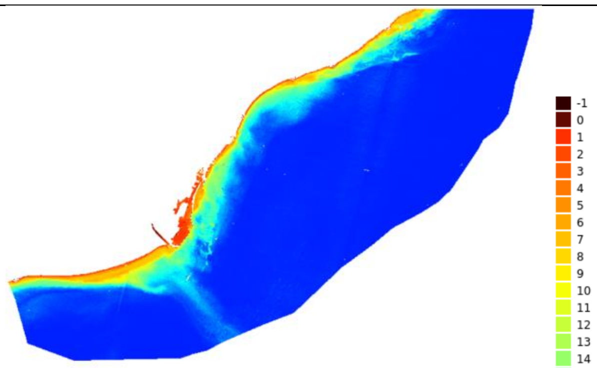
As the inversion to estimate the bathymetry is done at a pixel level, the image needs to be properly processed, in particular the correction for atmospheric effects. Therefore, the atmospheric correction is one of the main issues of the SDB models. To estimate the atmospheric correction for coastal areas, two values should be considered, the aerosol optical thickness ($\tau550$) and the water surface roughness in terms of wind speed (u10) (ATDB SDB, see AD-3). So far, four tests have been performed on a single image to verify the impact of these values on the SDB processor. The first test is performed using the values provided by the atmospheric correction choosing the deep depth values(estimation explained in the ATBD document for SDB, see AD-3). The second, third and fourth tests have been performed keeping one of them fix, and modifying the other by several orders of magnitude or by its reduction by a factor of two(values chosen using expert criteria).

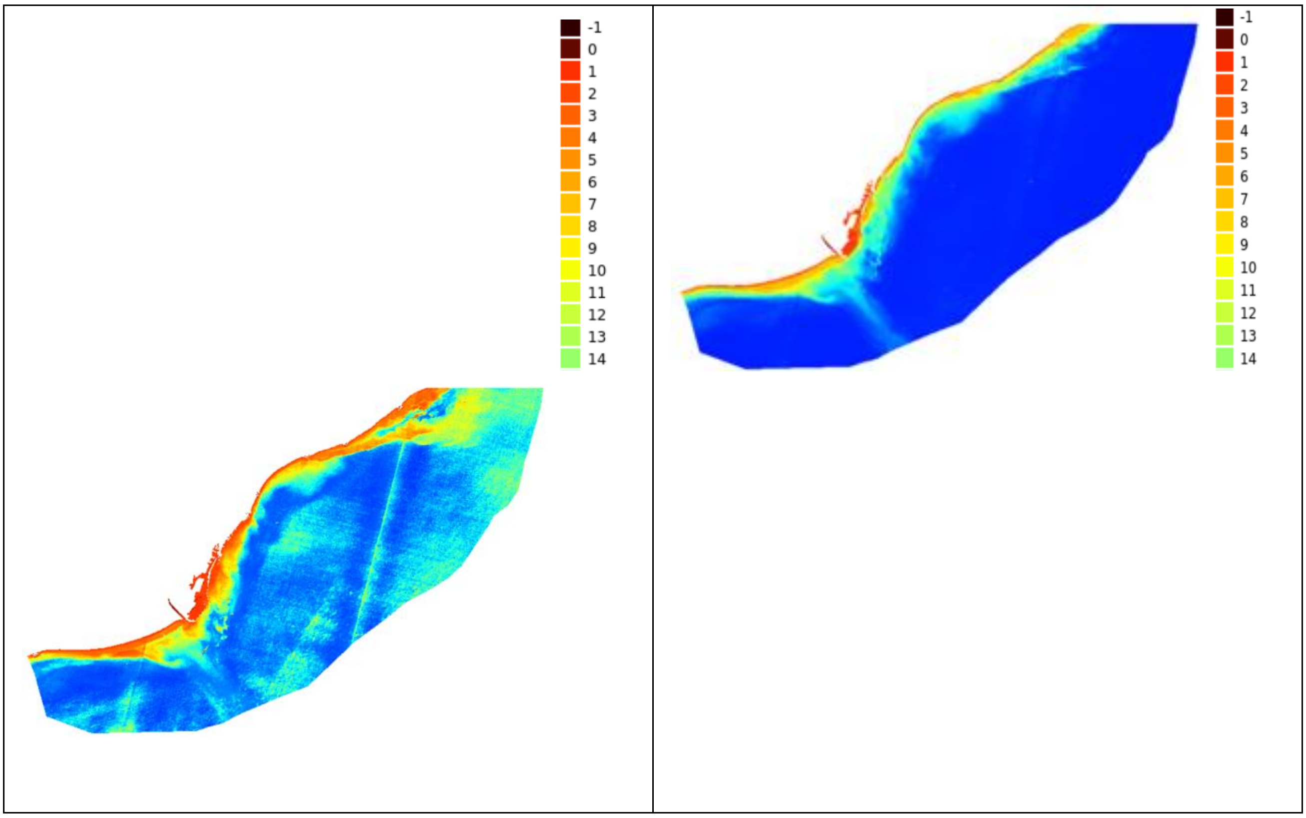
The described tests are conducted using the Sentinel-2 image from the 12 July 2017 (**Figure 1.1**).

Figure 1.1: Sentinel-2 image used to conduct atmospheric correction test

The image presents a sediment plume in the near shore coastal area that impacts also the results of the SDB processor (see point 5 of this section). However, no sun glint is present in the image, so the atmospheric correction would not be hampered by this issue, which makes the Sentinel 2 for that date a perfect one to test the impact of the atmospheric correction on the SDB retrieval (**Table 1.2**).

Table 1.2: Tests performed to verify the response of IDA to different atmospheric correction parameters (u10 and τ550)

τ550=0.217207 / u10=0.005877	τ550=0.217207 / u10=0.1
	
τ550=0.105 / u10=0.005877	τ550=0.217207 / u10=2.5

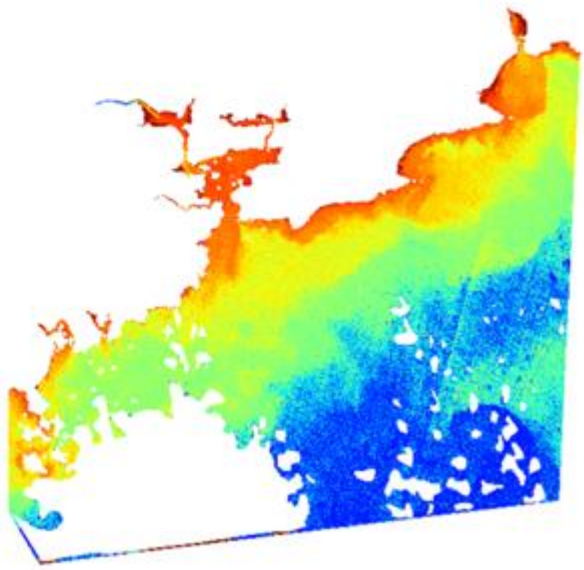
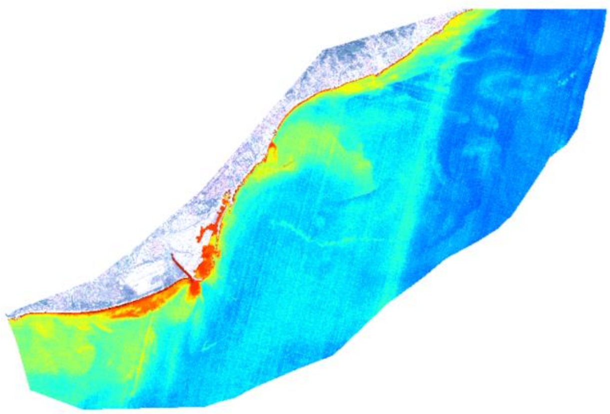


As already indicated, atmospheric correction is a critical factor. Between both parameters, the aerosol optical thickness (τ550) and the water surface roughness in terms of wind speed (u10), it seems that the aerosol optical thickness (τ550) has a biggest impact on depth estimation (**Table 1.2**). A decreasing of this parameter by means of 2 highly impacts the retrieval of SBD depths. It introduces noise on the SDB output, especially in deep waters. Near shore coastal depth is also impacted by this parameter, as depth values are 1.8 lower than in the reference image (**Table 1.2**). Thus, IDA processor is quite sensible to the aerosol optical thickness, and as specified in the ATBD, it should be chosen carefully so the results provided by IDA are correct. However, the u10 parameter seems to slightly impact the SDB output. It is observed for tests 2 and 4that (**Table 1.2**), even though this parameter is modified by several orders of magnitude, the impact of its modification is slightly appreciated as only more noise is observed in small areas were SPM are high. As indicated on the ATDB (see AD-3), the atmospheric correction is the step that introduces the biggest error on the SDB estimation, so the parameter aerosol optical thickness becomes a crucial one to assess bathymetry.

3. Independent of seasons

Due to the weather conditions existing in the different seasons, cloud cover will highly impact the number of available images for each season, as for example, in the case of Barcelona, 8 out of 34 treated images correspond to winter season. It has been observed that seasonality can affect light depth penetration, as in almost all winter images (here Cork and Barcelona as an example), deep water pixels present lower values of depth than expected. The Sentinel Image corresponding to Cork (RGB) shows how water pixels present a darker colour than the ones observed during summer (**Table 1.3**), hampering the estimation of depth values.

Table 1.3: Tests performed to verify the response of IDA to depth retrieval during different seasons

Sentinel image for Cork for the 12/11/2019	IDA depth retrieval
	
Sentinel image for Barcelona for the 01/03/2019	
	

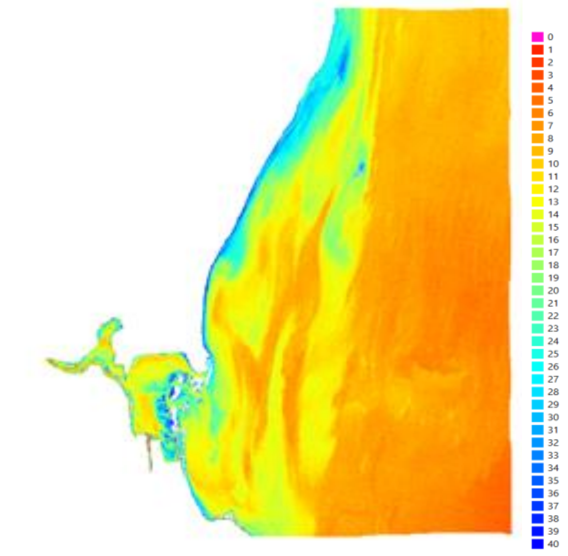
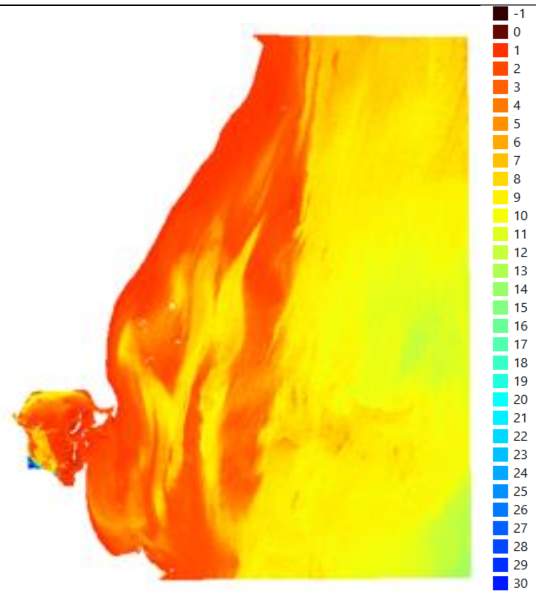
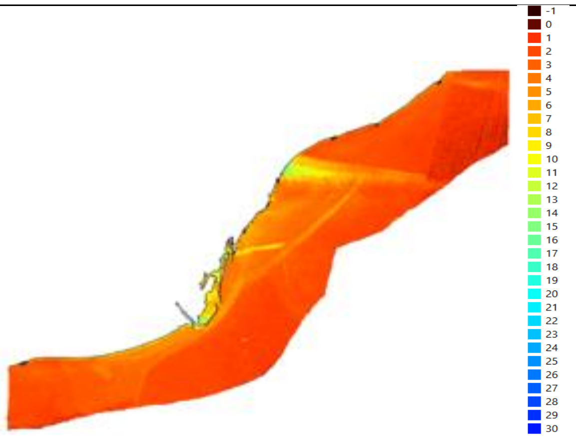
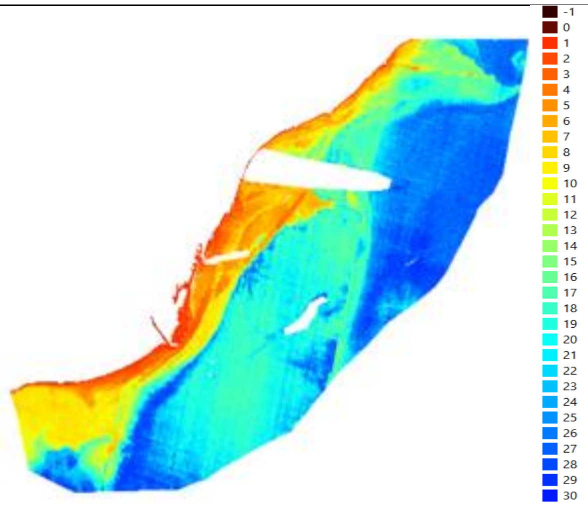
Besides, winter conditions will impact the sediment load, as well as the sea state. These conditions impact SDB retrieval, with an underestimation of depth related to the presence of sediments or to the glint associated to the existing waves during this season, as observed in the Cork example or the one for Barcelona (**Table 1.3**).So winter images depth estimation is highly impacted, and thus, summer images are preferred to calculate bathymetry depths unless a perfect image during winter is found (no glint, no sediments and appropriate light depth penetration).

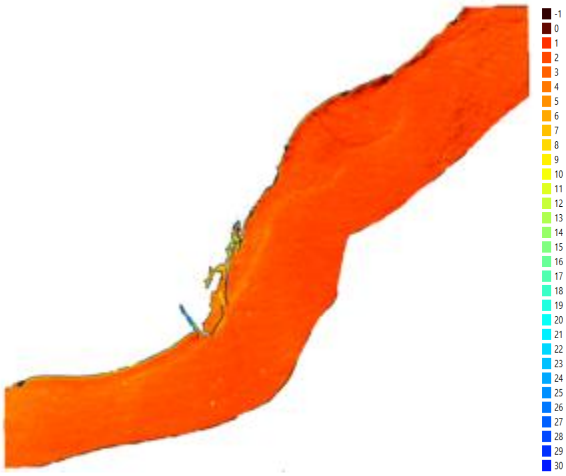
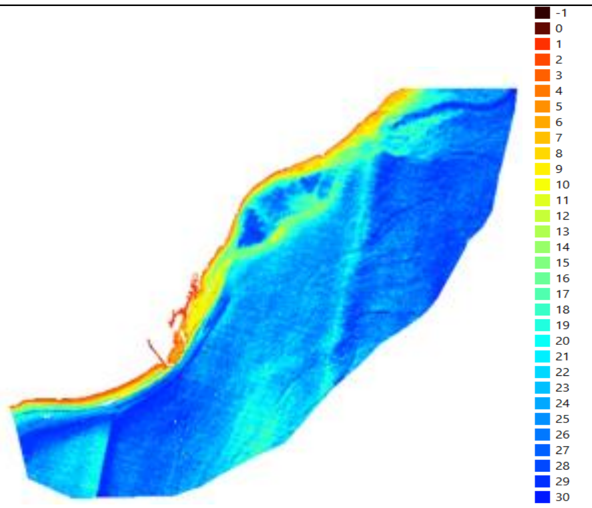
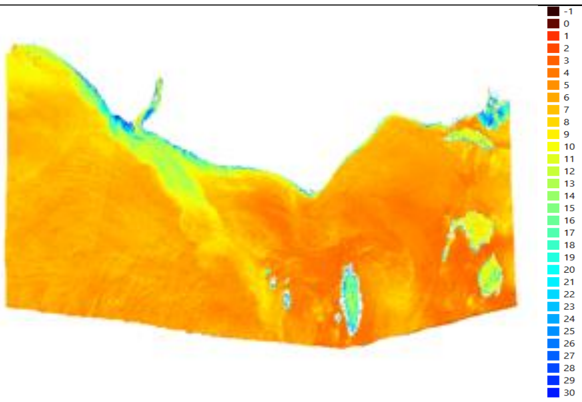
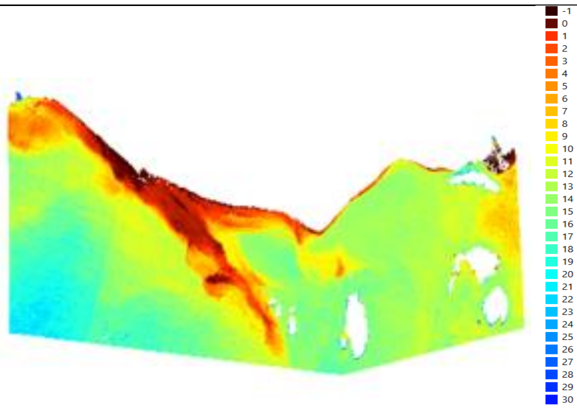
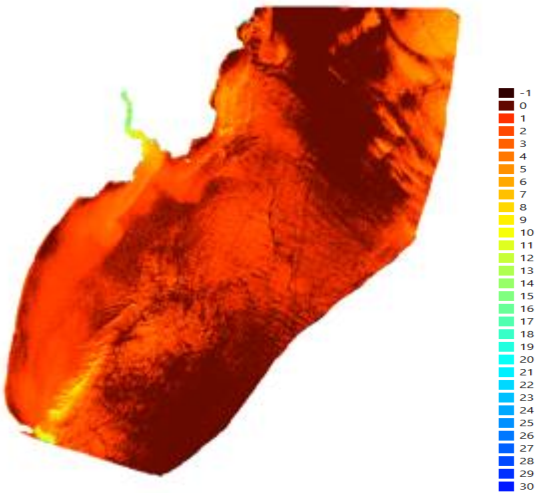
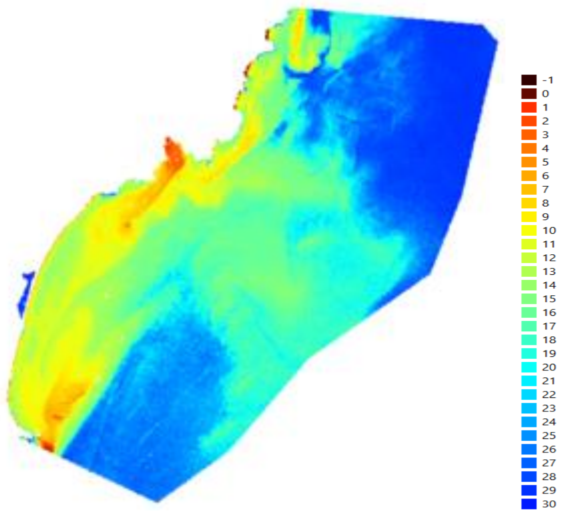
4. Sediment load

Sediment load highly impacts depth retrieval using the IDA method. This is related to the fact that the processor detects the suspended sediments present in the water column. Because of that, it is necessary to verify the processor outputs considering different levels of suspended sediments.

Suspended particulate matter has been estimated using the algorithm of Han et al. (2016), which considers several orders of magnitude for the SPM concentration (mg/l) (**Table 1.4**).

Table 1.4: Tests performed to verify the response of IDA when suspended load is present in the water column

Wexford SPM (mg/l): 29/11/2016	Wexford Depth (m)
	
Barcelona SPM (mg/l): 30/11/2015	Barcelona depth (m)
	
Barcelona SPM (mg/l): 26/08/2016	Barcelona depth (m)

	
Longue Pointe de Mingan SPM (mg/l): 31/07/2018	Longue Pointe de Mingandepth (m)
	
Start Bay SPM (mg/l): 15/05/2018	Start Bay depth (m)
	

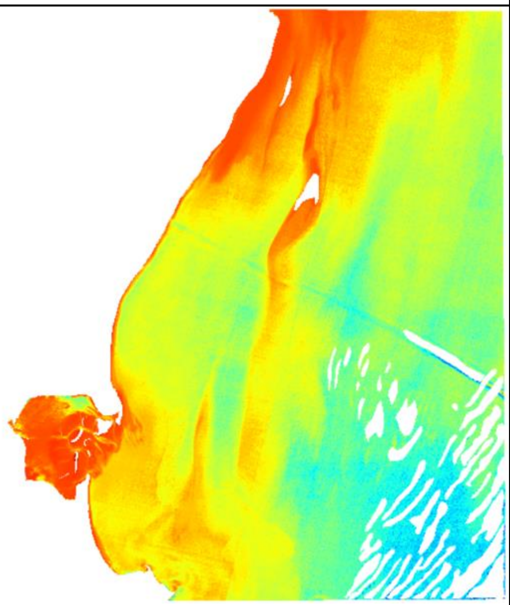
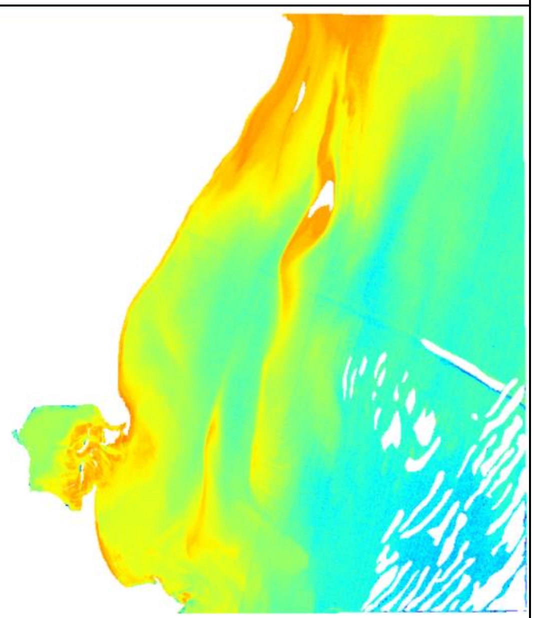
SPM highly impacts depth retrieval (**Table 1.4**). Five different Sentinel files have been used to estimate SPM and depth using the IDA processor. It is observed that, even though SPM concentrations can be considered low, as in the case for the Barcelona image of the 30/11/2015, with maximum values in the near shore coastal area of 10 mg/l, the retrieval depth for the image is hampered (**Table 1.4**). As explained, this is related to the detection of the suspended load on the water column. The minimum value of SPM that affects depth retrieval is observed on the images for Start Bay and Barcelona (26/08/2016), with 5 and 7 mg/l, respectively (**Table 1.4**). Therefore, in the case the treated images present values of SPM higher than 5 mg/l, depth values will be considered as non valid, providing a mask for the tile treated, indicating that depth values on those areas are affected by suspended solids present on the water column.

5. Bands selection

The depth of a specific site can be extracted by the radiance components received by the satellite using all different bands. In some cases, sediment load, as it has been seen (see point 4 of this section), can hamper the retrieval of the depth and of the coastal features. R_{rs} values are related to SPM, and the scatter observed in this relationship increases from the red to the blue. This can be explained by the fact that the relative contribution of pure water absorption to the total absorption increases with the wavelength, and also to the influence of the particulate backscattering coefficient observed on the R_{rs} variability increasing with wavelength too. Thus, two tests have been performed to evaluate the impact of the SDB computation using the blue, green and red bands on the Wexford bay (**Figure 1.2**), and using only the blue and the green bands on an image presenting high sediment load.

Figure 1.2: Wexford Sentinel-2 image for the 17th of June of 2017 used to conduct atmospheric correction test

Table 1.5: Tests performed to verify depth retrieval using different bands for the computation

Bands: 2/ 3/ 4 results	Bands: 2/ 3 results
	

As expected, depth retrieval is not possible in this kind of images (Table 1.5). Nevertheless, the selection of bands 2 and 3 allows the performance of a better identification and definition of the coastal features present in the image scene. Thus, in those images where coastal features can be identified, band blue and green should be chosen to perform a better definition of them in the presence of high sediment load.

2. Satellite Derived Bathymetry QC

In the case of SDB, two different quality controls are going to be performed: the first one is focused on the obtained depth values and the second one focused on the detection of seabed features.

1. Depth values: comparison between SBD products and bathymetric charts is possible to control the quality of the products. In this case, quality assessment is performed to evaluate the provided EO product.
2. Seabed features: by eye comparison with in-situ data (bathymetric charts, lidar to multibeam echo sounder, etc.). In this case, the seabed features detected using SDB values (depths lower than 30 m), should be located no more than 10% of the accurate location of the features from in-situ data identified in higher resolution traditionally surveyed observations. If this criterion is accomplished, the EO product is provided to the end user adding a flag indicating: only seabed features. This product should be used to check the evolution in time of the position of the detected seabed features.

The previous quality control is based on products provided using a single snapshot, ie a single LIDAR survey or a single echosounder survey. In the case of SDB time series (L3 products - DTMs), the quality control of the EO product is performed considering the tendency of seabed features based on theoretical truth (reference papers) and on reference data (in situ data provided by the end users).

End of Document