ACCURACY OF THE 2500 METER ISOBATH FROM SATELLITE BATHYMETRY

K. M. Marks[1] and W. H. F. Smith[1]
[1]*NOAA, Laboratory for Satellite Altimetry, E/RA31, Silver Spring, Maryland 20910, USA*

ABSTRACT

Locating the 2500 m isobath is a crucial component of a Coastal State's efforts to lay claim to its Juridical Continental Shelf under Article 76 of the United Nations Convention on the Law of the Sea. We compare depths from the altimetric bathymetry grid of Smith and Sandwell to depths surveyed by ships with multibeam acoustic echosounders to assess how accurately satellite bathymetry maps the 2500 m isobath. We find the satellite isobath meets IHO S-44 vertical accuracy standards 90% of the time in areas of smooth topography with good acoustic survey control, but only 31% of the time in a rugged, poorly surveyed area. A horizontal displacement of the satellite isobath with respect to the NGDC Coastal Relief Model offshore of New Jersey, USA, is due to the underlying depths being uncorrected for the velocity of sound in seawater in the Model and corrected in the satellite-derived bathymetry data.

1. INTRODUCTION

Accurately locating the 2500 m isobath is a crucial component of a Coastal State's efforts to lay claim to its Juridical Continental Shelf under Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS)[1]. The guidelines of the Commission on the Limits of the Continental Shelf (CLCS) [2] refer to International Hydrographic Organization (IHO) S-44 standards [3] for the expected accuracy in locating the 2500 m isobath in support of a claim. Bathymetry measured indirectly by satellite [4,5] can be a valuable tool in helping to locate the 2500 m isobath, but there is a trade-off: although the available satellite coverage is nearly global, it does not achieve the high resolution of state-of-the-art multibeam ship surveys. Thus there is a question as to whether the accuracy of bathymetry from space is adequate for UNCLOS purposes, or at least for reconnaissance assessment of potential claims.

In this paper we assess the vertical (depth) and horizontal accuracy of the 2500 m isobath from satellite bathymetry in light of IHO S-44 standards. We look along the continental slope in the Gulf of Mexico to determine how well the satellite bathymetry field predicts 2500 m depths in a region that has abundant ship control. We also look at a region in the Woodlark Basin, east of Papua New Guinea, which had only sparse constraints from old ship surveys available when the satellite bathymetry field was produced. Finally, we investigate a reported horizontal displacement of the 2500 m satellite isobath [6], when compared to the National Geophysical Data Center (NGDC) Coastal Relief Model [7] in a region offshore of New Jersey, USA.

2. ACCURACY OF THE 2500 METER ISOBATH

We use the most recent (November, 2000) version (8.2) of the Smith and Sandwell [5] global seafloor bathymetry grid in our analysis; hereafter, unless stated otherwise, satellite bathymetry refers to Version 8.2. This product is a two-arc-minute Mercator grid of global seafloor bathymetry that combines ship soundings where available with bathymetry interpolated from satellite gravity where there are gaps. The accuracy of the 2500 m isobath contoured from this grid depends on the number and quality of the ship soundings incorporated, the algorithms and assumptions used to derive bathymetry from satellite gravity, and the resolution that is a function of the grid spacing.

We examined the 2500 m isobath in the Gulf of Mexico because it is a region covered by dense ship data. Volume 4 of the NGDC Coastal Relief Model [7] (Fig. 1), which is constructed from dense single- and multibeam surveys, covers the Texas-Louisiana Shelf, the Central Slope, and much of the Sigsbee Escarpment

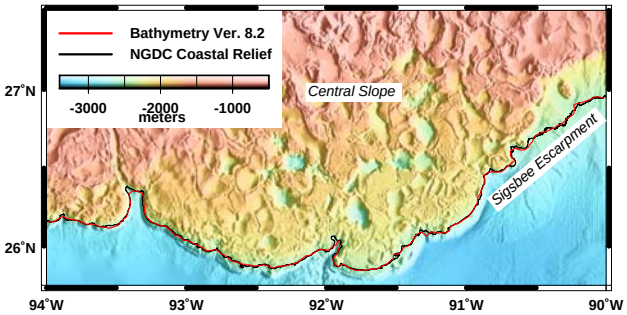

Figure 1. Color shaded-relief image of bathymetry from the NGDC Coastal Relief Model [7] over the Central Slope in the Gulf of Mexico, USA. Depths range from 3500 m (blue) to 500 m (orange), and are "illuminated" from the east. The thick red line is the 2500 m contour from Smith and Sandwell's Version 8.2 satellite bathymetry grid, the thin black line is the 2500 m contour from the NGDC Coastal Relief Model.

along which the 2500 m isobath lies. There is good agreement in the location of the satellite isobath (red line in Fig. 1) and the Coastal Relief Model isobath (black line), but the satellite isobath doesn't quite

resolve the sinuous twists that the Coastal Relief Model isobath does; these discrepancies are located mainly in narrow channels. This is expected because the 3-arc-second grid spacing of the Coastal Relief Model can resolve finer-scale topography than the 2-arc-minute grid spacing of the satellite grid.

To assess the vertical accuracy, we sampled the Coastal Relief Model depths along the satellite isobath and calculated the differences. The histogram in Fig. 2 shows that the depth values are within 125 m of 2500 m 90% of the time. The satellite isobath very nearly meets the 95% confidence level for bathymetric model depth accuracy set in IHO S-44, in a region where the satellite bathymetry solution incorporated abundant and good survey control.

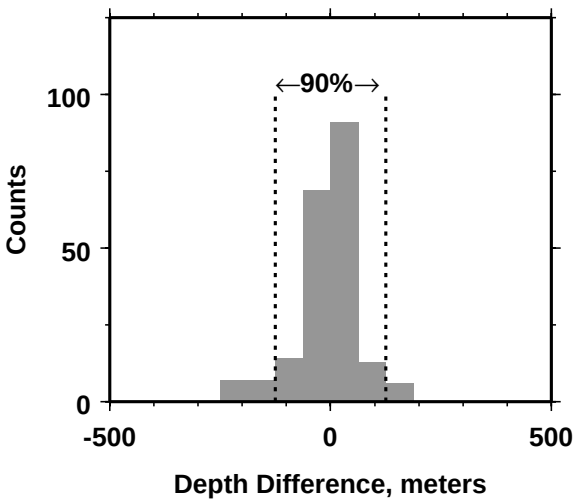

Figure 2. Histogram of depth differences obtained by sampling the Coastal Relief Model along the 2500 m satellite isobath. Dotted lines at ±125 m denote the 95% confidence level for bathymetric model vertical accuracy [3]. Depth differences are within IHO S-44 standards 90% of the time.

We next examined the eastern portion of the Woodlark Basin, east of Papua New Guinea that had only poor survey control available when Version 8.2 of the satellite bathymetry grid was produced. Subsequently, a high resolution multibeam survey of this area [8] was made available to us. By comparing the satellite isobath to a multibeam survey that was not incorporated into the satellite solution, it is possible to assess the accuracy of the satellite isobath in a case where predicted bathymetry dominates. This case is typical of most of the ocean's seafloor because multibeam surveys cover only a few percent of the deep ocean bottom.

Fig. 3 shows an image of the multibeam bathymetry data in the eastern portion of the Woodlark Basin. The red line in Fig. 3 is the 2500 m satellite isobath, and the black line is the isobath from the multibeam survey. The satellite isobath is considerably smoother than the multibeam isobath, and some canyons are not mapped by the satellite isobath at all.

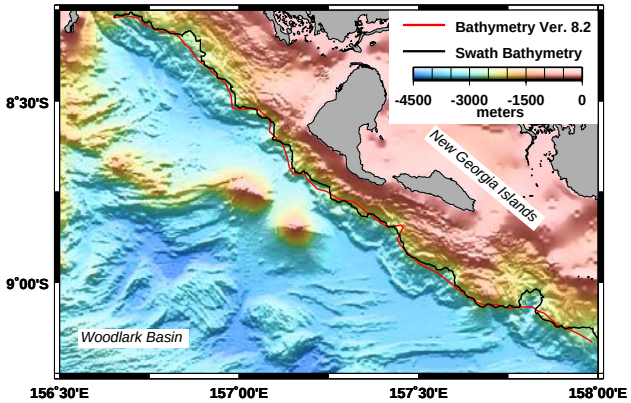

Figure 3. Color shaded-relief image of multibeam bathymetry [8] in the eastern Woodlark Basin, east of Papua New Guinea. Depths range from 4500 m (blue) to 0 m (orange). The thick red line is the 2500 m contour from the satellite bathymetry grid; the black line is the contour from the Woodlark Basin multibeam bathymetry grid.

We sampled the multibeam depths along the 2500 m satellite isobath, and calculated the differences. A histogram of these depth differences is shown in Fig. 4.

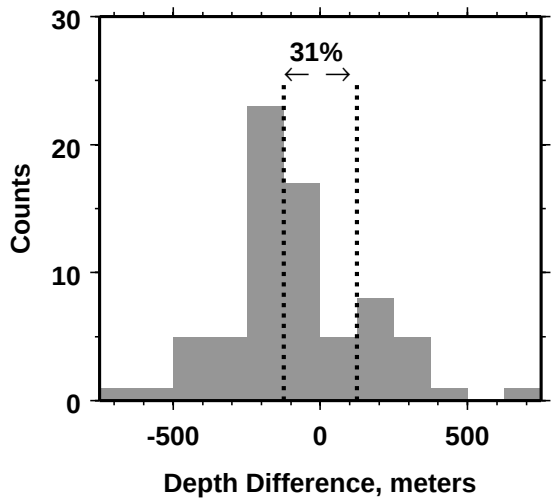

Figure. 4. Histogram of depth differences obtained by sampling the multibeam grid along the 2500 m satellite isobath. Depth differences are within IHO S-44 standards (dotted lines) 31% of the time, but most are between -250 m and 0 m. The multibeam depths are deeper than the 2500 m satellite isobath, particularly across the mouths of canyons.

In this region, only 31% of the depth differences are within 125 m of 2500 m. Further, most of the depth differences range between -250 and 0 m. This skewness towards negative values can be seen in Fig. 3 as places where the 2500 m satellite isobath traverses seafloor that is deeper in the multibeam survey- as an example the satellite isobath crosses the mouths of several canyons rather than bending inwards towards them. We think that the poor quality of the old ship data in this region that were incorporated into the satellite bathymetry solution are the most likely explanation for the skewness observed in Fig. 4.

3. ORIGIN OF A 2500 METER ISOBATH OFFSET

In a study by Monahan [6], the 2500 m isobath from Smith and Sandwell's Version 6.2 predicted bathymetry grid was plotted against that from the NGDC Coastal Relief Model [7], over a region offshore of New Jersey, USA. Because the Coastal Relief Model was constructed from recent multibeam surveys conducted using good positioning equipment, it was assumed to map the true location of the 2500 m isobath, and the horizontal distance between it and the predicted bathymetry contour was measured. Monahan observed a systematic, seaward, 2-3 km offset of the satellite isobath when compared to the NGDC isobath, but still found it to lie within the horizontal accuracy limits he derived from IHO S-44.

In our present investigation of the origin of this offset, we use Version 8.2 of the satellite bathymetry grid. We find the same apparent offset of the satellite isobath that Monahan did (see dashed line in Fig. 5).

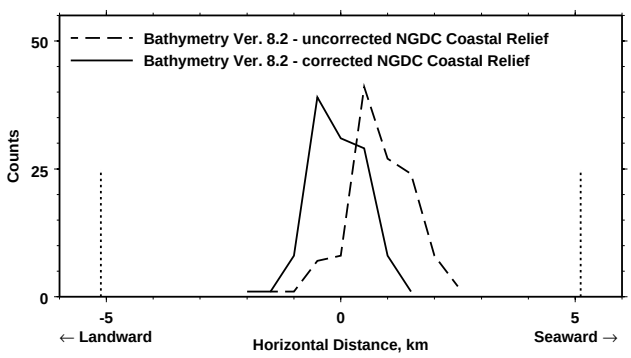

Figure 5. Histogram of horizontal distance between 2500 m contours from satellite bathymetry and the NGDC Coastal Relief Model. When the satellite bathymetry position is measured against the uncorrected NGDC Coastal Relief isobath (dashed line), there is a 0.5-1.5 km seaward offset. When the location is instead reckoned to the Carter-corrected Coastal Relief Model isobath (solid line), there is no offset. Both histogram curves lie within the IHO S-44 horizontal uncertainty limits of ±5.114 km (dotted lines) derived by Monahan [6].

Our first step in investigating the origin of this offset was to plot 2500 m depths obtained from soundings along ship tracks on top of the isobaths. We used sounding data from the NGDC GEODAS Marine Trackline Geophysics database [9]. We downloaded ship bathymetry data covering the study area both with the correction for velocity of sound in seawater [10] applied, and also as uncorrected depths. Both these corrected and uncorrected depths are plotted in Fig. 6. The corrected 2500 m depth soundings (black circles) lie along the 2500 m satellite isobath, and the uncorrected 2500 m depth soundings (red circles) lie on the NGDC Coastal Relief Model 2500 m isobath. This indicates that in this region, the Coastal Relief Model 2500 m isobath follows uncorrected depths, even though the documentation states that the Model is in corrected depths. The 2500 m satellite isobath follows corrected

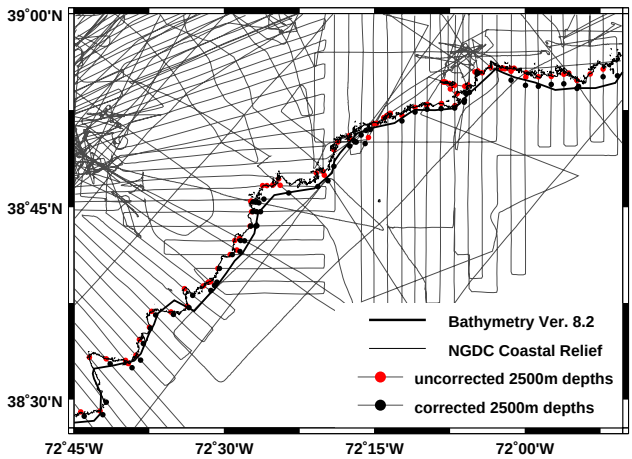

Figure 6. Ship tracks (gray lines) and depths from the NGDC GEODAS Marine Trackline Geophysics database [9]. The 2500 m depths corrected for the velocity of sound in water [10] (black circles) lie on the 2500 m satellite isobath (thick black line), and uncorrected 2500 m depths (red circles) lie on the NGDC Coastal Relief Model isobath (thin black line). This indicates the NGDC Coastal Relief Model assimilated uncorrected depths in this area, while the satellite bathymetry depicts corrected depths.

depths. We conclude the 0.5-1.5 km offset between the isobaths in Figs. 5 and 6 is due to the underlying data being uncorrected in the NGDC Coastal Relief Model, and corrected in the Smith and Sandwell satellite bathymetry grid.

We examined the underlying ship coverage in more detail and identified R/V Atlantis II legs A121 and A124 as comprising almost all of the surveys plotted in

Figure 6 (ship tracks are thin gray lines). We suspect that uncorrected R/V Atlantis II multibeam data were incorporated into the NGDC Coastal Relief Model, and that these uncorrected data dominate the Coastal Relief Model in this region offshore of New Jersey. Subsequently, the use of uncorrected R/V Atlantis II multibeam data was confirmed by John Campagnoli (personal communication, 2005) at NGDC. In our comparisons of the NGDC Coastal Relief Model 2500 m isobath to the Smith and Sandwell isobath in the Gulf of Mexico reported in this paper, and also in other regions including off the USA west coast, we found no offset between the isobaths, indicating they both follow corrected depths in their respective underlying grids. Volume 2 of the NGDC Coastal Relief Model extends from 31°- 40° N. The isobaths are offset to the north offshore of New Jersey, but they match up and there is no offset to the south offshore of North Carolina. This demonstrates an inconsistency in depth corrections in Volume 2 of the Coastal Relief Model.

We made a "corrected" version of the NGDC Coastal Relief Model by applying Carter's corrections to each depth point in the 3-second grid covering our study area offshore of New Jersey. We calculated the horizontal distances between the "corrected" NGDC Coastal Relief Model 2500 m isobath and that from the Smith and Sandwell predicted bathymetry grid. The solid line in Fig. 5 shows the histogram of these horizontal distances. The peak is centered on zero, indicating there is no systematic offset between the isobaths. This is because both isobaths follow corrected depths in their underlying grids. For reference, Fig. 5 also shows the horizontal accuracy limits for the 2500 m isobath location as reckoned by Monahan [6] from IHO S-44 standards and the mean slope in the region. Our "corrected" Coastal Relief Model result only strengthens Monahan's earlier conclusion that the satellite isobath location meets his interpretation of horizontal accuracy implied in the IHO S-44 guidelines.

4. SUMMARY

We have shown how well satellite bathymetry can map the 2500 m isobath in two disparate areas- one where the satellite solution incorporated abundant, good control data, the other where the control data were sparse and poor and predictions from satellite gravity dominate. In the former area the satellite isobath very nearly meets the 95% confidence level for bathymetric model depth accuracy set in IHO S-44, and in the latter it meets the requirements 31% of the time. Because Smith and Sandwell constrain the satellite bathymetry solution to agree with acoustic sounding control data wherever such data are available, it is no surprise that their product performs best where detailed ship data are publicly available. In the case where seafloor topography is rough and control data are poor and sparse, the satellite bathymetry field may still perform well enough to be used for reconnaissance purposes, though it will not meet IHO standard S-44.

We investigated the apparent seaward offset between 2500 m isobaths derived from the NGDC Coastal Relief Model [7] and the Smith and Sandwell [5] predicted bathymetry grid offshore of New Jersey, USA, which was reported by Monahan [6]. We determined that this offset is due to the incorporation of uncorrected depths into the NGDC Coastal Relief Model in this vicinity. When an isobath from uncorrected data (the NGDC model) is compared to an isobath from corrected data (satellite bathymetry), there will be an offset. We found that uncorrected depths from R/V Atlantis II legs A121 and A124 were inadvertently incorporated into the NGDC Coastal Relief Model.

This conference paper is a summary of results presented in full detail in a paper published in International Hydrographic Review [11].

5. ACKNOWLEDGMENTS

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