Article title: Improved bathymetry leads to 4000 new seamount predictions in the global ocean

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Improved bathymetry leads to 4000 new seamount predictions in the global ocean

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Abstract. Seamounts are important marine habitats that are hotpots of species diversity. Relatively shallow peaks, increased productivity and offshore locations make seamounts vulnerable to human impact and difficult to protect. Present estimates of seamount numbers vary from anywhere between 10000 to more than 60000. Seamount locations can be estimated by extracting conical shaped features from bathymetry grids. These predicted seamounts are a useful reference for marine researchers and can help direct exploratory surveys. However, these predictions are dependent on the quality of the surveys underpinning the bathymetry. Historically, quality has been patchy, but is improving as mapping efforts step up towards the target of complete seabed coverage by 2030.

This study presents an update of seamount predictions based on SRTM30 global bathymetry version 11. This update was prompted by a seamount survey in the British Indian Ocean Territory in 2016, where locations of two putative seamounts were visited. These 'seamounts' were targeted based on previous predictions, but these features were not detected during echosounder surveys. An examination of UK hydrographic office navigational (Admiralty) charts for the area showed that the summits of these putative features had soundings reporting "no bottom detected at this depth" where "this depth" was similar to the seabed reported from the bathymetry grids: we suspect that these features likely resulted from an initial misreading of the charts. We show that 15 phantom seamount features, derived from a misinterpretation of no-bottom sounding data, persist in current global bathymetry grids and updated seamount predictions. Overall, we predict 37,889 seamounts, an increase of 4,437 from the previous predictions derived from an older global bathymetry grid (SRTM30 v. 6). This increase is due to greater detail in newer bathymetry grids as acoustic mapping of the seabed expands.

The new seamount predictions are available at https://doi.pangaea.de/10.1594/PANGAEA.921688.

Keywords

Seamounts; Knolls; Bathymetry

Introduction

Seamounts are ’undersea mountains’, and although many definitions of this term have been used, they are commonly described as conical features that rise more than 1000m above the surrounding seabed (IHO 2008). Seamounts are important marine habitats, they provide a pathway for localized production (Hosegood et al., 2019), often increasing surrounding biomass and species diversity (Letessier et al., 2017), they can be hotspots of predator biodiversity in the open ocean (Morato et al., 2010), home to habitat-engineering species such as cold water corals (Tracey et al., 2011), important spawning grounds (Tsukamoto, 2006), and even act as refugia from ocean acidification for carbon-calcifying species (Tittensor et al., 2010).

The increased productivity associated with seamounts makes them attractive targets for fishing, and hence vulnerable to human impacts, particularly those with accessible summits near the surface. Fishing gear can cause long-lasting damage to habitat forming organisms associated with some seamounts (Althaus et al., 2009). Protection of seamount habitats is a priority for marine conservation (Morato et al., 2010), but our knowledge on these habitats remains limited, with estimates of only 0.4-4% of seamounts having been directly surveyed (Kvile et al., 2014).

Direct surveys require significant investment of resources and planning, and fundamental to this is identification of locations of interest for the survey. However, we do not yet know how exactly many seamounts there are, with estimates ranging from the tens to hundreds of thousands (Yesson et al., 2011). This has led to the publication of many predictive maps and databases of potential seamount locations, commonly based on pattern recognition of underlying bathymetry data (Yesson et al., 2011; Harris et al., 2014), but also using satellite altimetry to detect larger features (Wessel, Sandwell, and Kim 2010; Kim and Wessel, 2011).

Seamount predictive maps are dependent on the underlying data to extract features. Global bathymetry grids such as GEBCO (General Bathymetric Chart of the Oceans - Weatherall et al., 2015) and SRTM (Shuttle Radar Topography Mission - Becker et al., 2009) are models based on a combination of soundings (i.e. high resolution acoustic surveys) and satellite altimetry (lower resolution data from satellite sensors). Satellite altimetry provides global coverage and is the foundation of bathymetry models, but these sensors cannot determine small features (i.e. seamounts under 1.5km, Wessel et al., 2010). Acoustic surveys generate data best suited for determining seabed depth and these are utilised to constrain models used to create bathymetry grids (Becker et al., 2009). Despite global efforts to improve coverage, such as the Nippon Foundation-GEBCO challenge to survey the ocean floor across the globe by 2030 (Wölfl et al., 2019), soundings in the latest bathymetry grids are limited to a small proportion of the ocean, and the majority of bathymetry grid data is derived from the underlying model rather than acoustically surveyed. For example, only 18% of current GEBCO grid cells (each 30x30 arc seconds ≈ 1x1km at the equator) are directly supported by acoustic surveys (Weatherall et al., 2015). Since sounding data is limited, it is valuable to make use of all available data. Historical soundings based on weighted lines have been extracted from nautical charts to expand the data available (Becker et al., 2009).

BIOT Seamount Survey

The British Indian Ocean Territory (BIOT) is a region of the Indian Ocean encompassing a variety of undersea features, including the flat shallow banks of the Chagos Archipelago, and the high slopes of the Chagos-Laccadives ridge, and depths beyond 5000m (Sheppard et al., 2012). The area could be home to as many as 86 seamounts, based on estimates from an automated seamount-recognition algorithm applied to version 6 of the SRTM global bathymetry grid (Yesson et al., 2011). Two of these predicted seamounts, clearly discernible on the latest bathymetry grids, were targeted during a 2016 survey around the Chagos Archipelago (Letessier et al., 2016), between 5-24th February. These were seamounts ID 4050548 (latitude -5.354, longitude 71.292, summit depth 481m) and ID 4060551 (lat. -5.733, long. 71.396, depth 141m) from Yesson et al., (2011). The survey sought to visit these features for the purpose of establishing baseline monitoring sites for mobile oceanic predators (Letessier, Bouchet, and Meeuwig 2017). Seamounts in BIOT have previously been shown to be important location of bio-physical coupling between reef and pelagic ecosystems, and may therefore support elevated numbers of predators (Hosegood et al., 2019; Letessier et al., 2016; Letessier et al., 2019). Acoustic data were collected using a Simrad (Bergen, Norway) EK60 echosounder operating at 38 kHz with a pulse length of 1.024ms and ping rate of 2s. At these settings, the seabed was detectable up to 1,500m below the surface. Seabed was detected at around this depth for seamount A (predicted depth 183m), but no seabed was detected around the area of seamount B (predicted depth 491m) despite circling around the supposed summits up to 5km (Fig. 1 & 2). We note that the source of the reading that accounts for seamount B was a digital nautical chart from the National Geospatial Agency and this erroneous point is removed from construction of more recent bathymetry grids (D. Sandwell pers. comm.).

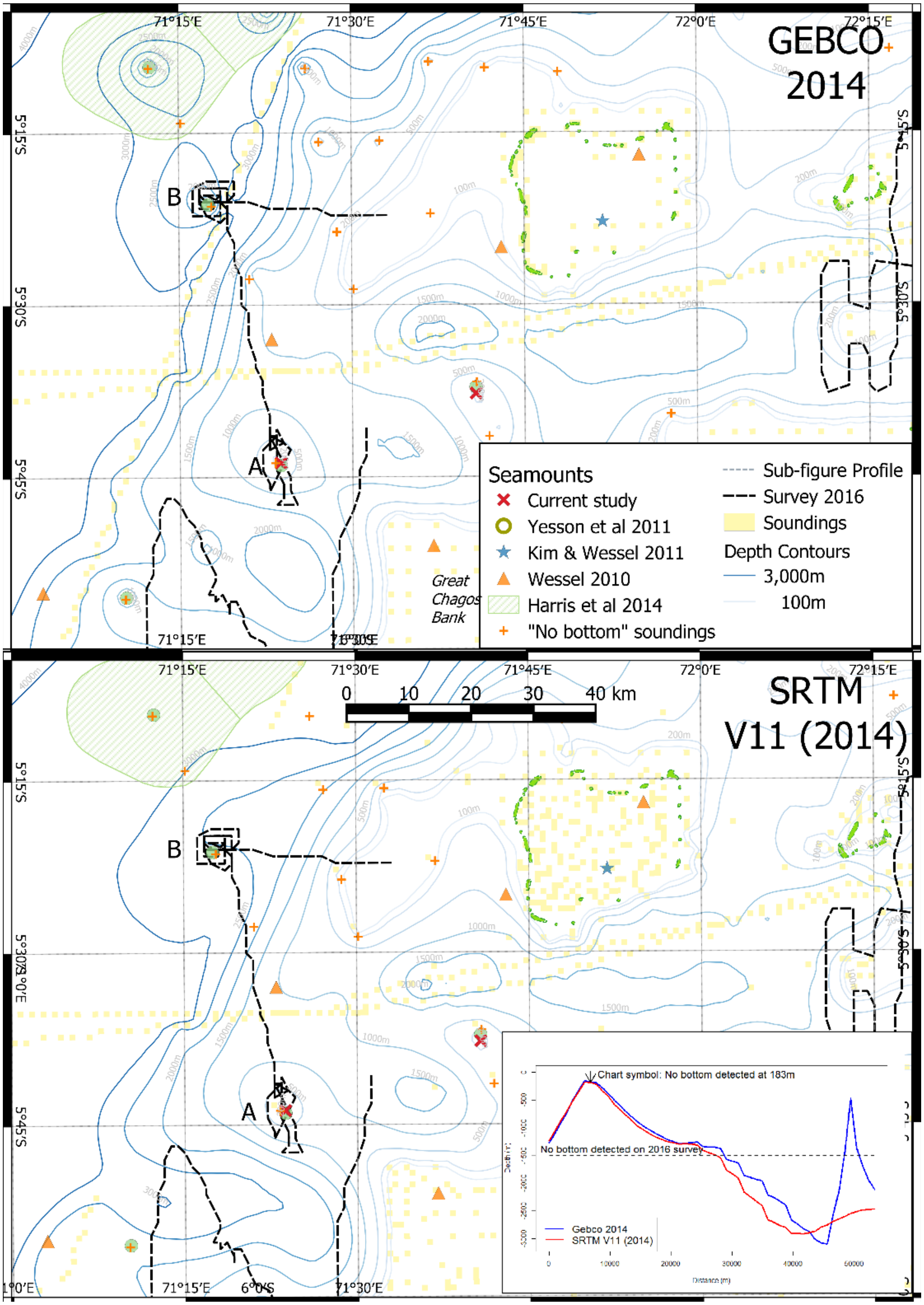


Figure 1: Location of survey conducted in 2016. Top shows depth contours based on the 2014 GEBCO bathymetry grid, bottom shows depth contours derived from SRTM v11. Both grids indicate the presence of a conical seamount c.20km NW of the Great Chagos Bank. No feature was detected by the 2016 survey (ship's track shown with black dashed line). Around 40km north of this, is another predicted seamount, again not detected on the 2016 survey. This feature is predicted by the GEBCO grid, but is not shown in the SRTM grid (although present in previous versions). Map projection UTM zone 43 south (epsg:32743).

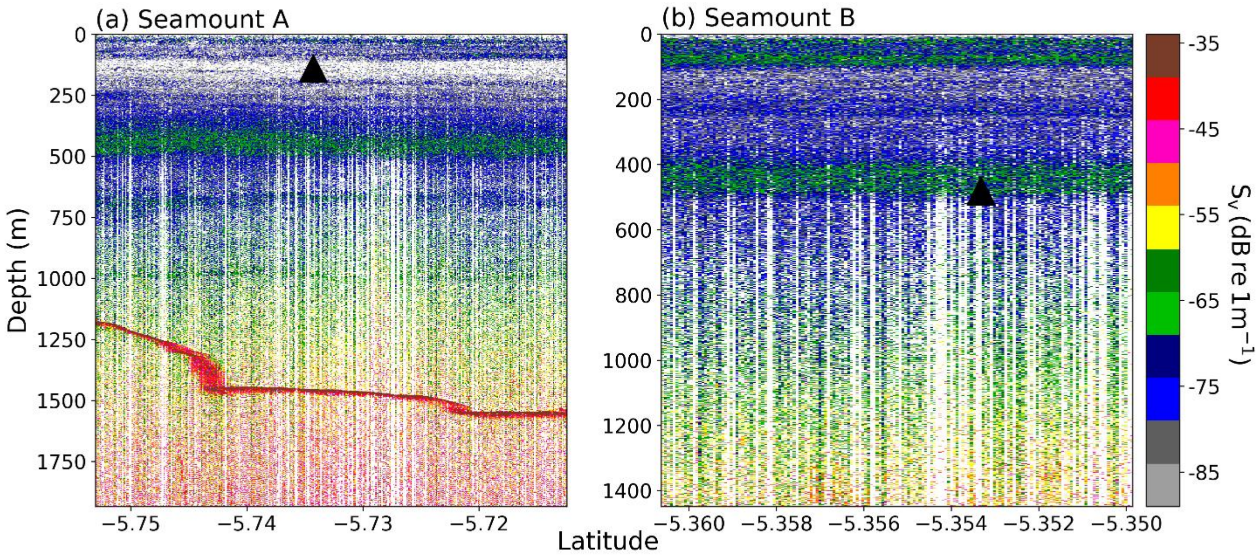


Figure 2: Latitudinal transects across apparent positions of the two phantom seamounts. Black triangles indicate the position and summit depth of the predicted seamounts. Colormap is Volume Backscattering Strength (Sv). A deep scattering layer was observed at c.450m for both sites. Seabed was observed at site A c.1500m. No seabed was detected for site B.

An examination of the admiralty chart for the region provided some insight. Soundings on charts are recorded by displaying the depth reading over the location. A different class of sounding is also recorded. Soundings where no bottom was recorded are annotated with $\frac{\cdot}{Depth}$ at the location of the sounding. These soundings are typically old, prior to the nineteenth century, dating from when soundings where conducted using handheld, weighted, lead lines, before the widespread use of sounding machines. It is easy to mistake these as bottom soundings, and this appears to be the root cause of the ’phantom seamounts’. For seamount A (Fig. 1) there is a sounding in the chart at the summit of the mound seen on the bathymetry grids. The chart shows no bottom recorded at 183m, while the GEBCO depth at this cell is 179m and SRTM depth is 183m.

However, the SRTM grid at the site of seamount B does not show a seamount-like feature, in contrast to GEBCO, which shows an isolated point of markedly higher elevation, which is interpreted as a conical seamount-like peak by seamount detection algorithms. It is noted that previous versions of the SRTM grid showed a seamount-like feature at this location. The version history reports the removal of isolated and outlier “bad pings” prior to the construction of version 11. The revision of SRTM has removed other seamount-like features from the revised bathymetry grid (i.e. NW corner of Fig. 1). It is apparent that bathymetry grids such as GEBCO and SRTM have mistakenly used these “no seabed detected” observations as soundings indicating seabed depth, and in regions with sparse sounding data, these spatially isolated erroneously interpreted records are sufficient to create a local maxima that creates the appearance of a seamount in the final bathymetry grid.

This study aims to update the Yesson et al., (2011) seamount predictions using the latest available bathymetry and assess the impact of no bottom sounding data on the prediction of seamounts.

Methods

Version 11 of the Shuttle Radar Topography Mission global bathymetry (Becker et al., 2009 – version 11 released 2014) was used to update the seamount prediction estimates of Yesson et al., (2011), using the same methodology previously reported based on the local radial inspection of the surrounding area of local summits (Yesson et al., 2011).

New seamount predictions were compared with the previous dataset (Yesson et al., 2011 – henceforward the 'old' dataset). Seamounts were defined as in the old dataset if the seamount bases of the latest predictions encompassed the summit of old seamount predictions. Seamount bases are defined by 8 radii 45° apart that terminate at the point the descent from the seamount summit levels off up to a maximum of 20km from the summit (thus the maximum base area is ~1,131 km2). The seamount bases can, and often do, encompass multiple peaks in the old dataset.

A dataset of 'no bottom sounding' observations was provided by Oceanwise Ltd, from a dataset of depth readings from digitised admiralty charts. These data include 1009 observations from charts covering the majority of the Atlantic and East Pacific, but with little data from the Southwest Indian Ocean and West Pacific. The depth readings of no-bottom soundings that were spatially located within seamount bases were compared with the summit depths.

Results

The total number of seamounts predicted based on the SRTM v11 bathymetry is 37,889. A map of these is presented in Fig. 3. There are 32,340 seamounts in the new dataset that overlap with predictions from Yesson et al., (2011) and 5,549 (15%) that do not. Conversely, of the Yesson et al., (2011) seamount predictions there are 3,429 / 33,452 (10%) that do not overlap with the seamount bases of the new dataset.

Of the 1009 'no bottom sounding' records, only 15 overlap with seamounts that are similar in depth (+/-50m) to the peak of the predicted seamount. In contrast there are 14 seamounts that fit this pattern from the 2011 dataset. These "phantom seamounts" are focused in the Indian Ocean (12/14 from 2011 data and 12/15 from the updated dataset), with 4 potential phantom seamounts around Chagos Bank and 6 from the southern Mascarene Plateau (Fig. 4).

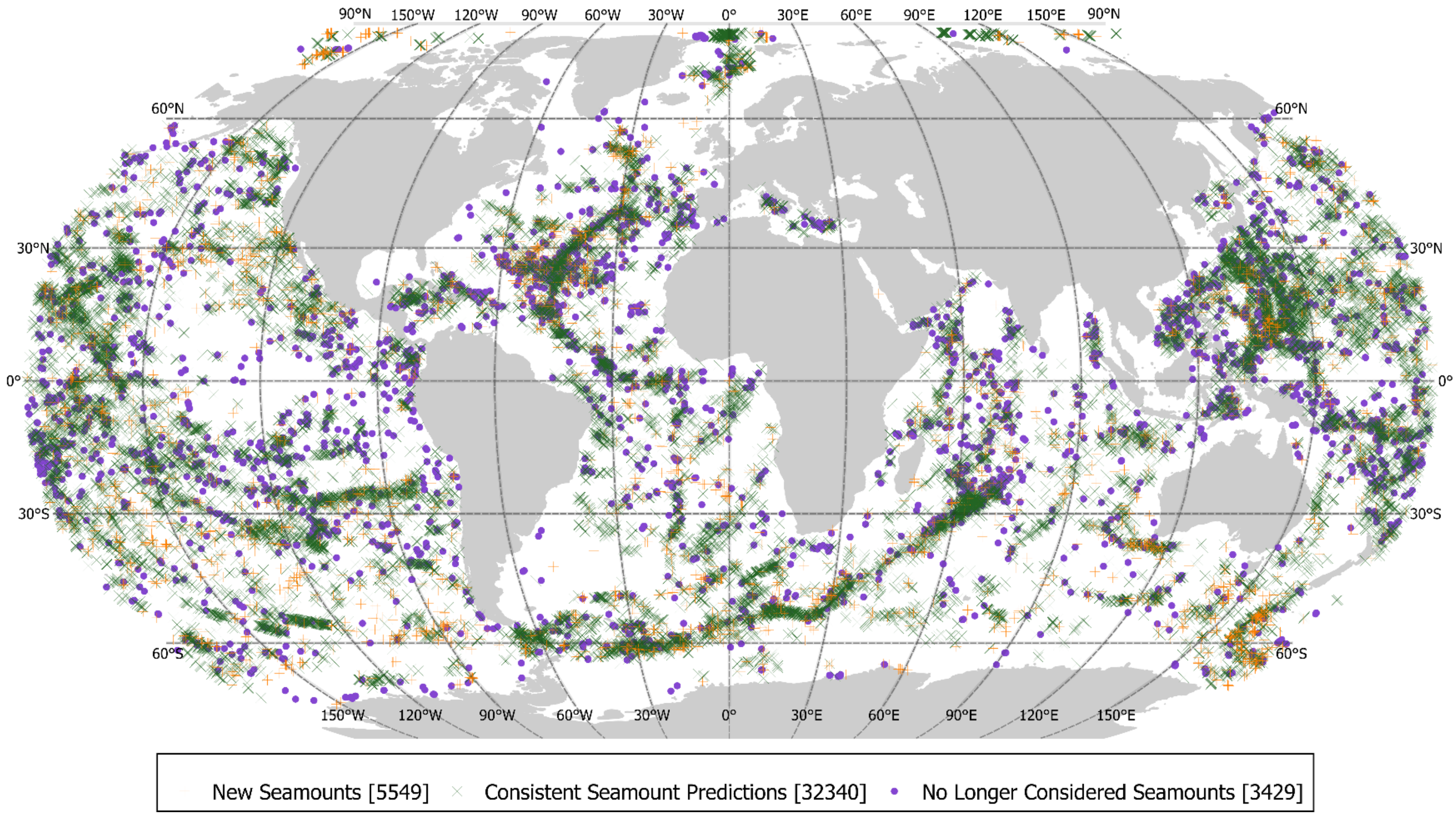
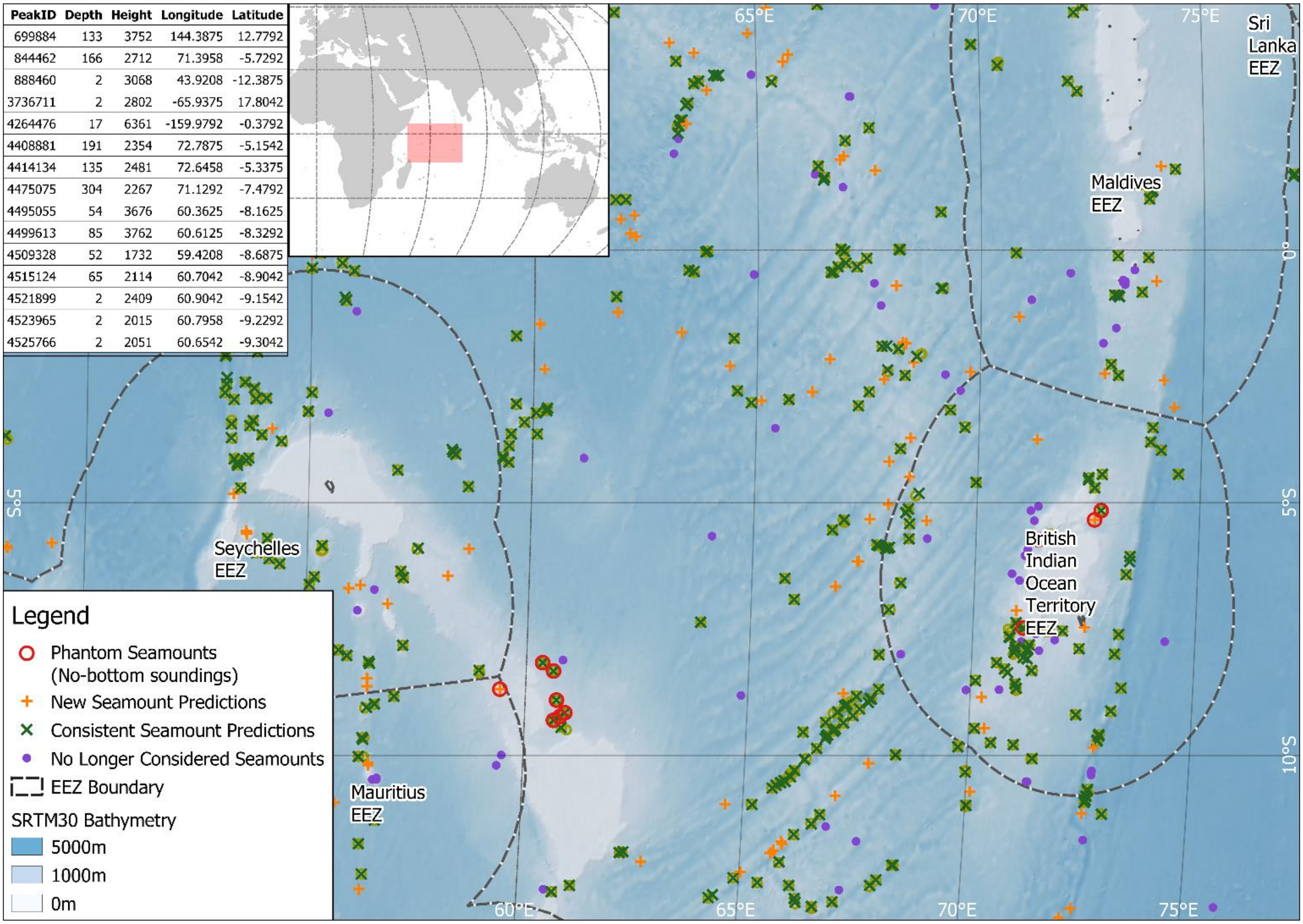


Figure 3: Map of predicted seamounts. New Seamounts are those in the new prediction that are not found in the Yesson et al., (2011) dataset. "Consistent predictions" are new predictions that are spatially consistent with Yesson et al., (2011), while those no longer considered seamounts are present in Yesson et al., (2011) but not in the updated dataset. Robinson map projection (EPSG:54030). Lat/Long grid lines at 30° intervals.



PeakID	Depth	Height	Longitude	Latitude
699884	133	3752	144.3875	12.7792
844462	166	2712	71.3958	-5.7292
888460	2	3068	43.9208	-12.3875
3736711	2	2802	-65.9375	17.8042
4264476	17	6361	-159.9792	-0.3792
4408881	191	2354	72.7875	-5.1542
4414134	135	2481	72.6458	-5.3375
4475075	304	2267	71.1292	-7.4792
4495055	54	3676	60.3625	-8.1625
4499613	85	3762	60.6125	-8.3292
4509328	52	1732	59.4208	-8.6875
4515124	65	2114	60.7042	-8.9042
4521899	2	2409	60.9042	-9.1542
4523965	2	2015	60.7958	-9.2292
4525766	2	2051	60.6542	-9.3042

Figure 4: Focus on Seamounts of NW Indian Ocean. Most of the 15 predicted seamounts based on no-bottom soundings are in the Indian Ocean. Inset table (top left) shows the full list of 15 "phantoms." Robinson map projection (EPSG:54030). Lat/long lines shown for reference.

Discussion

The 37,889 seamounts predicted from the latest SRTM bathymetry represents an increase in number (4,437=13%) of seamounts predicted from the previous study (N=33,452). The revised predictions are higher than other predictions that post-date Yesson et al., (2011) such as 24,643 seamounts in the Kim & Wessel (2011) dataset and 10,234 of Harris et al (2014), but it is still lower than some other predictions, e.g. 68,669 of Costello et al., (2010). It is worth noting that each of these studies uses different ways of detecting seamounts, for example Harris et al., (2014) have a stricter definition of seamount that excludes features along ridges, while the methodology used in this study (from Yesson et al., 2011) employs a distance-based filtering of adjacent features.

Regardless of the methodology used, it is important to keep prediction datasets up-to-date with the latest bathymetry grids. We note that a global 15 second bathymetry grid is available (SRTM 15 v2.1, Tozer et al., 2019), and that this greater detail may assist with seamount identification, although may require adjustment of the current methodology to fully utilise (Yesson et al., 2011). We expect the expansion of multibeam echosounder data (Wölfl et al., 2019) to allow the detection of smaller (<1.5km) features in regions where previously bathymetry grids relied on only coarse resolution satellite-derived data, which is why authors have extrapolated their 'detected' seamount numbers to higher global estimates (e.g. Kim & Wessel, 2011 detect 24,643 seamounts, but extrapolate this to a global total of 40,000-55,000). This pattern of increased seamount detection as more acoustic data becomes available fits our observation.

However, there is a competing pressure that may lead to a reduction of seamount numbers, as isolated 'bad pings' or erroneous readings are removed from bathymetry grid construction, so features defined by these mistakes will be removed (Becker et al., 2009; Weatherall et al., 2015). Although the scale of this error appears to be small, and the bathymetry grids are improving their products, all of these issues have not yet been removed.

Finally, although these predictions are based on a global bathymetry grid, we note that seamount predictions based on the lat-long bathymetry grid perform poorly at high latitudes where there is a large spatial distortion. Seamount predictions for Arctic and Antarctic regions should be remade based on polar specific grids such as the International Bathymetric Chart of the Arctic Ocean (IBCAO - Jakobsson et al., 2012).

Conclusion

Bathymetry grids are continually improving (Wölfl et al., 2019), whether that be from new multibeam acquisition, such as that collected during the search for Malaysian Airlines flight MH370 (Smith and Marks 2014), or improved satellite gravity data (Sandwell et al., 2014). However, these bathymetry grids still rely on sparse sounding data for many regions, and thus have the capacity to mislead if invalid historical weighted line measurements are used in the construction of bathymetric models as isolated falsely interpreted records can lead to the appearance of "phantom seamounts." Therefore, it is important that we use all the information available, including multiple seamount predictions, multiple bathymetry models and printed charts to assess potential seamount distributions, particularly when planning surveys to unsampled seamounts, or in the arena of conservation planning, where seamount distributions can be used as proxies for endangered predator distributions (Bouchet et al., 2014).

Data availability

Updated seamount predictions are available to download at (https://doi.pangaea.de/10.1594/PANGAEA.921688).

Author contribution

CY & TL conceived the work. TL, ANS, PH, AB & RP planned and conducted fieldwork. CY, TL & MH assembled the data. CY performed analysis. All contributed to writing.

Competing interests

The authors declare that they have no conflict of interest.

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