

# **The BASE-platform project**

## ***Bathymetry from combined satellite and crowd-sourced data***

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### **1. Introduction**

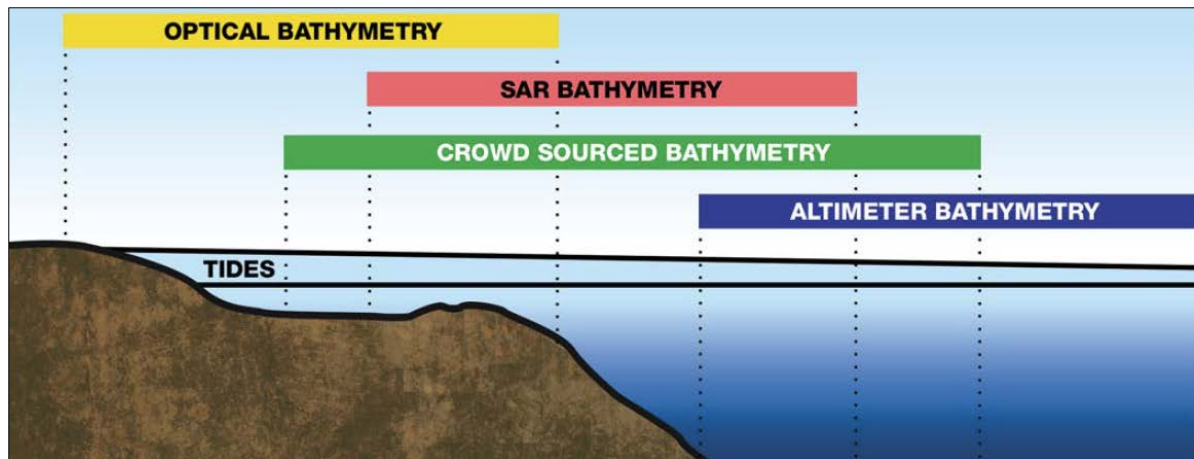
Bathymetric data of the oceans are often coarse or deprecated, often dating back to pre-GPS times or sometimes even to lead-line measurements of the 19<sup>th</sup> century. Using multiple satellite technologies supported by crowd-sourced data, BASE-platform derives the bathymetry in many areas worldwide, providing current, high resolution data which can be easily accessed via an online web portal.

### **2. Overview**

The BASE-platform project was created by the need for better and up-to-date bathymetry datasets which were inexpensive to create. The traditional method of ship soundings delivers accurate measurements, but at due to the effort of ship and crew, these data come at a very high price.

Modern Earth observation satellites, on the other hand, offer data cheaply or, for example with ESA's Sentinel fleet, even for free. During the BASE-platform project, existing technologies to derive bathymetry from such satellite data were further refined, automated and merged with crowd-sourced data and water level modelling to provide the most reliable data possible. These data allow very cost effective surveys or pre-studies, reducing costs for following multibeam surveys or even replace them completely.

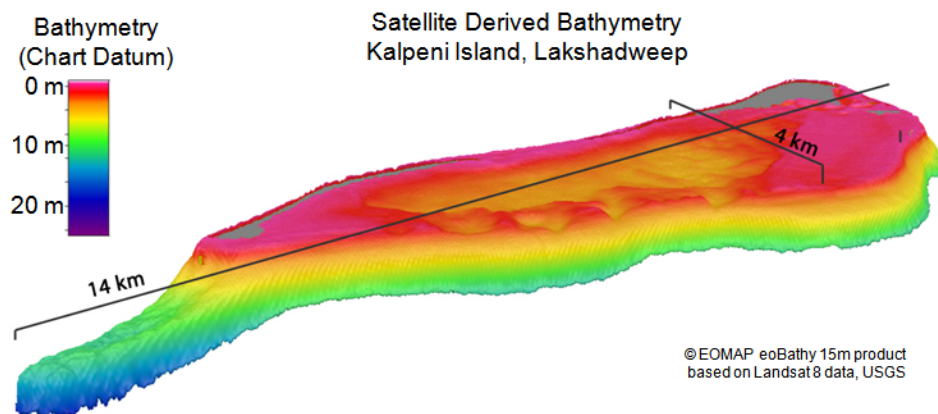
Five sources of information are combined in the project: Optical satellite images are used for coastal bathymetry up to 30m depth. The depth range from about 10m to 70m is covered by Synthetic Aperture Radar (SAR) acquisitions. Data from altimeter satellites cover the deeper and deepest waters. Crowd-sourced bathymetry recruits vessels tracking their position and depth sounder data while sailing along their regular routes. The fifth source of information is tidal modelling, which is used to correct all the previous data for tidal effects and translate them to a common reference system.



**Figure 1: Different techniques combined in BASE-platform with their applicable depth range.**

### 3. Optical data

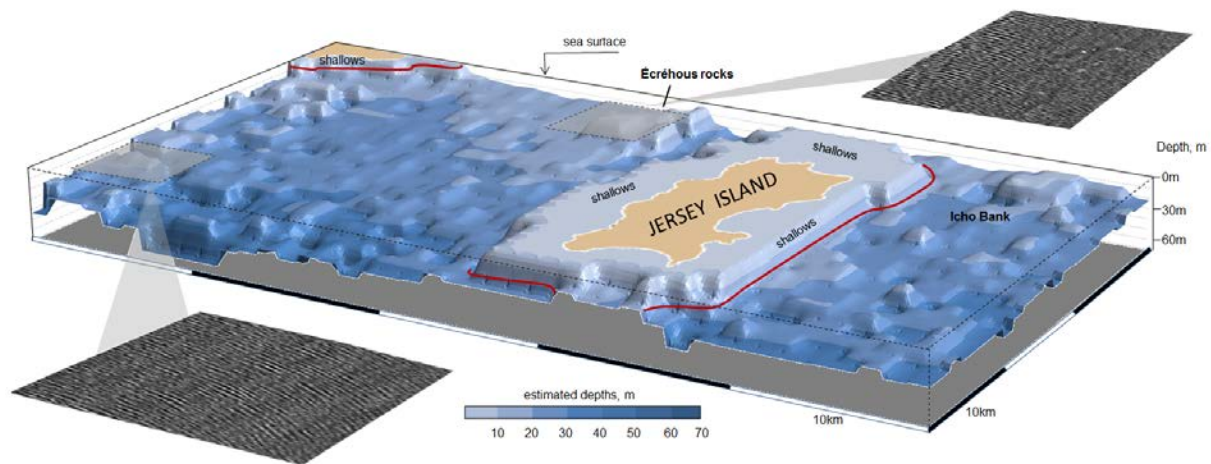
For the successful use of optical bathymetry, the sea bottom must contribute a detectable part to the signal measured by the satellite sensor. The depth of these so called optical shallow waters varies from <10m in regions like the North Sea to about 30m, e.g. in Caribbean waters. The environmental conditions of the recording strongly vary over time, hence, sophisticated correction algorithms have to be applied. These will remove, e.g., atmospheric effects, adjacency effects when land is nearby, sun glint on the sea surface or water refraction.



**Figure 2: Example of a satellite derived bathymetry product based on Landsat 8 imagery for the Kalpeni Island, Lakshadweep region, India.**

### 4. SAR data

While radar beams cannot penetrate the ocean surface to directly determine the underlying bathymetry, the bathymetry causes the so called shoaling effects which changes wave parameters at the sea surface. This shoaling effects makes waves become shorter and steeper when approaching shallower waters, hence, a direct relation between changes in wavelength and depth exists. With SAR, the ocean waves can be depicted independent of sunlight or weather conditions. The wavelengths are then determined using the Fast Fourier Transform (FFT) on small subsections of the acquired radar image. Due to recent improvements, artefacts like ships, sand banks or wave breaking zones can be filtered out automatically, allowing a consistent analysis of the scenes.



**Figure 3: Results of SAR bathymetry around Jersey, Channel Islands. The two sub images from the SAR scene demonstrate the changes in ocean wave length resulting from the difference in water depth.**

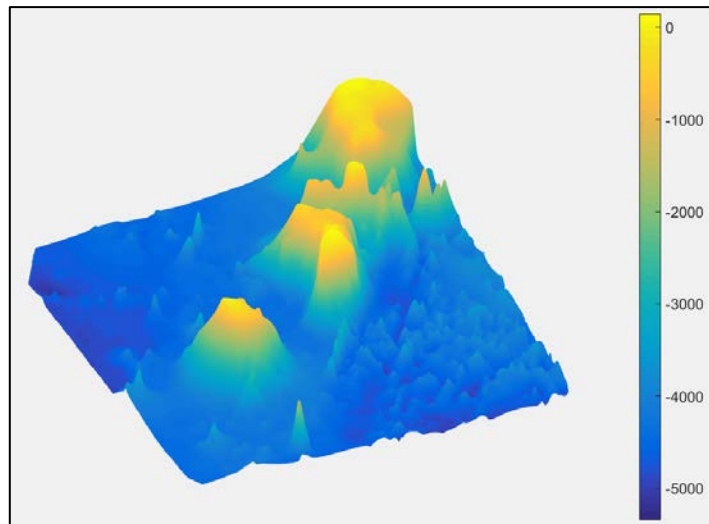
## 5. Altimeter data

Space altimetry also employs radar waves, but uses a very different procedure than the SAR approach described above. The altimetry method relies on the fact that topography on the seafloor creates gravity anomalies that tilt the ocean surface in ways that are measureable with a radar altimeter. From these, the underlying changes in bathymetry can be derived.

The estimation of gravity anomalies starts with a smooth version of the geoid (egm08) that can be used to apply the remove-compute-restore procedure widely used in geodesy. This allows the calculation of the rugosity over the smooth geoid model in a flat approach from altimetry data. Afterwards the residual heights are converted to slopes and interpolated into a grid. From the above surfaces the high resolution component of gravity anomalies can be estimated from the east and north vertical deflection by solving the Laplace equation in the Fourier domain. Finally the estimation of gravity anomalies is the sum between the recovered smoothed model (egm08) and the high resolution component.

The gravity anomalies principle is applicable for topographic variations reaching from about 10km up to several hundred kilometres. Smaller variations create too little influence on the ocean surface while larger variations are isostatically compensated and do not produce gravity variations

Adding bathymetric ship soundings to the procedure improves the results in two different ways. On one hand a smoothed version of the bathymetric surface (isostatically compensated component) can be estimated by filtering an interpolated surface from the soundings. On the other hand, gravity to bathymetry ratio grids can be estimated. This avoids defining the unknown seafloor density variations which have great influence in gravity anomalies.



**Figure 4: Bathymetry from satellite altimeter in Mauritius Islands**

## **6. Crowd-sourced data**

While regular seafloor mapping campaigns are expensive, crowd sourced bathymetry (CSB) asks vessels to log position and depth data while they carry out their normal activities. The gathered data are periodically uploaded to generate a bathymetric data product. Many vessels were already gathered for the TeamSurv platform during the previous CoSuDEC project, now reaching about 300 vessels plus other vessels like research ships. For BASE-platform, CSB data are used as in-situ measurements and offer a way of calibrating the results obtained via remote sensing.

## **7. Modelling**

All of the methods previously described measure the distance between the sea surface and the sea floor at their respective time of measurement. However, this water depth is strongly influenced by tidal and meteorological variations. Tidal amplitudes are often amplified near the coast, which may reach several meters of tidal range, even up to 14.5m in the Bay of Fundy.

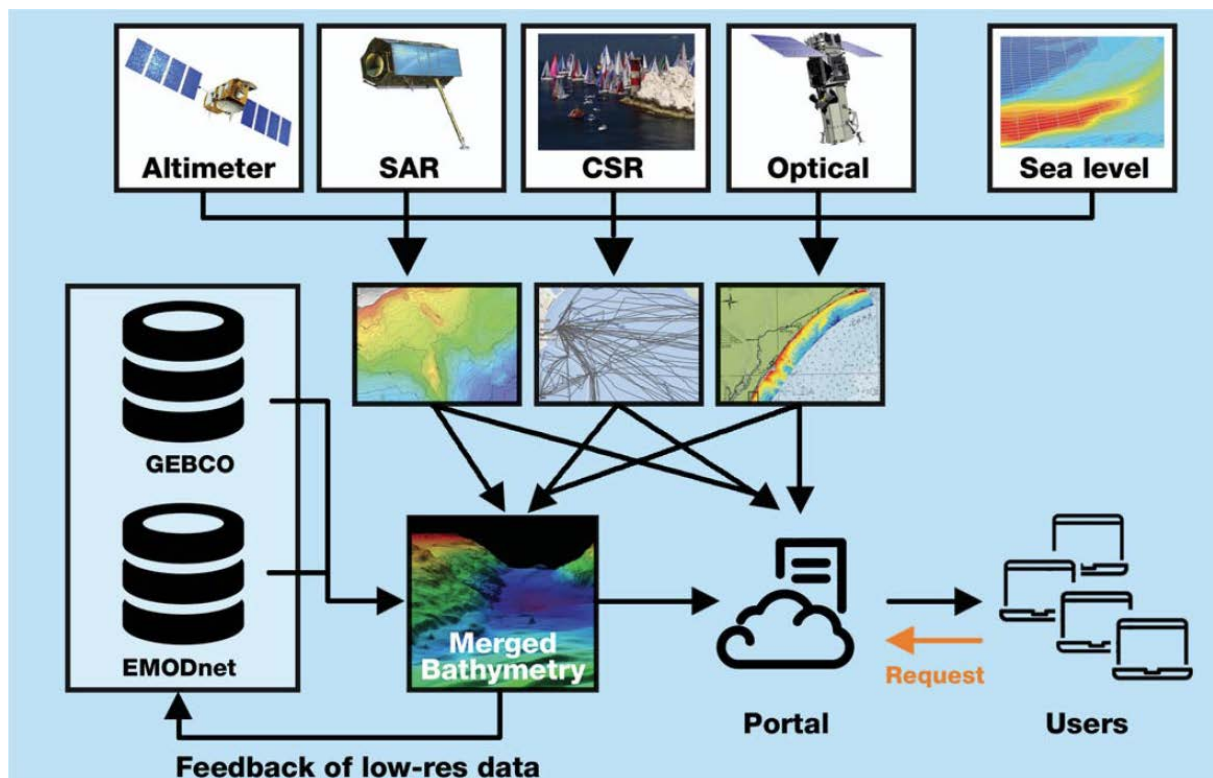
As permanently installed tidal gauges are mostly too scarce for global tidal interpolation, numerical hydrodynamic models are applied. Observations from tide gauges and satellite altimetry are included in these models to improve accuracy. For the BASE-platform project, this modelling allows to calculate the correct chart datum. According to the standard of the International Hydrographic Organization (IHO), this is based on the Lowest Astronomical Tide (LAT), and conversions to other reference systems like Mean Sea Level (MSL) and geoids are also possible with these hydrodynamic models.

## **8. Bringing the data to the user**

Most data extracted from an individual acquisition is not directly useable for a user; they need to be corrected for tidal variations and the coordinates and data format must be adapted so it can be directly loaded into the user's GIS tool. For more convenience, a combined bathymetry from all available sources is offered, where different sources are merged to a single product. This allows using a single dataset within the user's area of interest, even if it stretches from the coastline to deep waters and all sources were required for its generation.

With cheap data and low effort thanks to automated processing, BASE-platform can offer newly derived bathymetry data at prices of just a few Euro per square kilometre (or even only 1 cent in the case of altimetry data).

All data is offered in the BASE-platform web portal, which is an easy-to-use platform where available data can be downloaded off-the-shelf. This includes also four free datasets from the project's trial regions: German Wadden Sea, Channel Islands, Balearics and Mauritius. Since data has not yet been created for all areas of the world, users can also enquire for new data to be created for their respective region of interest.



**Figure 5: Workflow of BASE-platform.** The different data sources are corrected by sea level modelling and are offered on the portal individually and as a merged product.



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## Ressources

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**Links:**

[www.base-platform.com](http://www.base-platform.com)

**Multimedia:**

BASE-platform workshop: <https://www.youtube.com/watch?v=8HodaWSS2J8>

**BIOGRAPHICAL NOTES**

Stefan Wiehle finished his PhD in physics at the Technische Universität Braunschweig in 2014. Since then, he is researcher at DLR Maritime Safety and Security Lab in Bremen.

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