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Solid Earth Discussions

Interactive comment on "Distributed faulting following normal earthquakes: reassessment and updating of scaling relations" *by* Maria Francesca Ferrario and Franz Livio

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Conditional probability of distributed surface rupturing during normal faulting earthquakes Maria Francesca Ferrario1, Franz Livio1 1 Università dell'Insubria, Dipartimento di Scienza e Alta Tecnologia, Como, 22100, Italy

Response to reviewers: We wish to thank the two anonymous reviewers for their thoughtful comments, which helped in improve the quality of the manuscript. Here we provide a point-to-point answer to all the comments raised by reviewer 1.

Anonymous Referee #1 Received and published: 1 February 2021

Here are the comments that I would like the authors to explain for readers with interest of PFDHA. 1. The conditional probability of the distributed rupture 1-1. Why did the authors update only the conditional probability, not distributed fault displacement attenuation relation?

Thanks for the comment. We integrated the Introduction section by adding the following paragraph: According to Youngs et al. (2003), the attenuation function for fault displacement, i.e., the term iii) of the general PFDHA function, can be split into two terms (Fig. 1):

Where k is the position of the site of interest, n is the seismogenic source, D is displacement at the site, d is a given displacement threshold, m is magnitude, r is distance from the principal fault to the site. The first term is the conditional probability that some amount of displacement occurs at site k, i.e., it represents the actual occurrence of distributed faulting (D > 0). The second term is the conditional probability of exceeding a given level of displacement (d). In this paper, we focus exclusively on the first term of Eq. 1; this choice was driven by the fact that surface faulting can be an exclusion criterion for some plants (e.g., nuclear power plants).

1-2. Petersen et al. (2011), who uses the power function, used linear interpolation as mentioned (l. 185-186). On the other hand, Youngs et al. (2003) and Takao et al. (2013), who use the exponential function used same to this paper, do not exclude the near range from the principal fault. Why do the authors need to exclude the range of 0-1km from the principal fault? 1-3. If your conditional probability excludes the distance range of 0-1km from the principal fault, I would like the authors to describe the calculation of the probability in this vicinity as Petersen et al. (2011).

In the first version of the manuscript, we excluded the 0-1 km from the principal fault purely for mathematical reasons. The ratio of conditional probability in the 0-0.5 km and 1-1.5 km is 7:1 and 14:1 for the hanging wall and footwall, respectively. As a consequence, including the near-field in the fitting gives birth to higher misfits in the

far-field. Following the comments by both reviewers, we now fit the data on the entire range in terms of distance. We tested different functional forms, including a piecewise regression (linear in the near field, exponential beyond 1 km), which is an approach similar to the one adopted by Petersen et al. (2011). Goodness of fit were substantially identical when trying different functional forms, while a higher impact is due to variations in the input data (i.e., we slightly modified the L'Aquila 2009 and Stillwater 1954 events, following the comments by Reviewer 2). We thus maintain the functional form originally selected, in agreement with the work of Youngs et al. (2003). We updated the methods section and all the figures in the manuscript and we provide the new fitting coefficients in Table 2.

2. As the authors mentioned (l. 217-220), conditional probability is obtained from the global data set. Is this the reason for the greater probability than that of Youngs et al. (2003)? In other words, is Youngs et al. (2003) used for the US PFDHA and is the conditional probability of this study used for the non-US PFDHA?

Following this input, we tested whether there is a systematic difference between US and non-US earthquakes; this also corresponds to the comparison of events analyzed by Youngs et al. (2003) and the additional events included in our paper. We found no clear difference both in terms of percentage of earthquakes showing distributed faulting vs no faulting for each distance class (Figure 2), nor for the conditional probability of faulting (Figure 3). As we mentioned in the paper, a different behavior between Japan and US ruptures has been identified in the literature (Inoue et al., 2018; Petersen and Chen, 2018; Suzuki and Annaka, 2018); the current research does not show such difference, but it may well be possible that this is due to the limited number of available earthquakes.

Here are the minor comments. 3. Title It is difficult to understand the detail contents from the title. 'normal earthquake' is expressions that is rarely seen for me. Does 'scaling relation' mean a conditional probability?

Following also the comments by Rev. 2, the title has been slightly changed to "Conditional probability of distributed surface rupturing during normal faulting earthquakes"

4. Typo? FDHA -> PFDHA? (l. 63)

Thanks, corrected.

5. Caption of Table 1 22 earthquakes may be 21 earthquakes.

Yes, we corrected our mistake.

5. Eq.1 (l. 112) Please add unit of x.

Done, x is in km.

6. Figure 6(a) Why is the yellow-colored range near the main fault in the figure different between the hanging wall and foot wall sides?

Thanks for spotting this, it was a graphic error. We now have fixed it.

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$$P_{kn}(D > d|m,r) = P_{kn}(Slip|m,r) \times P_{kn}(D > d|m,r,Slip)$$

Fig. 1. equation 1

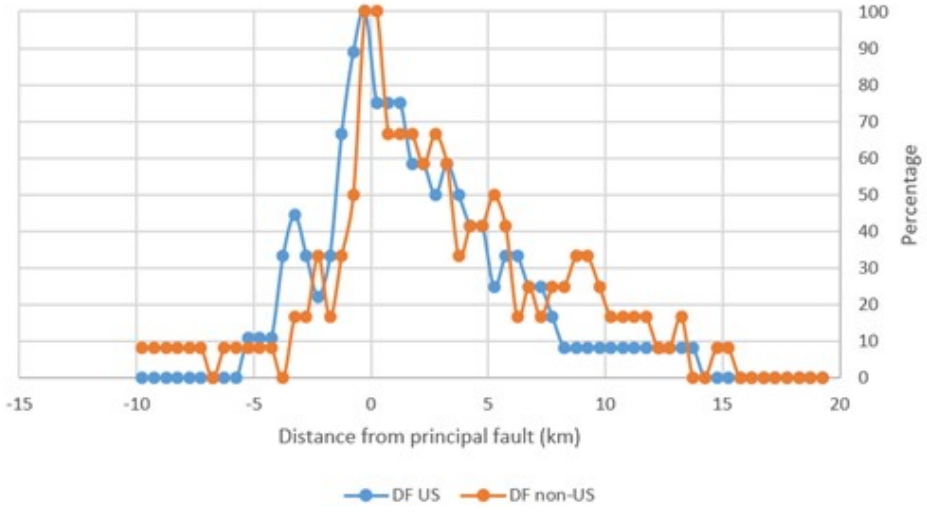

Fig. 2. percentage of earthquakes showing distributed faulting vs no faulting for each distance class, grouped according to geographical region (within and outside US).

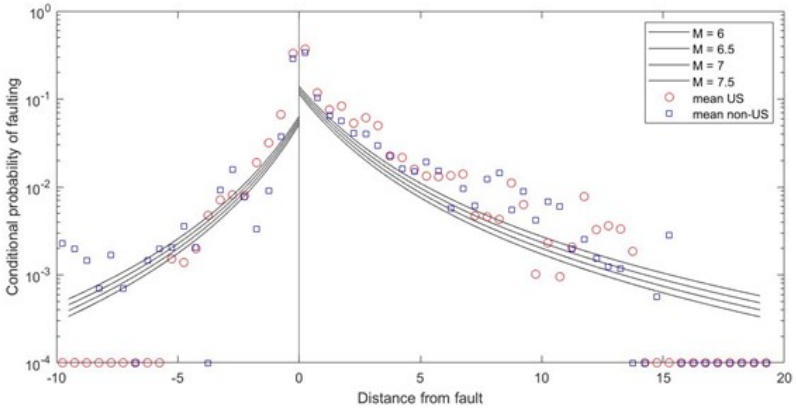

Fig. 3. Conditional probability of faulting for the subset of event in the US and those outside US.