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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Rainfall and weather conditions inducing intense landslide activity in northern Spain (Deba, Guipúzcoa)" *by* Victoria Rivas et al.

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Dear referee #2: Thank you very much for your comments.

1) You are right: in the periods 1954-1970, 1970-1983 and 1993-1997 many more landslides have occurred (109, 104 and 223, respectively) and numerous extreme rainfall episodes happened too in those periods, but we have not been able to discriminate the landslides that triggered each rainfall event. [Undetermined situations: periods in which shallow landslides have occurred, but the date is unknown and therefore cannot be attributed to any triggering event]. The dating of these episodes has not been carried out through the location of precipitation episodes that can explain them, but, as explained

in the text on the basis of different information sources: field works, technical reports, regional press reports, research papers, applications for indemnities to insurance companies and personal communication of neighbours. On the other hand, the high number of landslides during the periods mentioned does not necessarily mean that they occurred simultaneously; they could have been temporarily distributed throughout the entire period. Probably, many of those extreme precipitation events produced many landslides simultaneously and could be considered MORLE. On the other hand, the rainfall events of 2002 and 2011 have certainly produced landslides (23 and 18, respectively); they can be considered among the less severe MORLE identified. Figure 3c illustrates quite well this fact.

2) It is true, probably the text isn't properly explained, so we suggest to modify the paragraph as follows: c) Determination of rainfall episodes at each landslide location. From the 22,614 daily rainfall spatial distribution models obtained by interpolation, the daily rainfall was extracted at the precise points where known date landslides were triggered, 688 movements produced by 6 major rainfall episodes. Thus, more than twenty thousand of rainfall daily data for each landslide were obtained (representing the number of days within the period studied at each landslide location). Since the evidences obtained from scientific and press reports post-event (see below, section 4.1) reveal that such rainfall episodes were much shorter in time and much greater in intensity than those obtained automatically, a selective data extraction has been carried out on the basis of those evidences. In fact, automatically computed rainfall episodes show, in general, a few days of intense rainfall, preceded or continued by insignificant amounts of rainfall. In this context, instead of considering the entire rainfall episode, only the period in which the movements were really triggered was used. Then, rainfall episodes that triggered each landslide were extracted, resulting 688 pairs of data (rainfall amount and duration).

3) You are right, there are more extreme rainfall episodes within the undetermined landslide activity periods (undetermined) than MORLEs (particularly, excluding the one

of 2002). Those extreme rainfall episodes (for instance, rain episodes occurred during 1954-1970, 1970-1983 and 1993-1997) surely triggered landslides but at undetermined date (as several extreme rainfall episodes occurred in those periods). The identified episodes (responsible of >50% landslides of the area) occurred in 6 precipitation episodes while during the undetermined periods there have been 2306 precipitation episodes, with unknown consequences from the point of view of landslides. In order to clarify the explanation, we can modify the paragraph as follows: Concerning intensity, figure 3b represents I-D values of all rain episodes (automatically computed for the central point). Regardless of the duration, the intensity of the 6 well-known rain episodes associated with multiple landslides is among the highest of the 3,241 episodes and higher than those of no landslide activity. On the contrary, the rain episodes that coincide with periods of undetermined landslide activity (periods in which landslides have occurred, but the date is unknown and therefore cannot be attributed to any specific rainfall episode; Table 1) are in general lower and likely have produced landslides but of uncertain date of occurrence. In conclusion, although all of them are extreme, the multiple landslide events show important differences, both in the number of movements and in the amount and intensity of rainfall that triggered them; the 2002 event is clearly lower, since it was a quite long event of relatively low daily intensity, not exceeding 39 mm any day. The caption of figure 3b could be clarified as well.

4) Our intention was not to develop an I-D for warning system purposes. We refer to a possible subsequent application after a more robust evaluation (lines 281-284). Again, we agree your comment and accordingly, we suggest to modify the text as follows: The I-D data shows the usual descending trend of the minimum amount of average rainfall intensity needed to initiate the mass movements with increasing rainfall duration. The fitted line has been shifted downward until it low-bound all multiple landslides identified (lower envelope function). The I-D function provided in this study represents the lower limit corresponding to the 6 known major events that have triggered multiple shallow landslides. It refers to extreme conditions that enable the simultaneously occurrence of a large number of slope movements. Of course, there may be other rainfall episodes

(and probably have been) that produce similar landsliding effects but they are uncertain. In this sense, many of the landslides whose date of occurrence is unknown have probably occurred in extreme rain episodes within periods of undetermined activity. The resulting function is I = 7.7D-0.428 (Fig. 4). Therefore, any event exceeding that lower envelope could be considered as a potential trigger of multiple slides.

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