

## CLOUD-BASED TOOL TO ESTIMATE SHALLOW WATER BATHYMETRY USING SATELLITE OPTICAL IMAGERY

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### ABSTRACT

Shallow water bathymetry is crucial for navigation and to understand complex underwater morphodynamic processes in coastal areas. Satellite derived bathymetry (SDB) is an useful methodological approach that have the potential to overcome limitations of traditional in-situ approaches, namely the limited spatial coverage and costs related with the repetitiveness. In the present work we present a new tool, the CASSIE Bathymetry module, that enables SDB, based on optical inversion approach, to be applied at any coastal region of the world. To implement this tool, user require a minimal training dataset of observed depths, that is used to calibrate the SDB algorithm and to estimate errors of the estimated depths. This new tool is freely accessible via [www.cassiengine.org](http://www.cassiengine.org).

**Key words** — Bathymetry, shallow water, satellite imagery, Google Earth Engine.

### 1. INTRODUCTION

Mapping the bathymetry of shallow waters is crucial for a variety of applications, namely for hydrodynamic modelling in complex marine environments (e.g., estuaries), or to monitor the navigation safety in marine areas near ports and harbours. Traditionally, this information is gathered by *in-situ* surveys using single beam or multi-beam sensors, that despite the very high accuracy, required a very high logistical effort and have limited spatial coverage. Optical inversion Satellite-Derived Bathymetry (SDB) is a useful technique for mapping shallow water bathymetry, that exploits the physical principle that different wavelengths of the light spectrum are attenuated by water to varying degrees according to the depth [1,2]. This approach has been shown to be effective, with the advantage of being capable to cover extensive areas and regular repeatability [3]. Mapping SDB requires an exhaustive and multi-task process that involves selection and download of satellite imagery, image pre-processing (e.g., radiometric calibration and atmospheric corrections), development of depth inversion statistical

models (using a training dataset), and application of the developed model to satellite imagery. All these processes together are highly computational demanding (including storage space and processing power) that are not always available, reason why cloud-computing like Google Earth Engine (GEE;[4]) is becoming an interesting alternative to local processing approach. The aim of this work is to present a new module of the existing cloud-based web-tool CASSIE (Coastal Analyst System from Space Imagery Engine; [5]) – that can apply the SDB method to estimate shallow water bathymetries from satellite imagery, at any coastal area worldwide.

### 2. MATERIAL AND METHODS

The Bathymetry module of CASSIE is a graphical user interface (GUI) built with JavaScript & React programming language and using GEE API. This tool has a simple and intuitive workflow (Figure 1) and can be used to estimate shallow water bathymetry at any marine location on Earth where a minimal sub-sample of *in-situ* measured depth are available. The workflow of the different processes that involve the user interaction with this webtool and internal processing is presented in Fig. 1 and described briefly in the following subsections.

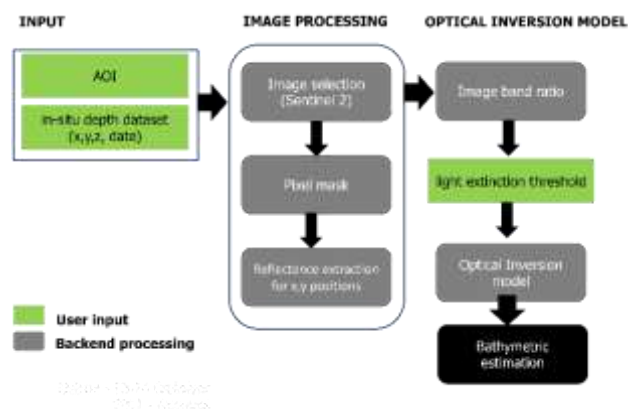


Figure 1. Workflow of SDB tool implemented in GEE tool, CASSIE.

### 3. RESULTS AND DISCUSSION

#### 4.1. CASSIE bathymetry module selection

After the user login into CASSIE, the user is able to select the SDB module on the right-side panel (Figure 2).

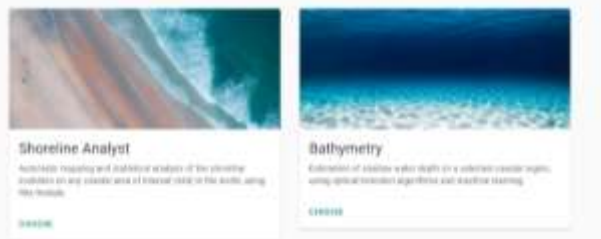


Figure 2. The two modules of CASSIE: (left) Shoreline Analyst, for shoreline mapping and analysis; (right) the Bathymetry module, for SDB.

Following the Bathymetry module selection, the user has to select the satellite optical imagery dataset to be used. For the moment only Sentinel 2 (ESA) time series are enabled to be used. The Sentinel-2 (MSI) Level-1C products (surface reflectance – SR) available in GEE, with 10 meters spatial resolutions, 5 days revisit time and covers the period 2013 to the present is used in the present module.

#### 4.3. Area of Interest and training dataset

Following the satellite mission selection, the user have to define the area of interest (AOI), the geographical limits (polygon) for which the SDB algorithm will estimate the bathymetry (Figure 3). In addition to this the user have to input a training dataset, using an ascii file that should contain three columns, with the x (longitude), y (latitude) and z (depth) measure in a subsection of the AOI. In the present work it is presented an application of this new tool to a coastal area located in Babitonga Bay, an estuarine environment located in the southwest of Brazil. A bathymetric survey performed with a single beam sensor (tidal corrections performed using RTK tides) was used to train the SDB algorithm presented in the following sections.

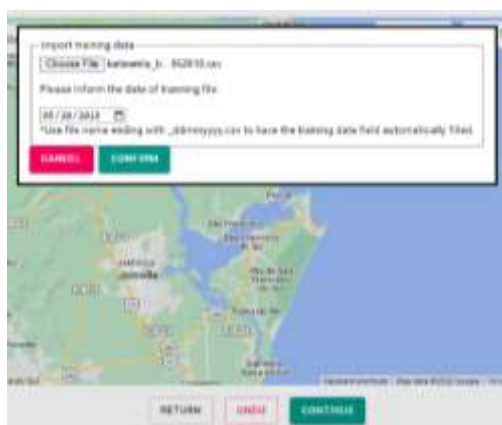


Figure 3. Print-screen of the CASSIE bathymetry showing the window where user should provide a polygon of the AOI (kml file) and the training dataset. User can also define the AOI using the drawing tools, instead of the imported polygon.

#### 4.4. Image selection

After the selection of the satellite mission and AOI definition, CASSIE Bathymetry performs a set of sequential operations in order to pre-process the available images. Pre-processing processes include image mosaicking (process of spatially assembling image datasets to produce a spatially continuous image), when ROI intersects more than one tile, image registration (correction of horizontal displacements between images), and cloud percentage, using the QA60 band. Following this pre-processing step, the user has to choose between two options the type of image to be used in the training phase: i) single image with the closest date of the in-situ survey dataset; ii) median image computed using a user-define time interval (Figure 4). To support the user decision in this step a thumbnail of the images options is provided (Figure 4).



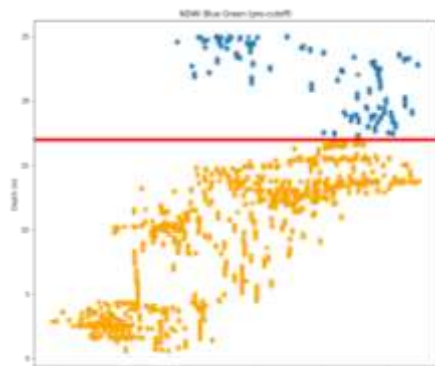
Figure 4. Image selection step that includes two options: (left) single image with the closest date of the training dataset; (right) median image, computed using a user-define time interval.

#### 4.5. Depth extinction and inversion algorithm

After the image selection the CASSIE Bathymetry module performs a number of image masking using the Scene Classification map (SCL) band to mask non-water targets including cloud shadows, vegetation, bare soil, clouds of medium probability, clouds of high probability, and cirrus. In addition to this several band thresholds values to mask high turbidity waters, sun glint and wave breaks after intensive testing (i.e., green band > 0.01, red edge 1 band < 0.1, NIR band < 0.03, 0.005 < water vapor band < 0.03) are implemented to remove undesired information from the selected images. After the image masking the Normalized Difference Water Index (NDWI) proposed by McFeeters (1996) is implemented, using the following equation:

$$NDWI = \frac{B3 - B8}{B3 + B8} \quad \text{equation (1)}$$

where B3 corresponds to the green band reflectance, and B8 to the near infra-red band respectively. The NDWI values for the locations of the training depth datasets (x,y provided by the user) are extracted and a scatter diagram is produced, as exemplified in Figure 5.



**Figure 5. Scatter diagram showing the relationship between measured in-situ depths and NDWI. Red line is the light extinction depth threshold.**

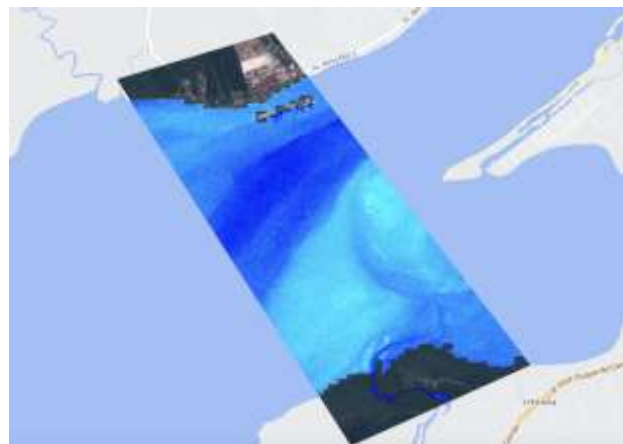
The light extension depth threshold (depth when light is completely lost by absorption and scatter in the water column) is identified and information below that depth threshold is removed from the analysis. Following this step an second order polynomial model is adjusted to the scatter diagram and a inversion bathymetric models is obtained, as presented below:

$$Z_{sat} = m2(NDWI)^2 + m1(NDWI) + m0 \quad \text{equation (2)}$$

where Zsat is the estimated depth, and m1, m2 and m0 the coefficients of the polynomial fit. The root mean squared error (RMSE) between the proposed polynomial model and measured depth for the present test was of about 2.4 m, which is within the range of errors commonly obtained with this methodological approach.

#### 4.6. Estimated bathymetry

The final step consists in the depth estimation using the developed algorithm (equation 2) that is applied to the entire AOI initially defined by the user (Figure 6). The result is exported to the final map and (overlapped on a google map layer) and a short report is provided, where descriptive statistics are provided (maximum and minimum depth, and root means squared error).



**Figure 6. Final map of CASSIE Bathymetry showing the SDB results computed for the AOI. The darker blue areas represent the deeper water depths while the light blue colours the shallow waters.**

## 5. CONCLUSIONS

In the present work we present a novel cloud based SDB webtool, the CASSIE Bathymetry module that estimated shallow water bathymetry using optical inversion approach. This tool enables the estimation of shallow water bathymetry at any coastal region of the world, where the only requirement is a small training dataset of locally measured depths. The method present errors within the standard magnitude observed in other studies that have implemented similar approach. The fact that this tool runs entirely on GEE, makes it extremely light for a local computer, where only internet access is required.

## 5. REFERENCES

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