The new wave of bathymetry data - uses and limitations for marine benthic habitat mapping and geomorphology

Margaret Dolan and Vanessa Lucieer

DIVERSE DATA SOURCES
Bathymetric data used for benthic habitat mapping and marine geomorphology can come from a variety of sources, offering information on seabed terrain at multiple data resolutions. Multibeam surveys have largely become the preferred means for acquiring bathymetry data, where funds permit. However, as mapping continues, people are increasingly making use of compiled datasets either by combining several neighbouring multibeam surveys or by including other sources of bathymetry data. The compilation process may be local, national or even regional (e.g. EMODNET Hydrography Portal and global (e.g. GEBCO) and typically the broader the area the more diverse sources of bathymetry have gone into creating the compiled bathymetry product.

MANY APPLICATIONS
These compiled datasets are a fantastic resource, providing ready-gridded bathymetry data, either at single or multiple resolutions. This meets a demand for bathymetry information which can be used for many applications, including benthic habitat mapping. However, compiled data resources, by their very nature, mean that the data user is increasingly distant from the original data source. Even if the quality of the data are assessed and provided, the user no longer has the same contact with the data acquisition and processing pipeline as they did with direct area surveys. This can make it all too easy to ignore issues of data quality and/or uncertainty which are inherent to the use of gridded bathymetry data.

DATA CONFIDENCE
Focusing on the application of such data to geomorphology and benthic habitat mapping we examine those issues that remain particularly important to consider when using bathymetry data from several sources or compiled datasets. Using slope as an example we focus on the implications of data resolution, quality and data analysis scale in deriving terrain variables which are quantitative measures of geomorphic properties relevant to habitat mapping. We also present a practical method for computation of a confidence index for ready-gridded bathymetry data which is based on a Monte-Carlo simulation.

COMPUTING UNCERTAINTY THROUGH TERRAIN ANALYSIS
Computation of terrain variables from bathymetric data has become common practice in marine benthic habitat mapping. Terrain are measures of the seabed which have relevance to the distribution of benthic fauna (or proxies to such variables), and as a means by which to help delineate geomorphic features. Depending on the computation method employed to compute such terrain variables, and the approach taken to deal with different spatial scales, the resulting values can vary quite dramatically. We present a selection of those results obtained by Dolan (2012) who computed slope values across a range of seabed structures of varying size. These results presented a cautionary tale which we hope will encourage more informed use of GIS-calculated terrain variables, especially when considered against a background of uncertainty already inherent in the bathymetry data, which we demonstrate through Monte Carlo Simulation.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
<th>Calculation method used by Dolan (2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Change resolution (spatial) then calculate terrain variable</td>
<td>Slope calculated using ArcGIS Spatial Analyst (3 x 3 cell analysis window)</td>
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<tr>
<td>2</td>
<td>Average depth over n x n windows then calculate the mean bathymetry depth</td>
<td>Focal Statistics tool in ArcGIS Spatial Analyst used to calculate the mean bathymetry depth in n x n analysis windows where n = 9, 21, 49</td>
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<tr>
<td>3</td>
<td>Calculate terrain variable then average result over n x n window</td>
<td>Slope calculated using ArcGIS Spatial Analyst (3 x 3 cell analysis windows) then Focal Statistics tool used to calculate the mean slope within n x n analysis windows where n = 9, 21, 49</td>
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<td>4</td>
<td>Calculate terrain variable at multiple scales using n x n analysis windows</td>
<td>Slope calculated at multiple scales (5 x 5 cell analysis windows) and Monte Carlo simulation method</td>
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<td>5</td>
<td>Multiscale analysis of terrain variables</td>
<td>Multiscale slope calculated for N = 49, i.e. across a series of analysis windows from n = 1 x 1 up to 11 x 11 using Landserf v2.3 software</td>
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Table 1: The five main approaches to obtaining terrain indices at different scales with a summary of the computation performed by Dolan (2012) to illustrate the effects of each approach. An example of approach 1 is shown in Figure 2.

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- Table that shows the multiscale analysis for all types of analysis beyond the 3 x 3 standard analysis window. For clarity we now adopt the term multiscale analysis to refer to analysis at successive analysis windows, whereas the term multiscale analysis refers to analysis in which the resolution is not constant across multiple scales. The standard deviation over all analysis scales considered, n x n refers to the size of the analysis window in marine grid cells where n = 9, 3, etc.

The results of this analysis show that the impact of uncertainty on the bathymetric surface and slope derivative is not equally distributed across the surface and is impacted as a result of many factors (including depth, ship movement, beam forming, acoustic noise etc.). The standard deviation result of the Monte Carlo simulation captures the variance in the bathymetric layer. This uncertainty will affect the spatial derivatives generated from the bathymetric surface. In the slope result this variance is as much as 9.4 degrees! Monte Carlo simulation is useful when you need to make an estimated decision about where there is significant uncertainty. It provides a number of advantages over deterministic analysis. The results can take the form of a probabilistic surface - where the results show not only what could happen, but how likely each outcome is. The results are graphical, it is possible to create spatial maps of different outcomes and their chances of occurrence, this is important for communicating findings to stakeholders. The results show the sensitivity of the results to different levels of uncertainty, and spatially where the impact is greatest.

REFERENCES:
European Marine Observation and Data Network (EMODnet) Hydrography Portal (http://www.emodnet-hydrography.eu/)
General Bathymetric Chart of the Oceans (GEBCO) (http://www.gebco.net)