

Interactive comment on “How to explain variations in sea cliff erosion rates? Insights from a literature synthesis” by Mélody Prémaillon et al.

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Received and published: 11 May 2018

We are grateful to Larissa Naylor (reviewer 1) for her very positive and insightful comments that helped improve the paper. We agree with her view that the paper was too focused on rocky coast and we add more context and links with shore platform evolution and geomorphic context.

General Comments

This paper presents a much improved, extended and comprehensive database of global coastal cliff erosion which brings together the rapidly expanding number of papers in this field, in a rigorous and comprehensive analysis. Of particular import is that their analysis allows for improved understanding of the impor-

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tance of rock resistance over lithology or climatic parameters as the key factor controlling erosion rates. They found that rock mass properties like joints and fractures are a fundamental control of coastal rock cliff erosion rates. They have come to these conclusions through creating a thorough, rigorous and repeatable database that can be extended through time as more papers are published. It is thus of great scientific importance and serves as a valuable tool which can be built upon. The authors are to be highly commended for their efforts. I really enjoyed reading this manuscript and once a moderate level of corrections are made, this will make a superb and much needed contribution to the literature. The key areas for improving this manuscript lie in six areas:

a) Improving the explanation of your methods and statistical analyses. Why did you use the tests you did? Which aspects did you test statistically?

For the purpose of this paper, we chose to follow a classical exploratory data analysis (EDA) scheme. An EDA is a prerequisite before embarking on more sophisticated methods such as machine learning algorithms. Machine learning classification and prediction is on our agenda and has been partly but we keep these results for a future paper. In the present paper, we tested the relation between a dependant variable (erosion rate) and (supposed) independent variables (external forcings). The relations between forcings was explored through principal component analysis. They appeared to be often strongly correlated. Concerning relation between erosion and continuous values, the non-normal distributions make us choose a non-parametrical approach. Spearman's rank correlation was chosen to evaluate the monotony of the relation.

b) Considering 'dating techniques' as an additional category of how erosion is measured and adding this category into your analysis (eg Figure 5) or explaining where this content best fits in your classification from 1D to 3D studies.

Erosion rates measured with 'dating techniques' were encoded into the database (e.g. Choi et al., 2012; Hurst et al., 2017; Regard et al., 2012) . However we choose

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not to include them in the analysis because they don't represent the same processes and are dependent of eustatic variations. Those studies are generally transect type and would be classified as "1D" techniques.

c) Threshold, non-linear behaviour of coastal rock cliff erosion. Many of the types of cliffs included often display threshold-driven, non-linear behaviour. Whilst I appreciate you needed to standardise your reporting of erosion to mm/yr-1, I also wonder if it is possible to evaluate the degree of stochasticity /non-linearity in the database. For example, it may be that certain rock resistance types are more prone to non-linear, stochastic erosion events or that the temporal frequency between erosion events varies by rock resistance category or another parameter. Finding a clever way including this alongside your mm/yr-1 would improve awareness of the behaviour of these systems for risk managers, hazard scientists and geomorphologists alike.

The question of stochasticity/ non-linearity of erosion is an interesting one. However, it is difficult to approach it with our database. In fact, the major part of our data corresponds to averaged erosion rates over decades, mainly computed through comparison of aerial photographs. Evaluating the non linearity would need a more regular temporal monitoring of cliffs. This kind of approach is only really possible since lidar and SfM methods have become available to examine cliff face erosion. These techniques go back 10 years ago, which is a very short period of time to convince oneself that non-linear behaviours were reliably observed. Then, threshold detection requires frequent surveys for a long duration in order to build rockfall scar inventories. This is a lot of scientific effort to sustain acquisition, consistent processing and funding over time. Only very few scientific teams have been able to do this so far. The most prominent one is probably Nick Rosser's group in Durham, UK with whom we have started to collaborate.

One way to evaluate the non linearity is to explore magnitude/frequency laws. Those laws appear to be power law and have been explored for rockfalls, specially for

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continental cliffs (Barlow et al., 2012; Brunetti et al., 2009; Dussauge et al., 2003; Dussauge-Peisser et al., 2002). One way to evaluate the different stochasticity of rock-fall could be to compare the coefficients of those power laws. However, the coefficients appear to be highly dependant on the observation duration (Dussauge-Peisser et al., 2002), spatial and temporal resolution (Williams et al., 2018).

In short, it is a very insightful question to which we cannot respond in a satisfactory fashion. We nevertheless acknowledge the question of rockfall stochasticity in section 2.4.1 Integration of punctual records, and further discuss it in 4.2.1 Erosion rates, study duration and stochastic behaviour.

d) Wider context. In places, the analysis and discussion of this paper is too narrowly focussed on coastal rock cliff erosion, rather than drawing on evidence from recent shore platform research which displays similar trends around the importance of geological contingency, the importance of rock mass properties and weathering/rock breakdown (bio/chem/phys) processes helping prepare rock coast landforms for erosion. This includes the early conceptual models of cliff erosion by Sunamura as well as recent papers on rocky shore platforms.

We added a last paragraph in discussion 4.2.4 Cliff retreat vs platform evolution and rock coast erosion. We also improved fig. 2 to show the platform more explicitly.

e) Figure 1 and your discussion of it shows the importance of the wider geomorphic context in influencing erosion rates. This does not appear to be taken into consideration in the current version of your model. It would be useful for the authors to explore how this may be possible, so that a global analysis of how submarine to cliff-top coastal landforms vary around the globe and how this affects erosion rates. For example, what proportion of cliffs globally are currently shielded by offshore features such as those in part of Figure 1? Does this vary by rock resistance of the cliffs or are other factors influencing this? I realise that much of this may be beyond the scope of your current paper, but it may be use-

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ful to signpost this in your current paper, perhaps using data from both parts of Figure 1 as an example to illustrate how cliff erosion rates are modified by their wider geomorphic context, and thus are partly geomorphologically controlled.

We agree that taking wider geomorphologic context would add a lot to the model. Currently, with the notable exception of cliff height, we don't take geomorphology into account neither for the cliff nor submarine geomorphology. It would be a big challenge to take it into account for two main reasons. The first one is to find appropriate geomorphologic descriptors that make consensus across the community, or propose our own, which could be regarded as a curiosity. The second challenge is to find available auxiliary data to get those descriptors consistently for all sites.

f) Lastly, it would be useful to signpost the wider significance of your work for coastal hazards scientists, geologists and in the context of changing storminess and sea level rise. It also would be helpful to highlight the potential to extend the database to include shore platform erosion rates. This would help show the wider relevance and import of your work. Ok, this was done in section 4.2.5 Toward a new rocky coast cliff research agenda

Specific Comments (SC), Technical Comments (TC)

Title

SC - You may wish to change the title to better capture the global database /analysis that is, to me, a significant strength of your paper and a very strong addition to the literature.

Thank you for this advice. The title was changed to: "GlobR2C2 (Global Recession Rates of Coastal Cliffs): a global relational database to investigate coastal rocky cliff erosion rates variations."

Abstract

SC - Show the wider relevance of your important work here

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We added a final sentence to allude to several impact of this research:

In this first version, GlobR2C2, with its current encompassing vision, has broad implications. Critical knowledge gaps have come to light and prompt a new coastal rocky shore research agenda if one day we hope to answer such questions as coastal rocky shore response to sea-level rise or to increased storminess.

Introduction:

TC - First sentence needs reference and second sentence needs a direct quotation.

We added reference to Moses and Robinson (2011) for the first sentence.

SP – wave-cut vs shore platform needs a little more discussion

We think the shore platform is already present in our description of the processes leading to cliff erosion. To make it clearer to both reviewer we improved the figure 2 and add some sentences within the introduction to better articulate between the shore platform and rock coast erosion.

TC – para 25 Fig 3 or Fig 5?

The figure reference was removed here.

TC – para 30 cite Viles 2017 Geomorphology

This reference was added

Method:

SC – define your boundary conditions and cite Kennedy who first used this term explicitly in rock coast geomorphology

Changed to

”However, marine and continental forcings conditions are often reported in a very het-

erogeneous fashion.”

SC – systematic search method needs improving, this can either be quite simple as per Figure 1 in Naylor et al. 2010 or following the more detailed PRISMA method (Moher et al. 2015) stemming from medical science.

We did not understand this comment

TC – Merise needs a year, pg. 3 para 25

The reference is Tardieu et al. (1985)

SP – pg 4, Para 10 sentence 1 examples adding would be helpful to aid understanding of your database.

In order to improve clarity, an example was added as the first paragraph of section 2.2 Database design. “As an example the cliff entity contains information about cliff settings. Each cliff description corresponds to a line in the cliff table and contains a unique primary key to identify this line/record. The measure entity contains information about cliff erosion. Cliff and measure are related through cliff erosion.”

TC – pg, 4 para 5, first sentence could be reworked

The wording was deliberately casual but we rephrased it as required in section 2.3.2 Cliff and lithology description

Cliff geology may exhibit a possibly very complex set of lithologic types, contact relationships, inherited tectonic structures and overprinted weathering and authors. . .

SP – section 2.3.1. a) Only English is mentioned here but Spanish and French is mentioned earlier. B) define your search method and strings (perhaps as supplementary material), this will make this part of your work reproducible and improve rigour.

a. Peer reviewed articles are in English and white literature is in English, French

or Spanish b. Our search method was :

- We started from a corpus of articles identified by an early undergrad student's work
- The references cited in this initial set of articles we then explored
- Searches were then launched in bibcnrs (national French research center bibliography engine) with keywords "erosion", "sea", "cliff", "rocky"
- Finally, this was completed with an email call to the coastal community via "coastal list"

This procedure may not be as rigorous and reproducible as Naylor would have wished for. But even if it is an organic growth of knowledge, the corpus of data is now contained and structured in GlobR2C2 and any new reference can be checked against existing records.

SP – 2.3.4 add Hurst et al. 2017 as reference for 1000s of years scale

The citation was added.

SP - 2.3.5 last sentence is unfinished

Sentence was completed: "We discuss this choice in discussion section."

SP – 2.3.9 can you validate your assertion in the last sentence?

The first attempt at global scale has been verified to be satisfactory (sentence before), but we cannot estimate the accuracy of cliff height indicated in the publications (maybe on the order of 10 meters).

SP – 2.4.4 Not all of your core readers will be familiar with the Hoek Brown criterion as it is a geotechnical/engineering criteria. I recommend you add some

background information and some rationale for why this was the best metric to use. Here it would be good to explain why Selby 1980 is less suitable than Hoek Brown.

This is done. We produce a new table (Table 1) and changed the text as: “Hoek and Brown (1997) describe field estimates of rock strength and experimental uniaxial compressive strength. They describe seven grades of rock resistance, from extremely weak to extremely strong. The table describing field estimates, resistance term, compressive strength and example is given in table 1. This table is associated with our Hoek and Brown classification and associated lithologies found in the database.”

Section 3:

SP – 3.3 See comment above about dating methods.

SP – 3.4.1 fewer medium resistance rock studies, perhaps make this as a suggestion for future research in your conclusions, along with the present geographic limitations?

The few records concerning medium resistance rocks is due to several reasons: 1. Medium resistance rocks concern a smaller spectrum of rock types than weak and strong ones (see table 1 for unique lithological names). Weak resistance rock varies from extremely weak (can be peeled with a nail) to weak. Our weak and strong rocks actually aggregate 3 class of Hoek and Brown criterion (extremely/very/ weak, and equivalent for strong) (see table 1). 2. The large majority of erosion rates in hard rock cliff is brought by the systematic survey of CEREMA along the French coastline (265 values over 343, 77%). Despite these justifications, we added a mention of this objective I section 4.2.5 Toward a new rocky coast cliff research agenda

Section 4:

SC- Para 5, page 11 - more detail on this conference, a specific pers comm would help here too.

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We cannot locate to what this comment refers to .

SC- Weathering, jointing, discontinuities – Sunamura included these parameters in his early conceptual models of rock cliff, rock coast and shore platform erosion, showing how they contributed to the reducing the resisting force of rocks. The influence of these on erosion processes and rates has been more recently discussed for rocky shore platforms (See Cruslock et al. 2010, Naylor and Stephenson, 2011, Stephenson and Naylor 2012) and biology (Naylor et al. 2012).

The citations are added.

SC - 4.2.1 para 20, this is where the threshold, non-linearity comment above relates.

SC - 4.2.3 pg 12, para 10, I recommend you refer to Kennedy et al. 2014 here as this volume has no chapter on Africa, which accords with your analysis of rocky cliffs. Doing so would strengthen this point.

The reference to Kennedy et al. 2014 was added.

SP – pg 12, para 20, does this mean it relates only to softer rocks? Please clarify.

The paragraph was modified to be clearer: “Studies also focus on fast eroding coasts because they represent bigger risks and also because of methodological limitation. Indeed, the French CEREMA study brings the majority of erosion values for hard rocks (265 values over 343, 77%) and medium rocks (47 values over 66, 71%). Without this systematic study soft rock represents 75% of measured cliff retreat. This fact biased the analysis by mostly documenting erosion distribution in higher values. The weight of this bias can be approached thanks to the French CEREMA study.”

TC - Pg 12, para 25, I think this is table 2?

The reference was table 2, the text was modified.

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SC - Page 13, para 25 there are many newer rock coast evolution models including consideration of the impacts of climate change (e.g. Limber, Ashton, Trenhaile) that are worth looking at to improve your link to modelling.

We just indicated some examples here. We added a citation to Limber et al. (2014).

Technical comments for the whole the Manuscript: Minor improvements to your English is needed occasionally throughout the manuscript The manuscript has be minutely checked for English. Measure often needs to be measurement

The text was checked to correct this.

Page 13 – inshore could be confused with ‘inshore waves’; I recommend using terrestrial instead.

This amendment was done

Page 20, what does Q83 refer to? To the 83% quantile, modified. Also add a final sentence, or extension to it that shows which rock categories this relates to.

In a few places you talk about rocky coast erosion, your topic is coastal rocky cliff erosion. For clarity about your scope and the contents of your paper, the latter term should be used throughout. Your remark was taken into account and the term coastal rocky cliff was used.

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