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Nonlinear Processes
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Discussions

Interactive comment on "Utsu aftershock productivity law explained from geometric operations on the permanent static stress field of mainshocks" *by* Arnaud Mignan

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Dear reviewer,

Thank you for your comments on the discussion paper by Mignan (2017). Below is my two-part answer:

1 Regarding the potential role of dynamic stress triggering

The possible contribution of dynamic triggering to aftershock productivity will be discussed in the revised manuscript: It must first be indicated that the debate around the static or dynamic origin of aftershocks has been based on the analysis of the power-law exponent of the spatial density of aftershocks (Felzer and Brodsky, 2006; Lipiello et al., 2009; Marsan and Lengliné, 2010; Richards-Dinger et al., 2010; Shearer, 2012; Gu et al., 2013; Moradpour et al., 2014; van der Elst and Shaw, 2015). However the original claim of a dynamic origin (Felzer and Brodsky, 2006) was later on discredited (Richards-Dinger et al., 2010) and static stress is at present the favoured theory to explain aftershock distribution in space (e.g., Moradpour et al., 2014; van der Elst and Shaw, 2015). I now also show the observed aftershock spatial distribution to support Solid Seismicity. From the SSP, and adding a uniform noise to the regional static stress field, I find a power law exponent q = 1.7, in agreement with the Southern California aftershock data and the literature on static stress (see my reply to reviewer #1 where I show the spatial distribution of aftershocks expected by the SSP and observed; Figs. X1d; X2a). This result will now be emphasized in both abstract and main text. Regarding the triggering of large remote events by dynamic stress (e.g., Fan and Shearer, 2016), those events have never been counted in the productivity law, declustering techniques being based on strong time-space-magnitude correlations. Even if the events shown to be triggered by dynamic stress were considered in the productivity curve, the total number of aftershocks would overshadow their role in the productivity law characteristics. Indeed, Fan and Shearer (2016) suggested the triggering of one or two M7+ aftershocks by dynamic stress per M7+ mainshock. This low number is dwarfed by the 1,000s of aftershocks produced by such mainshocks. What I infer is that static stress is sufficient to explain most of the aftershock observations over a large magnitude range, such as the aftershock spatial distribution and the aftershock productivity.

2 Regarding the geometry of the aftershock solids

The SSP expects the majority of aftershocks to occur in a volume centred on the mainshock rupture, which is clearly the case for the largest mainshocks in Southern California (Fig. 2c). This is also evident when looking at the density of aftershocks as a function of distance from rupture (new Figs. X2a – see reply to review #1). Those are "basic modern observations" that cannot be easily rejected. The result of Ross et al.

(2017) was already mentioned in the text and explained as a case in which the stress would only be partially relieved by the mainshock (line 97). Although other studies have found a deficiency of aftershocks on the main asperity, those works remain anecdotal and so cannot be considered “basic” (one M5.2 event in Ross et al.; Great 2011 Tohoku earthquake in Hasegawa et al., a giant earthquake that might show an anomalous behaviour). Figure 2c and X2a prove that it is not the case for the four major mainshocks in Southern California. Looking at smaller aftershock clusters also show no quiescence at the location of the mainshock. The red area shown in Figure 3 is also in agreement with the theory of static stress transfer (Fig. 2a-d), as described by the seminal paper of King et al. (1994). Finally, Solid Seismicity can still explain those anomalous behaviours. The aftershock deficiency case would mean that the term representative of the red volume is null, hence changing the shape of the productivity law (so the SSP is NOT “too simplified”). Unfortunately, two cases (Ross et al., 2017; Hasegawa et al., 2012) are not enough to populate such altered aftershock productivity dataset and test what modified productivity law would emerge (at least hundreds of cases would be needed). Concerning the mentioned study of van der Elst and Shaw (2015), they do not infer a deficiency of aftershocks on the mainshock fault rupture, only a deficiency in large magnitudes. This is independent of the Solid Seismicity application shown here, where only the total aftershock count is considered. In fact, van der Elst and Shaw (2015) verified that the “aftershock spatial decay is dominated by static stress transfer in the near field (several rupture lengths)” and they found q = 1.77 in California in good agreement with the SSP (see reply to review #1). This goes again against the dynamic stress alternative discussed in point 1.

On the last point (“further clarification regarding the time and spatial window used for aftershock counting for the case of Southern California is needed”), it will be clarified in the revised version of the manuscript that the nearest-neighbour method is used, with only first generation aftershocks considered. This will now be used systematically and figures updated accordingly, where needed.

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