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Interactive comment

Interactive comment on "Mapping the susceptibility of syn-eruptive rain-triggered lahars at Vulcano island (Italy) combining field characterization and numerical modelling" *by* Valérie Baumann et al.

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We thank Prof. Barclay for valuable and constructive comments. All comments have been addressed (see detailed description below):

1) One thing that may particularly help with some of the issues around choices to be made with parametrisation and applicability of the system is via the inclusion of any contemporary accounts of lahar activity from the 1888 eruption. Observations of lahars (or even immediate geomorphological change) are not included in the paper (just the

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Discussion paper

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discussion of existing ‘undisturbed’ lahar deposits left on the island now). Even if the population was evacuated it may be that there are some contemporary accounts which might help to validate some of the choices you have made in terms of analytical focus and also provide something against which to measure your conclusions, and might also help with the interpretation of those deposits you have encountered. Similarly, do you have contemporary accounts of weather patterns following this eruption?

Unfortunately, there is no accurate description of lahars in any of the available chronicles. Lahars clearly occurred as we see them in the deposit and because they occur even at present day (even if in small size given that the original material has almost all gone). Mercalli (1891) do not describe any mud flow, probably because he was not interested in this phenomenon. De Fiore (1922) describes erosion of the 1888-90 deposit which was still loose in 1921 when he observed it. Interesting to notice also that the eruption started on August 3, ie during the dry season, so when lahars are not expected to form. De Fiore 1922 also mentions that he installed a rain station that did not work and also the station in Sicily were not working at that time apparently. But he mentions that the most intense rain typically happens in November, while December is the months with the most frequent rain events. July is the month with the least intense and frequent rain events. All this is in agreement with the recent observations we describe in our paper (Fig. 2). So, it seems that the weather pattern in this region is pretty constant. We have added the information of De Fiore (1922) to the text to clarify this points.

2) Introduction: A distinction between lahar archetypes that is more generally made is that described in Pierson et al., (2014) – which is between ‘primary’ and ‘secondary’ lahars – this more obviously has a similarity in mechanism than the examples you give. I’d suggest you would use this more commonly used typology here and throughout – it might make things less confusing. I realise that you regard these as ‘syn-eruptive’ but really these are secondary lahar generated via syn-eruptive rainfall? (see also lines 0-7 on p. 4).

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Thanks for this comment. However, as we mention in the introduction, we follow the definition of Sulpizio et al. (2006), in agreement with Vallance and Iverson (2015) and Gudmunsson (2015), that syn-eruptive lahars occur during or just after the eruption. The modelled lahars are expected to initiate during the Vulcanian cycle (and therefore syn-eruptive to the cycle) or just after the subplinian eruption. In contrast, recent lahars can be clearly considered as post-eruptive lahars.

3) 2.1 and Figure 1. Eruptive history. To allow an evaluation of the validity of your choice in eruptive scenarios a summary figure of the last 1000 years of activity as a function of eruption size and duration would be useful (in a similar way to how you have synthesised typical rainfall in Figure 2).

We agree with the reviewer and we completely rewrote section 2.1, in order to better describe the stratigraphy of the selected period of activity. We also present the extrapolated recurrence of the eruptive scenarios (new Table 1). To help with this, we also redrew Figure 1 which is now accompanied by a synthetic log of the last 1000 years of activity.

4) 2.3 Recent lahars. This and the description September 2017 lahar (p.10) are a little distracting/confusing. They describe the cumulative morphological change and the nature of flows some 120+ years after the last eruption. It would be more salient here to describe some of the observations of any laharic activity or immediate morphological changes following the 1888 eruption, as mentioned above. A critical feature here of the eruption is the extent to which 30cm of deposit is representative of different eruptive phases. If the triggering mechanism is landsliding, then different eruptive stages might supply significant mechanical discontinuity.

We agree with this comment. This part has been moved to supplementary material.

5) Section 3.3 – would be easier to evaluate the 'likelihood' of the scenarios used here with a easier to read eruptive history than currently provided in 2.1

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Following the reviewer's comment and our strategy used for comment #3, we insert a table (Table 1) in which we show the number of events and the recurrence time for each type of activity.

6) 3.4 TRIGRS model: : :. This would be easier to follow to the uninitiated reader if the content of paras 2 and 3 was earlier than paragraph one.

We have restructured this section following this comment

7) Section 4,3 modelling. I was not sure of the justification for only one rainfall scenario here.

We have strengthened the explanation of the use of one rainfall scenario (section 4.3). In fact, the selected scenario (heavy-torrential precipitation) represents the most intense precipitation scenario based on available data and is used to investigate the maximum unstable tephra volume. We also note that the parametrization analysis was carried out using two rainfall scenarios in order to investigate the effect of variable rainfall (see Figs 11 and 12 and Table 6).

8) It was also not clear to me the extent to which you had evaluated the influence of deposits from differing eruptive phases (discontinuities in deposits mechanical characteristics). You do discuss in detail the influence of a fine-grained layer on the infiltration (and thus likelihood of instability controlled lahar initiation) but there are more insights available here from the experimental set up of Jones et al., (2017) – this would point to the influence of antecedent rainfall (in generating armouring conditions for subsequent intense rainfall too) – to go with the observational record from other lahar episodes. This would suggest that the overland runoff via Hortonian flow may be significant even immediately following an eruption. This could be compared for example to observed rainfall patterns which then may help assess the likelihood of the failure mechanism you explore (whether the possibility of both means lahars are even more likely). I think the nature of this analysis such that a summary diagram, considering the interacting dimensions of tephra thickenss, antecedent and contemporaneous rainfall and hydraulic

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conductivity (as a function of grainsize, porosity and saturation) may be more important in ‘suggesting windows’ of eruptive behaviour and rainfall where lahar generation may become a significant hazard. The conclusions drawn may then be more robust as given all the caveats and unknowns I am not sure the thresholds and % you present here are fully defensible.

In this work we did not consider the influence of discontinuities in deposit mechanical characteristics because this cannot be described in TRIGRS. However, PAL D deposits are massive and the thickness of individual layers for the 1888-90 deposit is very small (mostly < 1 cm) and, therefore, we assume that they are also massive. We added the rainfall simulation experimental results from Jones et al. 2017 on fine grained and coarse-grained tephra fallout deposits in section 5.1. However, our outcomes cannot be directly compared with the outcomes of Jones et al. (2017) because, unfortunately, hydraulic conductivity was not measured in this experiments and antecedent rain could not be investigated with TRIGRS. Regarding the armouring conditions, we have not observed any of this even at present days. This is also in agreement with the observations of De Fiore 1922. We consider then that this has a negligible effect on lahar triggering for 1888-90 and Pal D deposit. Nonetheless, we have added a discussion on this in section 5.1. Finally, we have added a summary table (Table 6) to better describe the outcomes of Fig 11 and 12 and simplified the description of this part in the main text.

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