ON THE INFLUENCE OF THE BATHYMETRY ON WAVE PROPAGATION

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Abstract

On the ocean surface, wind-generated waves may travel long distances without losing much of their energy. Wave transformation happens in transitional waters when the water depth becomes smaller than half of the wavelength. In such water depths, typical of continental shelfs, bathymetry is the major factor influencing wave transformation. Around islands, the continental shelf is often very narrow and its influence on wave transformation is not properly understood.

Bathymetries are usually extracted from hydrographic maps published by the hydrographic institutes, available either as analogic or digital versions. Multibeam surveys are also available, but they require patching to build the final bathymetry. Bathymetry can also be found on the web. Differences associated with wave transformation among different bathymetric sources are not well known.

In this paper the authors show the influence of the bathymetry on the wave propagation using a mathematical model that solves the Wave Action Balance Equation using three different bathymetries: a hydrographic chart, a bathymetry web and a multibeam survey. The exercise was performed on the southern coast of the Madeira Island, with a narrow "continental shelf".

The results show that, bathymetry from different sources will induce diverse wave propagation and transformation patterns close to the coast. The design wave height along the -20 mCD contour can differ by -15% up to +55%, depending on the bathymetry. This emphasises the need for a careful choice of the bathymetry when used in engineering applications, especially in narrow continental shelves.

Waves on the offshore of Madeira

Hindcast data was used to characterize the wave climate in the deep waters of Madeira Island. In the absence of the island, the wave characteristics are not expected to change from one point to another in the hindcast grid around the island. The hindcast wave data will be used as the offshore boundary conditions to study wave propagation and transformation towards the coast.

The data include hindcast for the significant wave height, Hs, peak period, Tp, and mean wave direction, Dir, from MetOcean as a time series from 01/01/1979 to 05/03/2022 at 3-hour intervals. The *hindcast* grid resolution is 0.5 deg of longitude and latitude. Five points located in deep water were considered for analysis around Madeira, Figure 1.

Since the southwest coast of Madeira is the study area, the offshore points were selected to identify wave events that might reach that coast. Wave roses were produced, and comparisons were made amongst the wave climates on those locations. Figure 2 shows the wave roses for Hs on the NW point and SW point. The two roses are similar which means that any of the points (NW or SW) might be used to set the offshore boundary conditions for the wave propagation model.

An extremal analysis was done for Hs annual maximum on point NW. The CDF that best fits the sample is the Gumbel distribution with parameters estimated using the ML method. Values of Hs corresponding to 50, and 100 yrs return periods were estimated as 11.3 m and 12.1 m.. The same analysis was done for the hindcast point S, including only waves travelling towards the coast. For the return periods of 50 and 100 yrs the estimation is Hs=7.3m and Hs=7.9m

POINT	LAT (°N)	LON (°E)
NW	33	342,5
N	33	343
NE	33	343,5
SW	32,5	342,5
S	32,5	343

Figure 1. Madeira Island. Hindcast data points from MetOcean: North East - NE , North -N, North West -.NW, South West - SW, and South - S.

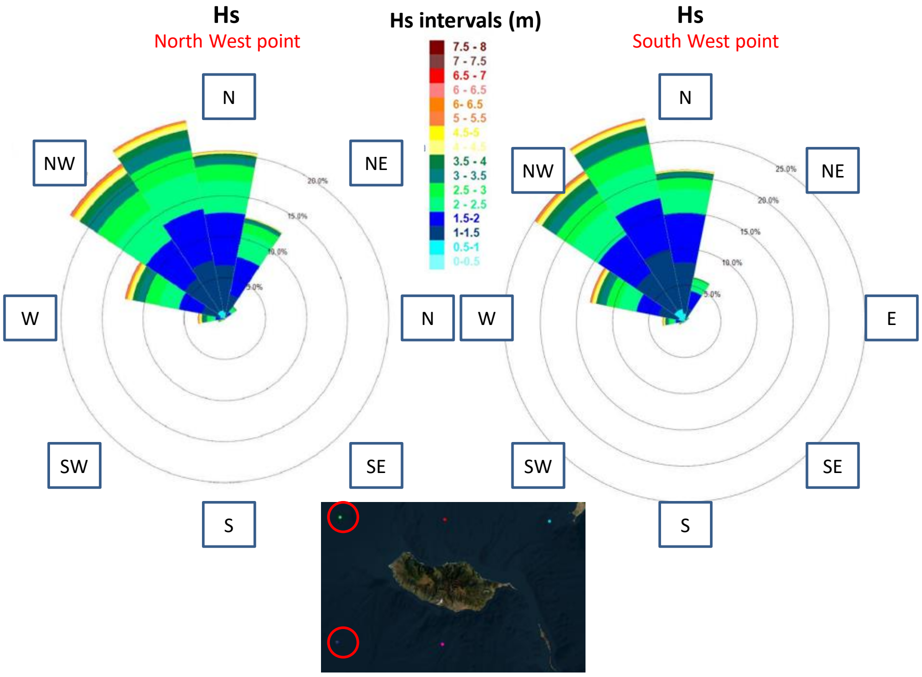

Figure 2. Madeira Island. Wave roses for North West point -.NW and South West – SW. Hindcast wave data from MetOcean. Series from 01/01/1979 to 05/03/2022 at 3-hour intervals

Influence of the bathymetry on the wave propagation and transformation.

The mathematical model STWAVE was used in the wave propagation. This model uses the values of the bathymetry on a computational rectangular grid. In the present situation the cell size has 40 m, set for a balance between accuracy and computational time. The model setup starts with the bathymetry. The bottom morphology is approximated by a TIN (Triangular Irregular Network) of points in the plane with known elevations. This set of points is called a “scatter set”. The density of points on the original scatter set is important in places where the bathymetry exhibits great irregularity. This happens in “continental shelves” that are narrow and new at a geological scale, as found in some islands. On the other hand, the computational domain on those locations is smaller because the deep water is close to the coast.

The question is: how is the original scatter set describing the bathymetry? In this research three sources were used: “Bathymetry Map”, “Bathymetry Survey Scatter Set” and “Bathymetry Web”. For reasons of space only the first two will be presented. The complete exercise may be found in the original work of Venturi, J. (2023).

“Bathymetry Map“ is constructed from a Hydrographic Chart in paper at a scale 1:000000. The chart is first digitized to create an image (bit map), the image is loaded on Surface Modelling System and after it is digitized on screen to create the scatter set. Typically, the operator will digitize points over the isolines of the chart, adding extra points where available. “Bathymetry Survey Scatter Set” is constructed from a detailed multibeam survey, (x,y,z) points between Ponta do Pargo and Lugar de Baixo on a stretch along the coast, merged with information from the previous scatter set.

Figure 3 shows the two bathymetries in 3D. At first glance they look similar, however the Bathymetry Survey Scatter Set is based on a cloud of points and the Bathymetry Map is based on the bathymetric contours present on the navigation map. Even small morphological features of the bottom (mounds) will influence wave propagation.

Figure 4 shows Hs along an arch that follows the 20 m deep contour in front of Calheta and Lugar de Baixo for waves from West for a return period of 100 yrs. The ratio of Hs between Bathymetry Map and Bathymetry Survey Scatter Set in front of Calheta can range from -15% at Distance = 3000 m to +25% at Distance = 450 m. These ratios increase in front of Lugar de Baixo, ranging from -15% at Distance = 2400 m to +55% at Distance = 1400 m. These differences are relevant for coastal engineering projects.

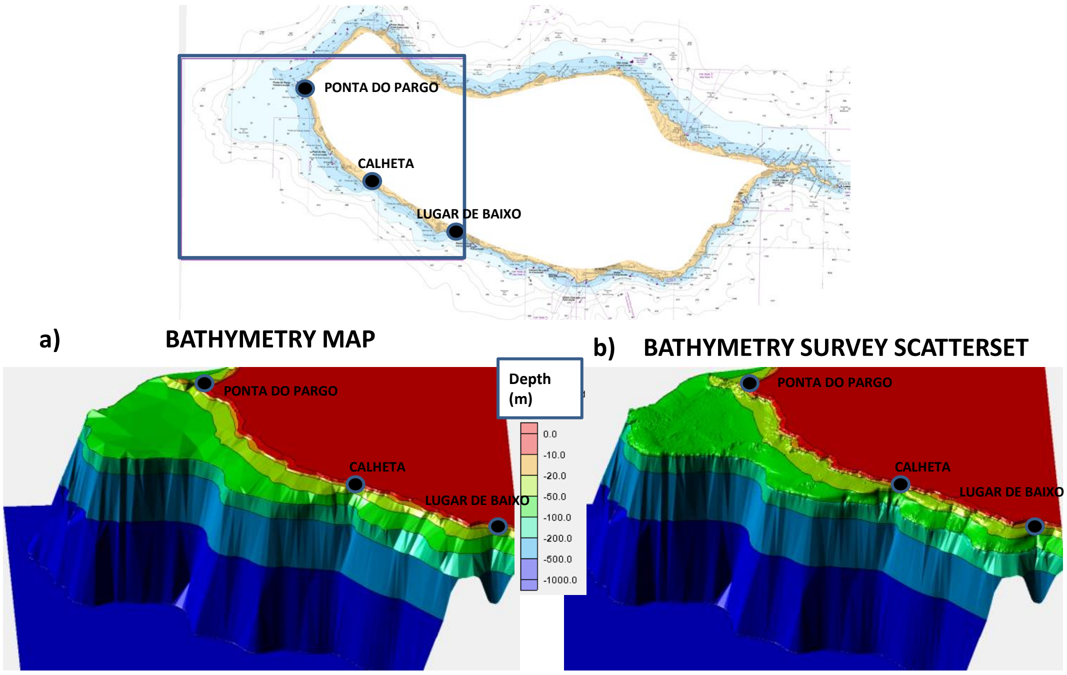

Figure 3. Madeira Island, area from Ponta do Pargo to Lugar de Baixo, Bathymetry imported to a 40 m rectangular grid from: a) “Bathymetry Map” ; b) “Bathymetry Survey Scatter Set”

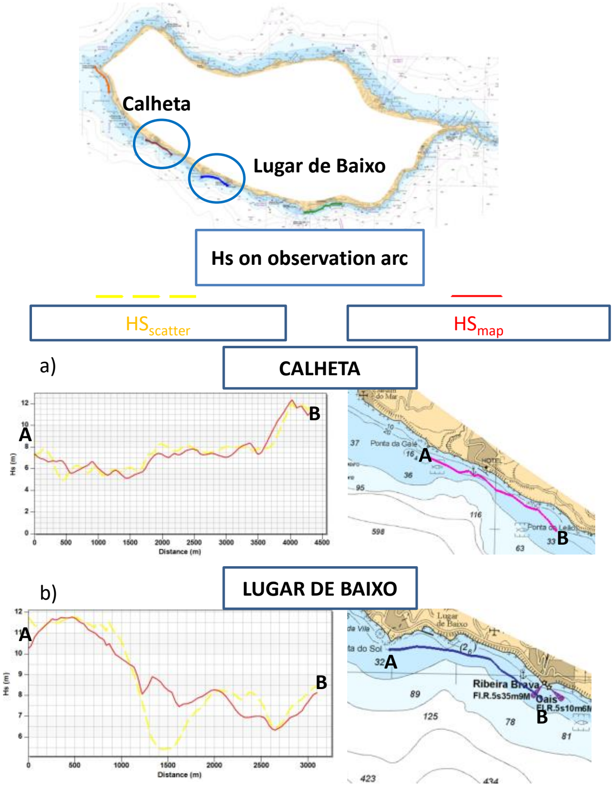

Figure 4. Madeira Island. STWAVE model results for Hs_{map} and $Hs_{scatter}$ along an arch following the 20m contour: a) Calheta; b) Lugar de Baixo. The offshore conditions: Hs =12 m, Tp= 20 s, Dir = 270 °N :

Conclusions

The irregular bathymetry on narrow “continental shelves” has an influence on wave propagation close to the coast. The bathymetry must have enough resolution to describe the sea bottom as a TIN -Triangular Irregular Network, prior to be importation into the computational grid of the wave propagation model. The modelling done with the STWAVE model for the south coast of Madeira Island shows that Hs is strongly influenced by the bathymetry used in the model. In this study, differences of Hs along the 20 mCD contour associated with different bathymetric data range between -15% to 55%.

References and acknowledgments

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