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

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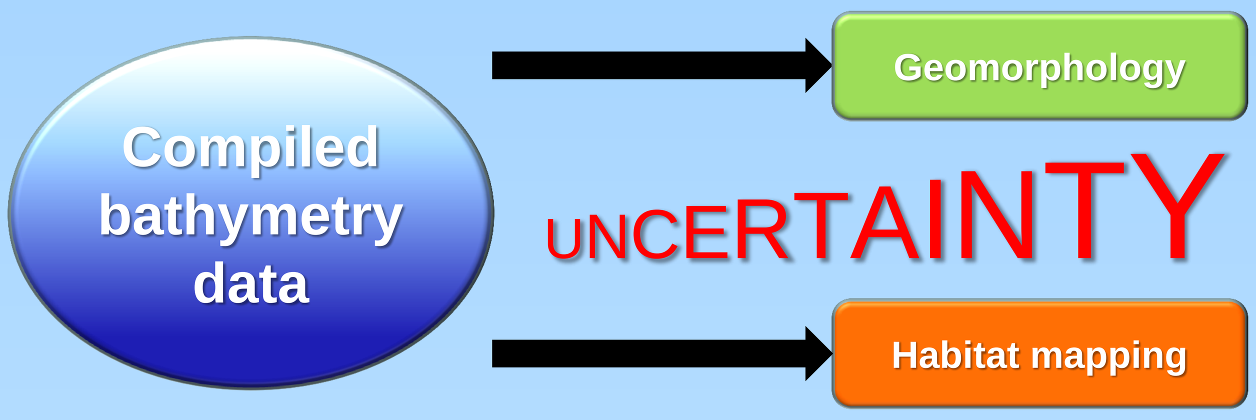
DIVERSE DATA SOURCES

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 discrete 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.



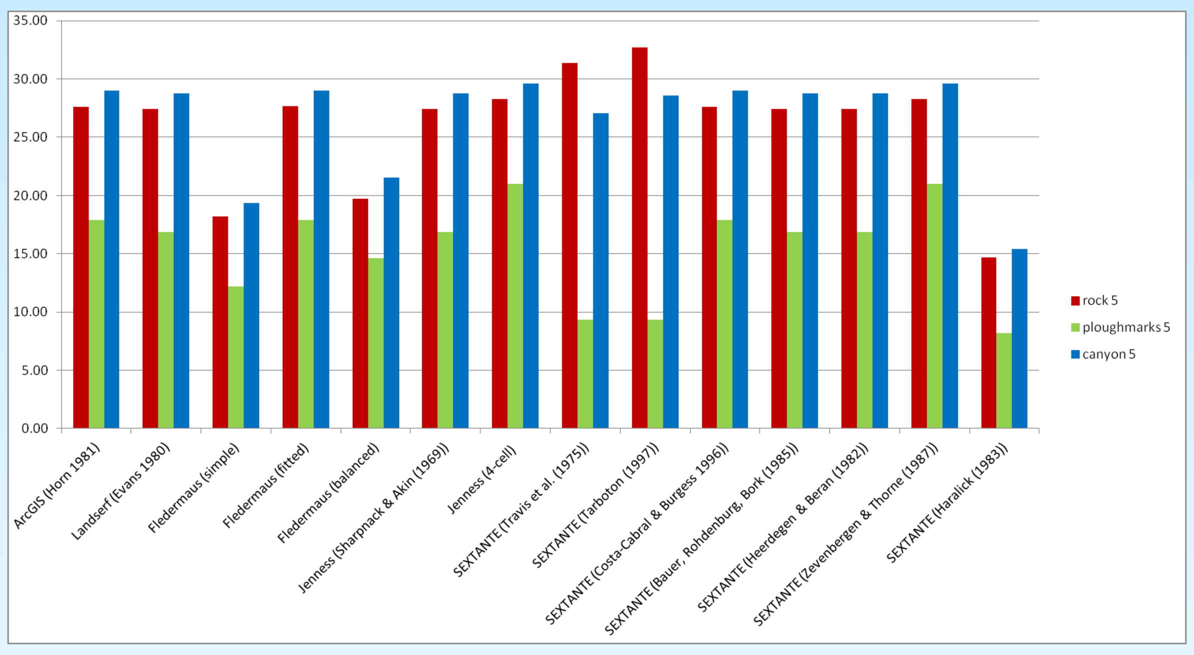
DATA CONFIDENCE

Focussing 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, and 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.

COMPOUNDING UNCERTAINTY THROUGH TERRAIN ANALYSIS

Computation of terrain variables from bathymetry data has become common practice in marine benthic habitat mapping. Terrain analysis can serve both as a way to derive quantitative 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 present a cautionary tale which we hope will encourage more informed use of GIS-calcultated terrain variables, especially when considered against a background of uncertainty already inherent in the bathymetry data, which we demonstrate through Monte Carlo Simulation.

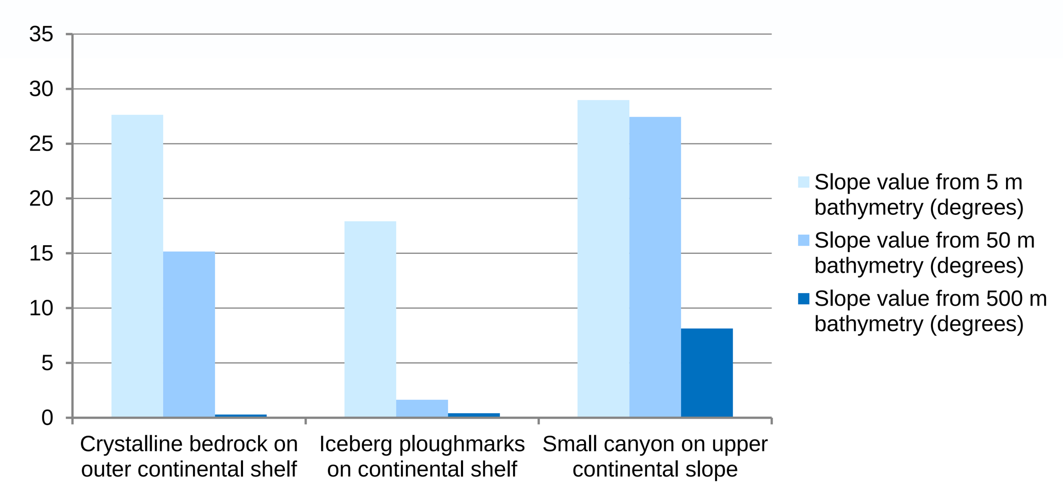
Figure 1: Showing the variation in calculated slope value (degrees) using different GIS-based computation methods. Slope values are presented for three types of terrain – crystalline bedrock, iceberg ploughmarks, and a small canyon. All computations were performed using a 3x3 analysis window on multibeam bathymetry data gridded at 5 m resolution.



Approach	Description	Calculation methods used by Dolan (2012)
1	Change resolution (resampling) then calculate terrain variable	5 m bathymetry data resampled to 50 m, 500 m and then slope calculated using ArcGIS Spatial Analyst (3 x 3 cell analysis window).
2	Average depth over n x n windows then calculate terrain variable	Focal Statistics tool in ArcGIS Spatial Analyst used to calculate the mean bathymetry within *n* x *n* analysis windows where *n* = 9, 21, 49.
3	Calculate terrain variable then average result over *n* x *n* window	Slope calculated using ArcGIS Spatial Analyst (3 x 3 cell analysis window) then Focal Statistics tool used to calculate the mean slope within *n* x *n* analysis windows where *n* = 9, 21, 49
4	Calculate terrain variable at multiple scales using selected *n* x *n* analysis windows	Slopes calculated at multiple n x n analysis windows where *n* = 9, 21, 49 using Landserf v2.3 software.
5	Multiscale analysis* of terrain variable	Multiscale slope calculated for *N* = 49, i.e. across a series of analysis windows from *n* = 3 to 49 using Landserf v2.3 software. Results report mean value of slope across all scales plus standard deviation in slope values across analysis scales.

Table 1: The five main approaches to obtaining terrain indices at different scales with a summary of the computations performed by Dolan (2012) to illustrate the effects of each approach. An example of approach 1 is shown in Figure 2.
* Note that Wilson et al. (2007) used the term multiscale analysis for all types of analysis beyond the 3 x 3 standard analysis window. For clarity we now adopt the term *multiple scale* analysis to refer to analysis at successive analysis window, while reserving the term *multiscale* analysis for analysis which runs concurrently at multiple scales and reports the mean value and standard deviation over all analysis scales considered. *n* x *n* refers to the size of the analysis window in raster grid cells where *n* = 3, 9, etc.

Figure 2: Variation in slope values calculated for three contrasting terrain types from multibeam bathymetry data gridded at 5, 50, and 500 m. Calculations performed in ArcGIS (*n*=3).



MONTE CARLO SIMULATION– a method for visualising uncertainty

In this research we explore the application of a Monte Carlo approach to model error propagation in the bathymetric DTM to understand the robustness of terrain derivatives such as *slope, aspect and curvature* . Monte Carlo simulation performs risk analysis by building models of possible results by substituting a range of values—a probability distribution—for any factor that has inherent uncertainty, in this case depth. It then calculates results over and over, each time using a different set of random values from the probability function. Monte Carlo simulation produces distributions of possible outcome values.

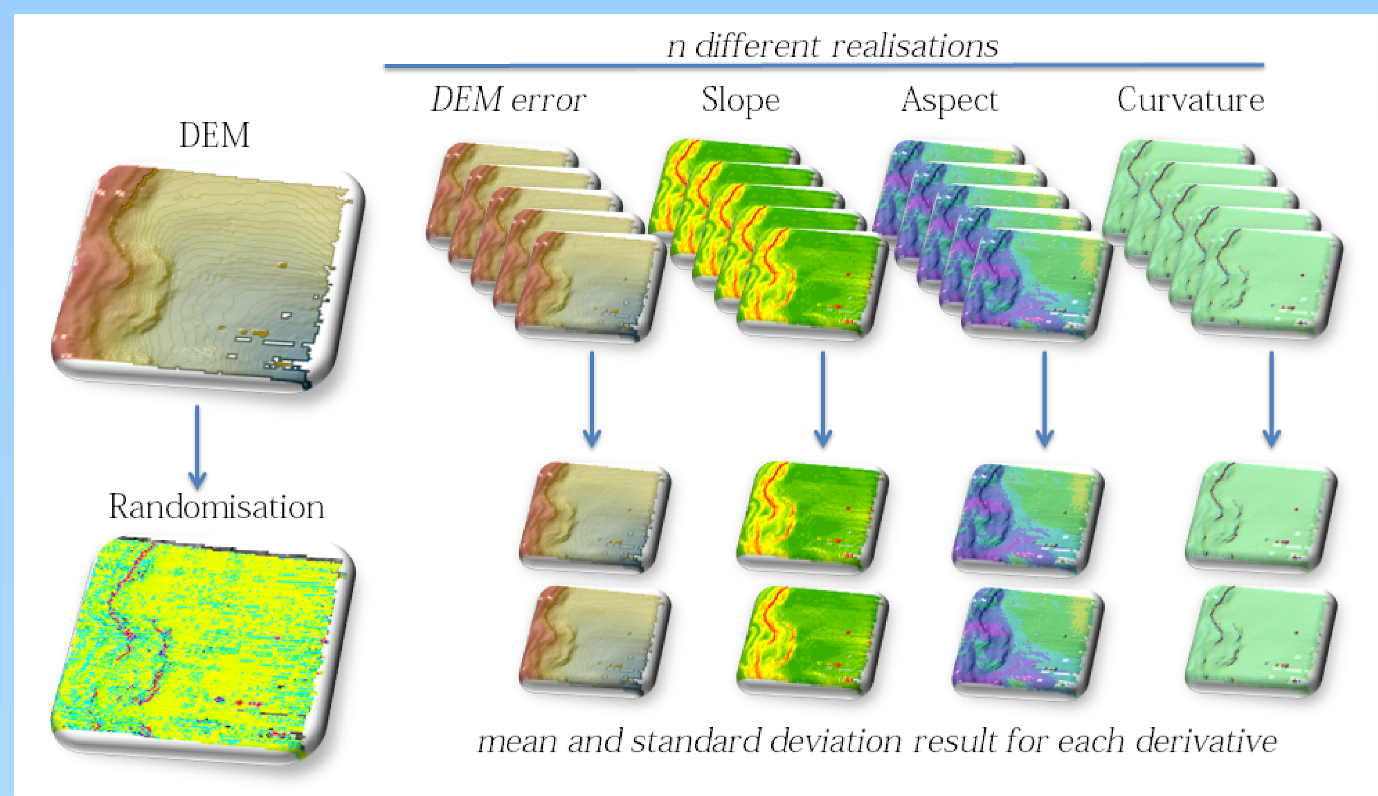


Figure 3: Flowchart of Monte Carlo Simulation.
Randomisation layer used in these results = standard deviation of bathymetry from CARIS.

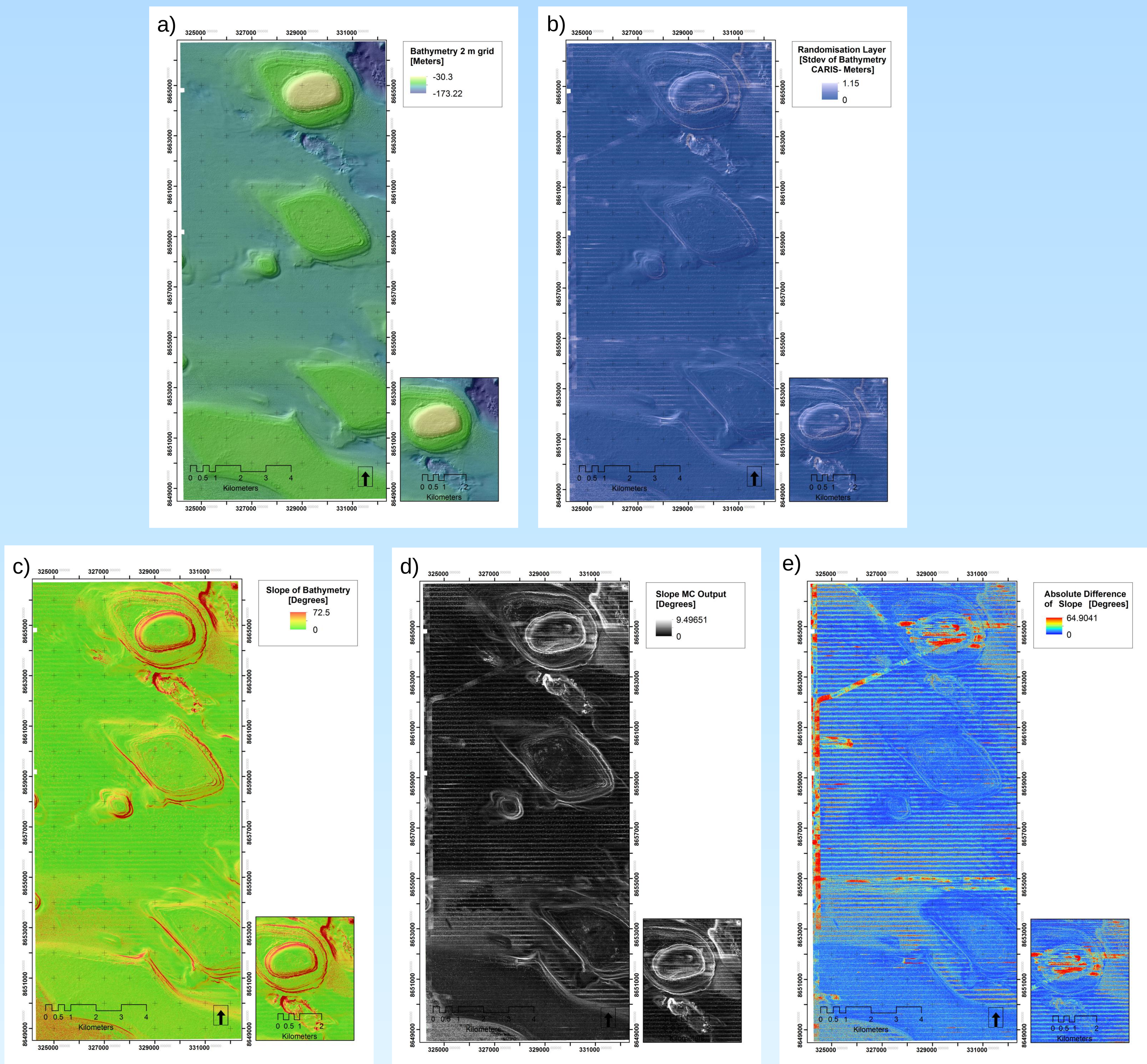


Figure 4: Results of Monte Carlo Simulation. a) DEM input to Monte Carlo simulation model b) Standard deviation of bathymetry used as the randomisation layer input c) Slope calculated from the 2m bathymetric DEM surface d) Monte Carlo simulation result standard deviation of 100 iterations e) Absolute difference map showing the regions of greatest impact of bathymetric uncertainty in the slope derivative [Bathymetric slope – Mean of the Monte Carlo slope calculation] [*stripes in Slope outputs relate to uncertainties across the survey line- as seen in Stdev of bathymetry input].

MONTE CARLO SIMULATION - SUMMARY

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.

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General Bathymetric Chart of the Oceans (GEBCO) (http://www.gebco.net/)

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Wilson et al. 2007. Multi-scale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. *Marine Geodesy* 30 (1-2): 3-35.