Replies to the reviewer's comments on "Analysing the spatial patterns of erosion scars using point process theory at the coastal chalk cliff of Mesnil-Val, (Normandy, Northern France)". (NHESSD, 2, C2384–C2387, 2014)

We would like to thank the anonymous reviewer N°2 for his/her constructive comments. We agree with most of his/her suggestions. In the following we recall the review (in italics) and we reply to each of the comments in turn (in blue). Additions and changes in the manuscript are indicated in blue.

Please note that the indicated page numbers correspond to the manuscript posted on the discussion forum.

Reviewer N°2

The paper addresses important questions regarding the evolution of slope (cliff) failure. It uses a unique set of observations and a suitable statistical approach. It is well written as well.

There are two 'mechanical' points that I think deserve some more discussion:

1. It is not clear (and important to understand and to present) what limits the size of the failure events (from large and small ends). It was observed in the current work that fractures are not significant in limiting scar sizes. Does the host rock characteristic affects the event size in any other way? Maybe resolution of TLS?

On page 6089 in section 5, we highlighted that "Our regular observations of chalk cliff rupture over the last 10 years have shown us that existing fractures do not always limit scars" (lines 6-7). As suggested by the reviewer, the host rock characteristic influence the failure spreading, hence the size of the events. The role of the complex mechanical rheology of the chalk material was proposed as a possible explanation in section 5, lines 7-14: "Rather the contrary, we have observed many times that chalk ruptures propagated through the matrix often ignoring the existing faults and fractures, or only following them to some distance and continuing to rupture seemingly intact matrix further on. The mechanical behaviour of this rock material can be very complex, and in particular characterized by low material cohesion (e.g., Lawrence et al., 2013) and strong sensitivity to chemical and physical nature of pore fluid (hence promoting matrix failure relatively to failure along pre-existing discontinuities)".

On the top of that, we highlight that contrasts in rock materials' properties and the presence of joints/bedding surfaces should also play an important role, more especially the vertical failure spreading could be complexified by the presence of the Lewes Marl layer as discussed on page 6086, lines 20-27. A sentence recalling this aspect was added at the end of section 5. Besides, we recall that a qualitative description of the physical processes is provided in section 2.2, on page 6075.

The influence of the TLS resolution is investigated in details by Dewez et al., 2013 (this is recalled on page 6075, line 14). Point clouds from TLS were interpolated to a 2.5D 5cm x

5cm gridded cliff Digital Surface Model. Erosion scars show up as coherent patches of negative values (potentially very large) amidst a random pattern of positive and negative pixels. Finding the edges of these erosion scars was a challenge. We resolved it by examining the statistical distribution of unstructured positive and negative values, which is due to measurement noise. Thresholded grids were turned into polygon layers in order to extract erosion patch parameters.

Rockfall inventory completeness was assessed based on the approach developed by Stepp (1972) in seismology. In essence, the method assumes that annual event frequency follows a linear trend in log/log space. Completeness fails to occur if the linear trend is broken. In our dataset, events smaller than 10^{-3} m^3 (corresponding to objects larger than 15 x 15 x 5 cm^3) and larger than 103m3 are too rare to reflect completeness and corresponds to the censoring effect described by Stark and Hovius, (2001). Single point position precision at 2-sigma is 1.5cm. Precision of scar depth at 2-sigma is only 1.8 cm. We noticed that the lens-shaped patches are “truncated” meaning that small volumes may be under-estimated. Nonetheless, the influence is expected to be limited regarding our categorisation into “small” (10^{-3} m^3 < volume <10^{-2} m^3) and “large” events (10^{-2} m^3 < volume <10^{1} m^3).

Going in more details (regarding the processes governing the sizes of the events) would be of great interest, because the application of the statistical tools highlighted that the spatial structure of both types of events (small and large) differs: this suggests different underlying physical mechanisms (as discussed in section 5, on page 6087, lines 24 and following). Such a study would require integrating additional controlling factors and explanatory variables like rock mass properties in a similar manner as Le Cossec et al. (2011), fracture network (e.g., Duperret et al., 2004) or wave regime (and energy distribution) along the coastline and engineering works induced disturbances (e.g., Mitchell and Pope, 2004). The described statistical tools can be useful to address such questions. This is indicated in the conclusion on page 6090.

References added

Stark, C. P. and N. Hovius (2001), The characterization of landslide size distributions, Geophys. Res. Lett., 28(6), 1091–1094, doi:10.1029/2000GL008527.

Stepp, J. C. (1972). Analysis of Completeness of the Earthquake Sample in the Puget Sound Area and Its Effect on Statistical Estimates of Earthquake Hazard. Proc. Microzonation Conf. University of Seattle, Washington: Vol. 2, 897-909.

2. Temporal and spatial correlation reflect the failure mechanism, e.g. wave induced notch development at the cliff base followed by migration of the failure upwards to the cliff top (Katz and Mushkin, 2013). Do the spatial and temporal observations presented in the current work correlate with a suggested failure mechanism?”

A line for possible mechanical interpretation was highlighted on page 6086, section 5 (lines 28-29): “Vertically, erosion scars thus belong to two domains. At low elevation, a domain assaulted by waves at pretty much every high tide but with energy modulated by hydrodynamic of which a sharp lithological boundary appears to limit upward scar propagation”. This behaviour is possibly tangled with the presence of mechanical discontinuities: the Lewes Marl (see location of the geological marker unit in Fig. 10) and harder nodular chalk beds (highlighted in section 5, on page 6086, lines 20-27).
“The second domain is above this 15–20m where both projected sea-water has little energy to detach small blocks and mechanical lithological discontinuities are more pervasive. Only continental processes affect the rock face and act evenly on the remainder of the cliff” (page

6087, lines 1-5). Besides, the difference in the spatial distribution of the small and large events was highlighted, which suggest different failure mechanisms. On page 6087, section 5, lines 26-28: "From a spatial distribution perspective, both behaviours cannot be considered equivalent. This distinction suggests that erosion processes and triggering factors differ between small and large scars".

Going into a more refined physical explanation (i.e. clearly identifying the physical process(es) among the numerous ones acting on the cliff) is beyond the scope of the present article. Here, we showed how advanced statistical tools could be used to highlight different spatial structures, hence suggesting different physical behaviours (bottom and top of the cliff, small and large events, winter and summer, etc.). These should be seen as a guide for further in-depth characterisation studies once the (statistical) significance of the observations has been verified. This is underlined in the conclusion (on page 6090, lines 3-11), "Spatial point process statistics is a class of exploratory data analysis techniques helping supporting qualitative geomorphological observations and test their significance. They clearly are only a first step to explore the physical processes underlying coastal cliff erosion. We have formulated a few hypotheses to explain the statistical significance of tendencies outlined by the approach at Mesnil-Val (France). Future studies should account for more controlling factors and explanatory variables like rock mass properties in a similar manner as Le Cossec et al. (2011), fracture network (e.g., Duperret et al., 2004) or wave regime (and energy distribution) along the coastline and engineering works induced disturbances (e.g., Mitchell and Pope, 2004)".

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