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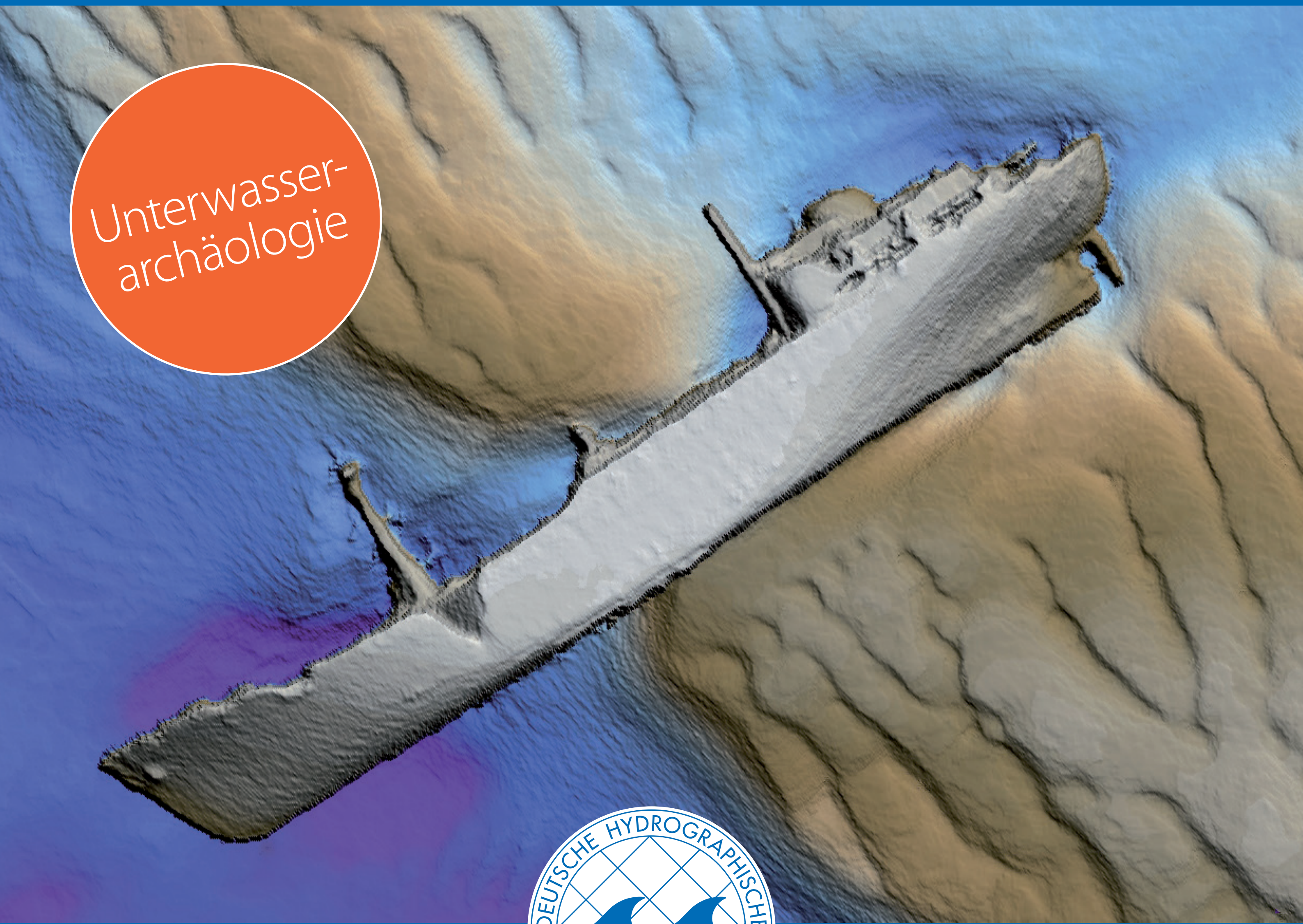

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Validation of altimetry-derived seamount morphology using a multibeam echo sounder in the Atlantic Ocean

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High-resolution mapping of the global seafloor remains incomplete, with large areas mapped using global satellite altimetry models. These models are often used to identify and describe seamounts, although their capability to show the morphology of seamounts accurately is unclear. This study evaluates how well satellite altimetry models derived from vertical gravity (VG) anomalies represent seamount morphology compared to multibeam echo sounder (MBES) data. Eleven uncharted seamounts in the Atlantic Ocean were surveyed during a transit cruise between France and Brazil using a hull-mounted MBES. Seamount height, basal radius and base depth were computed from MBES data and then compared with values from a global seamount catalogue based on satellite altimetry. MBES-derived heights exceeded altimetry estimates for seven of the eleven seamounts, with height differences ranging from approximately 200 m to over 1200 m. The height to basal radius ratio varied widely for MBES data (0.08 to 0.39), while altimetry-derived seamounts exhibited a constant ratio of 0.14. These results show the limitations of altimetry-derived models for describing the morphology of seamounts, especially for steep features, and highlight the importance of ship-based bathymetric surveys for accurate seafloor characterisation.

seamounts | satellite altimetry | MBES | vertical gravity gradient (VGG) | bathymetry
Seamounts | Satellitenaltimetrie | MBES | vertikaler Schwerkraftgradient (VGG) | Bathymetrie

Die hochauflösende Kartierung des globalen Meeresbodens ist nach wie vor unvollständig, wobei große Gebiete anhand globaler Satellitenaltimetriemodelle kartiert werden. Diese Modelle werden häufig zur Identifizierung und Beschreibung von Seamounts verwendet, obwohl ihre Fähigkeit, die Morphologie von Seamounts genau darzustellen, unklar ist. In dieser Studie wird bewertet, wie gut Satellitenaltimetriemodelle, die aus vertikalen Gravitationsanomalien abgeleitet wurden, die Morphologie von Seamounts im Vergleich zu Fächerecholotdaten (MBES) darstellen. Elf nicht kartierte Seamounts im Atlantik wurden während einer Transitfahrt zwischen Frankreich und Brasilien mit einem am Rumpf montierten MBES vermessen. Die Höhe, der Basisradius und die Basistiefe der Seamounts wurden aus den MBES-Daten berechnet und dann mit den Werten aus einem globalen Seamount-Katalog auf der Grundlage von Satellitenaltimetrie verglichen. Die aus MBES abgeleiteten Höhen lagen bei sieben der elf Seamounts über den altimetrischen Schätzungen, wobei die Höhenunterschiede zwischen etwa 200 m und über 1200 m lagen. Das Verhältnis von Höhe zu Basisradius variierte bei den MBES-Daten stark (0,08 bis 0,39), während die aus Altimetrie abgeleiteten Seamounts ein konstantes Verhältnis von 0,14 aufwiesen. Diese Ergebnisse zeigen die Grenzen von altimetriebasierten Modellen zur Beschreibung der Morphologie von Seamounts, insbesondere bei steilen Strukturen, und unterstreichen die Bedeutung von schiffsgestützten bathymetrischen Vermessungen für eine genaue Charakterisierung des Meeresbodens.

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1 Introduction

Seamounts are underwater volcanic structures that are found on the seafloor of the oceanic crust and reach a height of at least 100 m (Staudigel and Clague 2010). They are important features in the oceans that are studied by many different disciplines like geology, oceanography, biology and ecology (Wessel et al. 2010). They are also local hubs for species diversity and underwater ecology (Iyer et al. 2012). The general knowledge on seamounts and, more generally, on the oceans is still very limited. Large areas of the seafloor are still not well mapped, and many seamounts have only been found indirectly with satellite-derived bathymetric models. Satellite altimetry has become an important tool for seafloor mapping, especially in areas where ship-based measurements are unavailable. Satellite altimetry measures sea surface height, from which variations in the Earth's gravitational field are calculated and are then used to calculate the morphology of the seafloor at a larger scale (Gevorgian et al. 2023a). This method is therefore used to estimate the global distribution of seamounts and collect this data in global seamount catalogues. However, the resolution of satellite altimetry data is limited (~6 km) and smaller seamounts measured with this method may not be represented accurately.

Measuring seamounts more accurately requires multibeam echo sounders (MBES) which offer high-resolution bathymetric data (100 to 200 m) (Gevorgian et al. 2023a). Comparing altimetry-derived seamount models with MBES data allows the assessment of the reliability of global seamount catalogues. This research investigates how well altimetry-derived models describe the morphology of seamounts in the Atlantic Ocean when compared with MBES data. The aim of this study is to compare the morphological parameters, height, radius and base depth of uncharted seamounts between satellite altimetry data and bathymetric data from MBES.

2 Theoretical principles

2.1 Seamounts

Menard (1964) defined seamounts as isolated volcanic structures at least 1000 m high from their base located on the ocean floor. In 2010, Staudigel and Clague (2010) defined seamounts as any isolated topographic feature on the seafloor taller than 100 m. Seamounts can be as small as 10 m high domes or as huge as several kilometres-tall structures and sometimes they have flat circular summits or steep external slopes and collapsing features (Iyer et al. 2012; Wessel et al. 2010).

The morphology of seamounts is usually described with parameters such as height and basal radius. Small seamounts have a slope angle proportionate to their maximum height and tend to be much flatter (Gevorgian et al. 2023a). Although there are differences in shape and flatness (height-to-basal radius ratio), Smith (1988) observed a constant relationship between height and basal radius where the summit height of seamounts is approximately one fifth of the basal radius.

Seamount mapping is needed to advance ecological knowledge, understanding volcanic and tectonic processes and higher resolution bathymetric mapping. The majority of seamounts have not yet been surveyed with MBES (Wessel et al. 2010). Global seafloor mapping requires broad multibeam coverage, which is costly and time-consuming. It is therefore important to use indirect mapping methods for the areas between MBES survey tracks. These areas are mapped using global satellite altimetry models derived from vertical gravity (VG) anomalies, which have lower resolution and accuracy (Gevorgian et al. 2023a).

2.2 Satellite altimetry

Satellite altimetry determines the height of the sea surface by measuring the time it takes for a radar pulse to travel from the orbiting satellite to the sea surface and back (Tarpanelli and Benveniste 2019). An equipotential surface called the geoid is approximated by measuring the mean sea surface height with satellite altimeters. Spatial variations in the sea surface height indicate variations in the Earth's gravitational field, which is influenced by mass differences such as the seafloor topography (Kim and Wessel 2011). The density contrast between water and bathymetric structures is the primary cause of the spatial variations in the gravitational field since the gravity field is locally enhanced over bathymetric features (Kim and Wessel 2011; Wessel et al. 2010). Gravity anomalies are derived from the sea surface height measurements and are processed into vertical gravity gradient (VGG) grids that are used to detect seamounts (Gevorgian et al. 2023a). VGG suppresses long-wavelength trends while amplifying short-wavelength signals, such as those seen over seamounts (Kim and Wessel 2011).

However, satellite altimetry has several limitations. One is upward continuation where short wavelengths are attenuated more than long wavelengths in the gravitational signal, which attenuates exponentially with distance from the bottom (Wessel et al. 2010). Seamounts that have a diameter less than the mean ocean depth (~4 km) are then smoothed and attenuated. Another limitation is sediment cover where sediment on the seafloor often covers older tiny seamounts. Despite not being obvious in the topography, the gravity anomaly will still be visible above the buried seamount (Gevorgian et al. 2023a). Sediment thickness on older seafloor can be more than 1 km, hiding many tiny seamounts underneath (Wessel et al. 2010).

2.3 Global seamount catalogue

The global seamount distribution catalogue used in this study is based on VGG grids derived from marine gravity models (Kim and Wessel 2011). The original global seamount catalogue created by Kim and Wessel (2011) used the 1-min Mercator VGG grid to find 24,643 seamounts with heights higher than 100 m. An updated version used an improved VGG grid which found 19,325 additional seamounts (Gevorgian et al. 2023b). The morphological parameters of the seamounts were estimated using Gaussian fitting methods which give information on the height, basal radius and base depth.

3. Methodology

3.1 Data acquisition

The data was collected during the MSM140/2 transit cruise on the Atlantic Ocean from Brest (France) to Rio de Janeiro (Brazil) on the *Maria S. Merian* research vessel. The vessel left Brest on 17.10.2025 and arrived in Rio de Janeiro on 05.11.2025. Eleven seamounts were surveyed along the way (Fig. 1). The Kongsberg EM-124 MBES was used to record the seafloor bathymetry. The frequency used was fixed at 12 kHz with an opening angle of 150°. Modelled sound velocity profiles obtained from World Ocean Atlas 2023 were regularly imported into the acquisition software to correct the refraction of the sound pulses through the water column.

During the transit, the latest global seamount catalogue by Gevorgian et al. (2023b) was used. This allowed the identification of eleven uncharted seamounts along the survey track. Their coordinates are found in Table 1.

3.2 Data processing

Quality check and processing of the MBES data was conducted on board using Qimera. Seamount morphology was analysed in QGIS. Contour lines at 100-m intervals were added, and terrain profiles were drawn through each seamount to determine their base depth, summit depth and height. The base radius for all seamounts was calculated by drawing polygons around the base contour and using the formula $r = \sqrt{Area : \pi}$. The height-to-base radius ratio ($h : r_b$) was then calculated for each seamount. The parameters height, base radius, base depth and height-to-base ratio were compared with the values from the VGG-based global seamount catalogue.

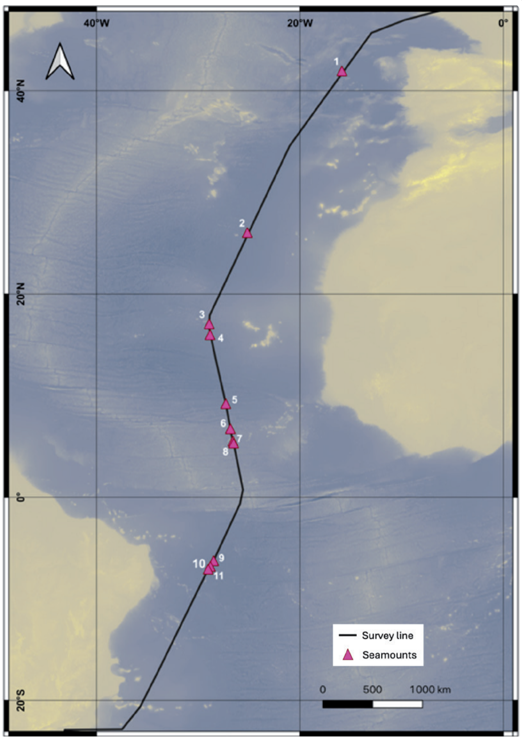

Fig. 1: Survey track of the MSM140/2 transit with the location of the eleven surveyed seamounts (representation in QGIS)

4 Results

Seamount heights measured from MBES ranged from 560 m (seamount 4) to 2,571 m (seamount 11), while altimetry-derived heights ranged from 1,000 m to 2,000 m. Seven of the eleven seamounts had MBES-derived heights higher than altimetry estimates. Base depths measured with MBES varied between −5,802 m (seamount 9) and −4,559 m (seamount 8), with equivalent altimetry base depths between −5,570 m and −4,200 m. The basal radius of the seamounts, measured from MBES data, ranged from 5.7 km (seamount 3) to 12.6 km (seamount 10). The altimetry-derived basal radius ranged from 7.2 km to 14.6 km. The calculated height-to-base ratios from MBES data ranged between 0.08 (seamount 5) and 0.39 (seamount 7). The height-to-base ratios from the altimetry-derived catalogue were equal to 0.14 for all seamounts. Table 2 summarises the results and the corresponding values from the altimetry-derived seamount catalogue (Gevorgian et al. 2023b).

5 Discussion

The results show that altimetry-derived models do not fully represent the morphological characteristics of the surveyed seamounts. The comparison between MBES and altimetry-derived data demonstrates significant differences in base depth, height and morphological ratios. Altimetry-derived base depths are consistently shallower than MBES measurements, with MBES depths on aver-

Seamount	Longitude	Latitude
1	−15.875°	41.958°
2	−25.175°	26.042°
3	−28.925°	17.058°
4	−28.842°	15.992°
5	−27.292°	9.208°
6	−26.842°	6.742°
7	−26.592°	5.525°
8	−26.525°	5.325°
9	−28.492°	−6.242°
10	−28.808°	−6.808°
11	−29.025°	−7.075°

Table 1: Coordinates of the eleven surveyed uncharted seamounts

Seamount	MBES height	Altimetry height	MBES base depth	Altimetry base depth	MBES base radius	Altimetry base radius	MBES height-to-base ratio (h/r_b)	Altimetry height-to-base ratio (h/r_b)
1	1,506.68 m	1,300 m	−5,556.13 m	−5,332.758 m	11.213 km	9.461 km	0.13	0.14
2	1,952.24 m	1,300 m	−5,341.15 m	−5,183.175 m	8.015 km	9.461 km	0.24	0.14
3	801.42 m	1,000 m	−4,933.78 m	−4,824.575 m	5.666 km	7.278 km	0.14	0.14
4	560.34 m	1,800 m	−5,184.06 m	−5,092.997 m	6.206 km	13.100 km	0.09	0.14
5	930.97 m	1,500 m	−5,422.61 m	−5,188.081 m	11.518 km	10.917 km	0.08	0.14
6	1,050.28 m	1,700 m	−4,722.68 m	−4,372.370 m	8.774 km	12.373 km	0.12	0.14
7	2,384.85 m	1,200 m	−4,595.86 m	−4,200.837 m	6.121 km	8.734 km	0.39	0.14
8	2,532.98 m	1,700 m	−4,559.25 m	−4,269.173 m	8.100 km	12.373 km	0.31	0.14
9	1,768.01 m	1,500 m	−5,801.65 m	−5,570.354 m	9.317 km	10.917 km	0.19	0.14
10	1,833.98 m	1,600 m	−5,550.73 m	−5,357.896 m	12.587 km	11.645 km	0.15	0.14
11	2,571.07 m	2,000 m	−5,666.27 m	−5,402.928 m	10.194 km	14.556 km	0.25	0.14

Table 2: Morphological parameters from MBES and altimetry data

age approximately 230 m deeper. This difference can be explained by upward continuation of the gravity field, which results in the gravity-derived model smoothing the bathymetry and underestimating true depths.

Altimetry often underestimates values, as seen in the heights of seamounts 7 and 8. Their basal diameters (12 km and 16 km) are close to the VGG resolution limit, which probably causes spatial smoothing and lower height estimation. Their MBES-derived height-to-base ratios (0.39 and 0.31) indicate steep morphology, while the altimetry model has a constant ratio of 0.14. This comparison shows the limitations of VGG-based models for representing the true morphology and steepness of seamount structures. Fig. 2 shows the visual comparison of seamounts 7 and 8 between altimetry and MBES data.

Seamount 5 shows an opposite behaviour in height estimation, where altimetry overestimates the actual height measured by MBES. Seamounts smaller than 1 km are generally difficult to detect using VGG because their gravity signals are weak and more strongly affected by upward continuation. However, a locally stronger gravity signal may be caused by the capacity of altimeters to detect buried volcanic structures beneath sediment cover. In this case, the altimetry model interprets the feature as higher than it actually is while MBES measures the actual bathymetric surface. The very low height-to-base ratio of 0.08 supports this interpretation, as it indicates a very flat and wide structure that may have undergone long-term sedimentation. Fig. 3 shows the visual comparison of seamount 5 between altimetry and MBES data.

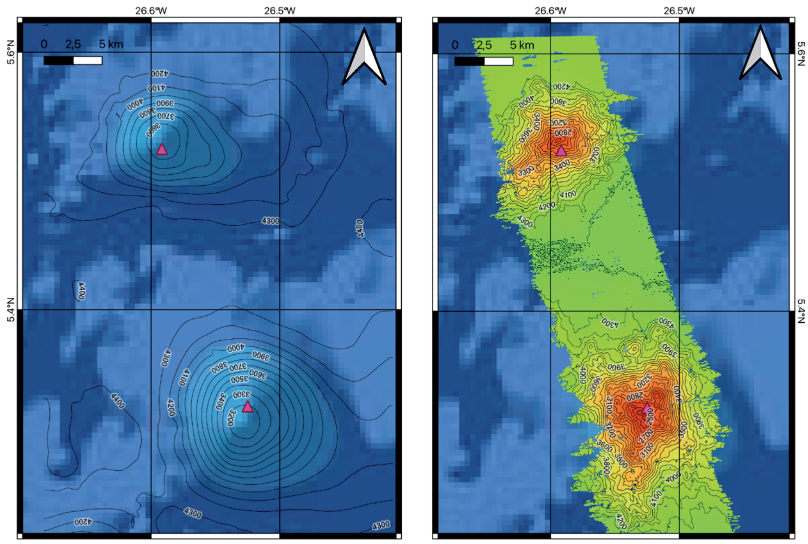

Fig. 2: Seamounts 7 and 8 with 100 m depth contour lines shown by altimetry model GEBCO (left) and MBES data (right) (representation in QGIS)

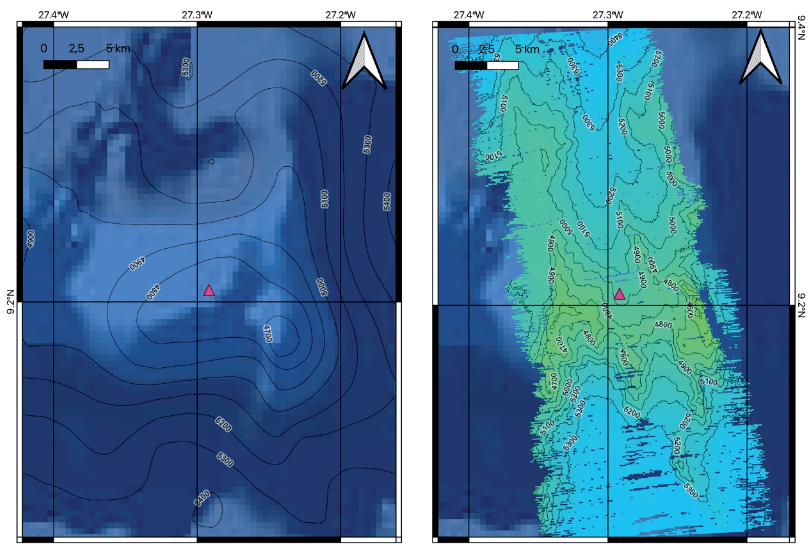

Fig. 3: Seamount 5 with 100-m depth contour lines shown by altimetry model GEBCO (left) and MBES data (right) (representation in QGIS)

6 Conclusion

This study evaluated the validity of altimetry-derived seamount morphology by comparing the parameters from the VGG-based catalogue to MBES data for eleven uncharted seamounts in the Atlantic Ocean. The results show significant differences in height, base depth and height-to-base ratio between the two datasets. The altimetry-derived base depths are shallower, and the steep seamounts have underestimated heights due to spatial smoothing. In contrast, other seamounts showed an overestimation of height in the altimetry model, possibly related to sediment-covered structures which influence the gravity signal. The MBES data show that the height-to-base ratios vary widely, ranging from very flat and wide to steep and narrow morphologies, which are not represented in the constant ratio used in the global catalogue. While satellite altimetry is important for global seamount detection, morphological characterisation requires high-resolution multibeam surveys to accurately represent seafloor features. //

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