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Interactive comment on "Characterising the ocean frontier: A review of marine and coastal geomorphometry" *by* Vincent Lecours et al.

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This article sets out to review efforts to quantify different aspects of shape of the ocean floors. It has ambitious intent, covering data collection, processing and analysis. A purpose of the article is to highlight the growth of the subject (hence justifying its inclusion in a discussion forum such as HESS).

I found the graphs in Figure 1 interesting. However, the terms 'geomorphometry' and 'geomorphometric analysis' are not widely used in marine geology and geophysics, so the shapes of the graphs in Figure 1b, as the authors acknowledge, strongly reflect how these terms have been adopted, rather than representing the rise in practice in this subject area. Researchers began frequently measuring aspects of ocean floor shape from at least the 1960s onwards if not earlier, e.g., the work in characterizing how

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the seabed subsides with crustal age (some of the original articles cited by Parsons and Sclater (1977)). There is a lot of text in this new article devoted to data collection and processing, which is fine (and important), though I thought distracting and left little room for meaningful insight into marine geomorphometry, considering the term in its general sense. The later discussion I therefore found disappointing, focusing on largely practical issues. The authors have already invested significant effort in generating the present version of the article, so they may not wish to invest much further time, though I thought the basic practical steps and data issues (for sonar methods, for example) could be strongly reduced and relevant sources for this information cited, leaving more space for developing insight into how the analysis of bathymetry has evolved.

I would also like to encourage the authors to repeat Figure 1b after attempting to find out how many articles measured shape characteristics from bathymetry in practice. This may take some effort, but the tables presented suggest they have already got part of the way. I have suggested some articles at the end of this review from my own experience. I suspect there are many more, sponsored in part by the US navy (Office of Naval Research). The results would hopefully show how efforts compare with the history of instrument development and number of research vessels. There are at least data on the history of geophysical research cruises to compare against (Wessel & Chandler, 2011) and there may be other information on, for example, the sales of multibeam sonars available from the sonar companies.

As the term "geomorphometry" is not widely used, it may be better to use the title to clarify the meaning for readers not familiar with it (as the aim of the article stated in the conclusions section is to raise awareness). I suggest: "A review of marine geomorphometry, the quantitative study of the shapes of seabed features"

It is of course an author's decision what style to choose to write in. The text to me seems too exaggerated. It is almost in the style of a research grant proposal rather than in the dry style of a serious research article. This is important because the text tends to distract the reader from the facts presented. I recommend Strunk and White (ref below), which may help in making the text more succinct.

Detailed comments The logic in the text needs to be tightened - some examples below, though I have not captured all problem text. Page/line # 1/10 ... the science of quantitatively describing terrains ... (science doesn't do anything strictly speaking, its the humans that do things in using the scientific method) 1/12 ... (GIS) and other software ... 1/15 ... investigate the characterization of -> characterize 1/19 delete "the science and application of" 1/19 ...we learn from experiences in terrestrial geomorphometry. 1/20 This sentence is too vague. The issues need to be spelt out. 1/23 This paragraph is the only description of the content of the article (the preceding text is background). In my opinion, this needs to be more extensive and the preceding text greatly reduced. 2/2 Geomorphological studies have improved ... 2/3 Morphology - and quantitative measures of topography - are considered .. components ... 2/4 ...because the interpretation of the origins of geomorphological features and their ages necessarily follow it/them 2/5 The shapes of terrestrial landscape are important for ... 2/11 Geomorphology also plays a fundamental role beneath sea level. I'm not sure the following sentence is correct - we always collect samples or data within the water column (depends what we define as the surface exactly). 2/14 .. for many subjects (the following list does not contain questions) 2/18 ... can affect the efficacy of model predictions of marine species dispersion.... (delete "of different elements") 2/20 ..that 90% of the oceans are ... 2/23 ... explaining what is meant by "explored". Delete: "The fact is that " 2/25 an estimate of global bathymetry, which revealed .. 2/29 were all identified as requiring -> require 2/29 Delete the sentence "It is therefore .." and instead specify resolution in previous sentence. 3/3 as above, a subject area does not measure, rather humans measure. Later in the sentence, we use the methods of these disciplines. 3/6 Sentence "Methods in ..." includes citations to recent articles - wouldn't this provide better historical context if the text started out with more original articles? Also, what is meant by "Methods" - this seems a bit too vague to me. 3/10 What "differences"? 3/22 I would not say the field is recent, only the use of the term "geomorphometry" is recent.

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4/15. There have been attempts to reconstruct bathymetry from wave refraction, using the effect of water depth on wave celerity. To my knowledge, nobody has analyzed the results in the way considered here, however.

4/23 I wouldn't say the data were used to 'define' the geoid, rather they have been used to derive the marine geoid. The geoid is not 'relative' to sea level, it is sea level in the absence of any ocean currents (dynamic effects). The sea is an equipotential (almost). 4/27 Here 'gravitational field' is mentioned, but previous sentences talk about the geoid. 5/1 I wouldn't say that thick sediments are a problem. Rather, the method relies on using a single density value for the seabed in a given area, but in practice density varies. 5/7-9 This is vague - needs to be more explicit about what the data products contain. The Shuttle radar dataset was collected over land using interferometry, so the other data were needed to fill in marine areas. 5/25 ...in uniformly attenuating water ... 5/30 I would just say that the attenuation rate is obtained by correlating log10(local water depth measurements) with optical amplitude, if that is how it is done. The ground truth measurements don't 'verify' the relationships as such, rather they are used to derive them. 6/13 These methods do not rely on attenuation (please specify)? 6/16 bottom types vary with depth. 6/19 how shallow? 7/1 Please do not use words like 'vector' that have specific meanings in science. The velocity of sound in water is not increased by density (acoustic velocity actually decreases with density if occurring in isolation), rather water has a much higher bulk rigidity and that dominates velocity. 7/7-8 also knowing the speed of sound in the water. 7/13 ...seafloor, water depth can only be measured from the first echo in SSS amplitude data, the remaining parts of the data provide only indirect information on water depth. 7/15 ... by combining data from two receiving ... This is a similar form of bathymetry to that derived using multibeam sonars (e.g., the Kongsberg systems, which use the split beam method do compare phase between pairs of split beams). 7/18 how? This is too vague. This section is missing a couple of methods (unless contained in the cited literature, which is unclear from the text given) - relief of objects from acoustic shadow lengths (which has been used for many years, e.g., in military applications (mine assessments)) and shape-from-shading

(I think illustrated in Blondel and Murton). 7/27 many early systems were not narrow beam. The multibeam sonar is arguably the most important instrument used for marine surveying - it is a shame that it is described in such a limited way here. There is no adequate description of the sounding geometry and no mention of motion sensors and sound velocity issues (although some of these do appear later on). I suggest referring to one of the review articles on these instruments, such as by de Moustier. 8/18 This still doesn't quite say how these systems derive water depth from the data (e.g., time of flight and velocity of light, but time of flight from the laser or through the water (detection of sea surface and seabed)?). 9/7- No system generates truly continuous bathymetry, they all provide samples. Some systems effectively filter the bathymetry by imposing a resolution (e.g., acoustic beam width in the case of multibeams) before sampling. Other systems you might say sub-sample the bathymetry without first filtering, hence 'alias' the bathymetry (widely spaced single beam soundings, for example). 9/26 Also see Smith & Wessel (1990) for interpolation issues. 10/4 Is it the technique that is sensitive to errors or the DBM that is produced using it? 11/6 They are surely not the "principles" of radar altimetry that limit resolution, rather the beam width and noise characteristics of the data? This is too vague. 11/7 not the platform as such, but the distance of the platform from the seabed or sea surface. 11/11 I think why sampling density increases needs to be explained (because of the cycle time of sounding systems limited by the speed of sound in water and beam widths, etc). 11/28 .. and may be amplified in some attributes computed from them. 12/30 This is an obscure sentence. I think what is meant here is that there are no other data to check whether a feature is an artifact or not. 14/5 This is rather trivial and I'm not so sure that grids of bathymetry ought to be negative always (water depth is positive downwards) - a negative depth implies terrain above sea level. 15/29 and 31. I would stick to either 'variability' or 'rugosity' rather than use both terms. 16/1 Is meant here comparing depths with a planar surface fitted to the data? 16/3,4 alternative measures of rugosity that are less affected by gradient. 16/6 between them (what exactly?) 16/11-12 Not in marine geophysics. For example, the subsidence of the seabed with age was first looked at in the 1960s as far as I am aware (references in Parsons and Sclater, 1977). 18/2,3 Is it bathymetry that is influencing the biology or rather a number of other properties vary with water depth (light because of attenuation, waves, etc)? 19/16 What is meant here exactly by scale invariance in terms of statistics and morphology? 20/1 I think references need to be cited for these, e.g., Fox et al or Malinverno for the spectral method. 24/32 I wouldn't say they are more affordable, rather the oil and gas industry has invested an enormous amount (with often dubious success) to acquire these datasets. Academic and government researchers have benefitted from access to these data. 26/27 Figure 1 only shows the uptake of the word 'geomorphometry', not practice. 27/7 If >50 years can be described as infancy, I am an infant!

p 55. Table 2 contains only a selection, so I would make that clear in the table title.

Figure 2 - surely "pre-processing" should occur before interpolating the data onto a grid? Or am I misunderstanding what pre-processing means here (an iterative stage of binning and gathering statistics before filtering the data and forming a final grid)? A better term might be needed.

Figure 3 caption. The last sentence does not really inform us of what is in the figure. Standard deviation is presumably computed within each cell. It is really not clear what is meant by "hypotheses" - I would not use that kind of term here for what I think is meant a working grid of the data. This kind of language is only going to confuse readers.

Figure 4. I understood the GEBCO charts to contain information from the hydrographic agencies that is not freely available. The caption needs to say where these data were taken from (geographically) for the discussion to have much meaning. I suspect the remaining data were not only obtained from altimetry measurements. axis -> direction We don't know the survey direction, ship track etc, so difficult to read the middle panel. Hence, "are mainly caused by the roll motion" - I suspect this is not roll motion exactly, rather a roll motion that is not compensated by the motion sensor used. Strip-

ing can arise because of other errors caused by bubbles passing over transducers in bad weather. Figure 6 is really not very useful, given that the sample set is effectively censored by the limited use of the terms searched.

__________ NC Mitchell University of Manchester, March 2016

Suggested additional articles within the field of geomorphometry (only a small sub-set from my personal experience):

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Geol. 236:189-208 Mitchell, N.C., Stretch, R., Oppenheimer, C., Kay, D., Beier, C., 2012. Cone morphologies associated with shallow marine eruptions: east Pico Island, Azores. Bull. Volcanol. 74, 2289-2300. Shaw, P.R., 1992. Ridge segmentation, faulting and crustal thickness in the Atlantic Ocean. Nature 358, 490-493. Shaw, P.R., Lin, J., 1993. Causes and consequences of variations in faulting style at a Mid-Atlantic Ridge. J. Geophys. Res. 98, 21839-21851. Shaw, P.R., Smith, D.K., 1987. Statistical methods for describing seafloor topography. Geophys. Res. Lett. 14, 1061-1064. Shaw, P.R., Smith, D.K., 1990. Robust description of statistically heterogeneous seafloor topography through its slope distribution. J. Geophys. Res. 95, 8705-8722. Smith, D.K., 1988. Shape analysis of Pacific seamounts. Earth Planet. Sci. Lett. 90, 457-466. Smith, D.K., 1996. Comparison of the shapes and sizes of seafloor volcanoes on Earth and "pancake" domes on Venus. J. Volcanol. Geotherm. Res. 73, 47-64. Smith, D.K., Jordan, T.H., 1988. Seamount statistics in the Pacific Ocean. J. Geophys. Res. 93, 2899-2918.

Other cited references: Blondel, P., Murton, B.J., 1997. Interpretation of sidescan sonar imagery. John Wiley, Chichester. de Moustier, C., 1988. State of the art in swath bathymetry survey systems. Internat. Hydr. Rev., Monaco 65, 25-54. Parsons, B., Sclater, J.G., 1977. An analysis of the variation of ocean floor bathymetry and heat flow with age. J. Geophys. Res. 82, 803-827. Smith, W.H.F., Wessel, P., 1990. Gridding with continuous curvature splines in tension. Geophysics 55, 293-305. Strunk, W., White, E.B., 1972. The elements of style, 2nd Ed. MacMillan Publishing, New York. Wessel P, Chandler MT (2011) The spatial and temporal distribution of marine geophysical surveys. Acta Geophysica 59:55-71

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