Interactive comment on "Long-term volcanic hazard assessment on El Hierro (Canary Islands)" by L. Becerril et al.

J. Lindsay (Referee)

General comments

1. The use of "susceptibility"map requires further explanation as this is not a common name for maps in volcanology. An explanation of what information was used to determine the zones on the susceptibility map would be helpful; it would also be interesting to see some structures on the susceptibility map, such as faults and rift axes. I acknowledge that the authors do cite Becerril et al. (2013) for this information, but at least a brief explanation should be presented here.

The term "susceptibility" was introduced by Felpeto et al. (2007), that means spatial probability to host new future eruptions. These authors followed the criteria used in other geological risks such as landslides, rockfalls, where the same term "susceptibility" is used. Since this work the term has been used widely by other authors in the volcanic field. See: Cappello et al., 2009; Martí and Felpeto., 2010; Cappello et al., 2011; Vicari et al., 2011; Cappello et al., 2012; Alcorn et al., 2013; Bartolini et al., 2013; Becerril et al., 2013.

We consider that a figure with structures on the susceptibility map is not necessary for this work due to it is included in the work of Becerril et al., 2013. Nevertheless a brief explanation of what information was used to construct the susceptibility map has been included in the text (section 3.2 Where: Spatial analysis).

2. The Malpaso Member adds interesting complexity to the hazard analysis, and is appropriately addressed in the body text, but could be mentioned again the discussion's reference to the completeness of the catalogue of eruptions on El Hierro.

We have included in the discussion section a brief mention about Malpaso Member.

3. Some potential questions that could be addressed regard the temporal analysis dataset and the visual complexity of the resulting qualitative map. The authors use the historical dataset for the whole of the Canary Islands. What are the implications of this choice?

We have based the study of temporal probability on 25 eruptions documented from the last 158 ka on El Hierro. 14 more eruptions from historical dataset of the whole Canary Islands are taken into account in our temporal analysis in order to assign data weights for each node considering similar eruptive characteristics in the whole Islands. This choice reinforces the results obtained in the Event Tree.

The qualitative map is very complex with many small discrete hazard zones – how would this affect how the map is used in emergency management?

The small discrete zones are the result of the hazards overlapping. We have distinguished from very low hazard to high hazard.

This map could be useful to define "Red Zone" (Ricci et al., 2013) which is the area exposed to maximum expected hazard from overlapped scenarios. For example, this map could be helpful to determine which roads could be more affected and then to take decisions over which are the useful roads in case of evacuation.

Specific comments

1. In the authors' addresses – should Becerril's address be "Volcanology Group" rather than "Group of Volcanology"?

You are right, maybe is more correct Volcanology Group, but the affiliation in our webpage is Group of Volcanology of Barcelona. http://www.gvb-csic.es/GVB_english/, therefore we wrote it according to the webpage.

2. Abstract line 2: "To ensure qualitative results" Is that really what you want to say??? Should 'qualitative' be replaced with 'robust'?

We wanted to say quality. It has been replaced.

3. Abstract Line 2: Consider changing "territorial planning" to "land-use planning"

Done

4. Abstract Line 12: The sentence starting: "We analyse the past eruptive activity. . .. . ." is a bit awkward. Maybe change to: "We analyze the past eruptive activity to determine the spatial and temporal probability and likely style (i.e. the where, when and how) of a future eruption on the island".

Changed

5. Abstract line 17: "..the first qualitative volcanic hazard map". Is "qualitative" really what you mean? Do you mean "the first qualitative integrated volcanic hazard map"?. What exactly do you mean here? Do you mean an "all volcanic hazards" or "integrated scenario-based all-volcanic-hazards" map? What does "total qualitative" mean? This is not a commonly used term. Might be good to explain what you mean.

We have completed the sentence accordingly:

"The end result through the combination of the most probable scenarios (lava flows, pyroclastic density currents and ash fall) is the first total qualitative integrated volcanic hazard map of the island"

6. Introduction line 20: "preventative" is spelled wrong. Not only that – it is probably the wrong word choice here. I suggest "mitigative" instead of "preventative".

Replaced

7. Introduction line 21: add comma after "risk" and "analysis", and change "analysis" to "analyses".

Changed

8. Introduction line 23: Territorial planning: consider changing to "land-use planning", and insert an "and" before "emergency management, and then delete the "etc" at the end of the sentence.

Changed

9. Page 1801 line 11: "consists of", not "consists in".

Correted

10. Page 1801 line 12: By "further" do you mean "future?"

Yes, we wanted to say future; it has been changed.

11. Page 1801 line 14: What do you mean by "structural data"? You need to expand here. Structural data can mean different things to different readers, (fault and folds vs tectonic setting and everything in between). It would be good to expand on what you mean. Surely this must include things like the underlying geology, zones of weakness in the crust, depth of melting etc? Locus of past events? Be more specific.

We have included here and in other parts of the text information related to structural data.

12. Page 1801 line 23: ". . ..some authors use statistical methods. . ..." What do others use? Do you mean "most authors use. . ."?

We have included new information and references in the text to clarify this issue:

"In this regard, some authors use probabilistic statistical methods based on the Bayesian event-tree for long-term volcanic hazard assessment (Newhall and Hoblitt, 2002; Marzocchi et al., 2008; Sobradelo et al., 2010) while some others use a deterministic approach (Voight and Cornelius, 1991; Kilburn, 2003; see also Hill et al., 2001)."

13. Page 1802 line 8: This list of volcanic hazard studies directly contradicts what you said in the abstract, i.e. that no systematic hazard assessment has ever been carried out for the Canary islands.

Studies carried out in Canary Islands have been focused on the analysis of only one component of the volcanic hazard, that is for example, some of them only have calculated the temporal probability (Araña et al., 2000; Sobradelo et al., 2011), others have studied the spatial probability (Martí and Felpeto, 2010; Becerril et al., 2013) but none of them analyzed systematically the hazard. We meant these studies do not integrate the how, where and when to determine a complete analisys of volcanic hazard.

14. Page 1803 line 7: "Atlas"??????

Atlas Mountains

15. Page 1803 line 14: After introducing the islands refer to Fig 1.

Done

16. Page 1803 line 14-15: maybe change to: ". . .historical eruptive activity has produced mafic eruptions ranging in intensity from Hawaiian to violent strombolian, and. . .."

Changed

17. Page 1803 line 18: State what island the Timanfaya eruption occurred on. ***"****Lanzarote"* has been written to clarify it and also we have drawn the eruption extension in Figure 1.

18. Page 1803 line 20: Maybe change "extruded" to "erupted"

Changed

19. Page 1803 line 22: just confirming – all historical eruptions at Teide and surrounds have been monogenetic?

Yes, all historical eruptions at Tenerife, and also those close to Teide-Pico Viejo complex have been monogenetic.

20. Page 1804 line 4 change "emerged" to "emergent"

Changed

21. Page 1804 line 15: give age of the Tanganasoga eruption

There is no a precise dating age for Tanganasoga Volcano, but geomorphological criteria allow us to constrain its age (at most 20 ka) following the criteria establish by Carracedo et al. (2001). Lavas forming eroded coastal cliffs were emitted before and during the last glacial maximum (more than 20 ka ago; Fig. 1), while eruptions that fossilize the mentioned cliffs or generate coastal lava platforms, as the case of Tanganasoga volcano, occurred after this date.

22. Page 1805 line 1: What do you mean by structural data? Be more specific.

We have included information related to structural data.

23. Page 1805 line 7: Name the "three parts", it is unclear what you mean.

These three parts are referred to the spatial and temporal probability analyses, and the development of the scenarios. We have specified them into the text.

24. Page 1805 Characterisation of the eruptions. Make sure the eruption record is clearly presented (for example, make sure you refer to Table 1).

We are not really sure about what you mean, but we have described how the eruptions have been for the last 158 ka. We have refer the eruptions included in Table 1, that are those for which geochronological data exist and that are consistent with the field relative stratigraphy established in this study.

25. Page 1805 line 15: change to: "Some felsic components of dikes and lava flows associated with. . .. . ." or just: "Some felsic dikes and lava flows. . .."

Done

26. Page 1805 line 19: Give age of El Golfo, and delete "and" after "El Golfo".

This information has been included.

27. Page 1805 line 21: This sentence doesn't make sense. Do you mean: "Eruptions typically occur from fissures, and produce proximal fallout, ballistic ejecta and lava flows" ???

Yes, this is just what we meant. We have changed the sentence as you suggest.

28. Page 1805 line 24: "but only generate secondary products when compared to other deposits" doesn't make sense.

We have deleted the unclear sentence as it is unnecessary.

29. Page 1806 line 18: Explain in more detail what you mean by "susceptibility maps".

We have written a definition of "susceptibility map" in the Introduction section. A brief explanation has also been included in the section 3.2 Where: Spatial analysis.

30. Page 1806 line 22: Change "elaborated" to "presented" or "developed" Changed

31. Page 1807 line 4: How were susceptibility values derived? What do the 5 sectors mean?

Susceptibility values were derived from the map developed by Becerril et al., 2013. Regarding the sectors defined, firstly we differentiate the subaereal and the submarine area taking into account differences in the expected hazards (submarine hardly will affect subaereal zones). After that, the emergent part of the island has been subdivided according to areas with different structural controls (different strike of the volcano-structures as dykes and fissures), different topographical constrains (Zones 1, 3 and 4 represent rift areas while zone 2 is an embayment), different susceptibility values according to the map developed by Becerril et al., 2013.

This explanation has been added to the text for better understanding.

32. Page 1807 line 10: Change "field revision" to "field work".

Changed

33. Page 1807 lines 17-18: It is a little confusing to say you used the whole data set from the Canary Islands for the historical period because not all of the eruptions that have occurred in this period have been identified or dated. Surely this part of the record for El Hierro would be the best documented? If not – explain why. Also – explain clearly what the implications are of using the data set of historical eruptions from the whole of the Canary Islands. Surely by applying this to temporal recurrence at El Hierro the rate will be higher than it actually is? I think this needs more explaining.

Text added for further clarification.

34. Page 1807 line 23: Perhaps provide some more detail on the seismic unrest episode. In fact, somewhere there should be a more detailed explanation about both historical unrest episodes on the island.

We have included a brief description of both seismic unrests at the end of the section: Node 4.

35. Page 1810 line 12, Again – how were these 5 zones established? "based on structural susceptibility" is very vague. Please give more detail.

We have included some more explanation in the text (section 3.2) as we have detailed in the comment 31.

36. Page 1813 Node 8 extent: Explain in more detail how this was determined. Was each hazard considered separately?

The following sentences have been included in the text: *"Extents of scenarios were determined from the study of lava, PDC, ballistic and fallout deposits by field work. We considered small distances for those short lava flows that reach up to 5 km, medium distances (5-15 km) refer to PDC, ballistics and lava flows that reach the sea, and large extent include mainly fall out deposits that can expand more than 15 km*".

37. Page 1813 line 19: Do you mean "THE" episode of seismic unrest? (give year)
Year has been given in the text.

38. Page 1815 line 26: Change "deposited" to "exposed".

Changed

39. Page 1817 Total hazard map: How were the different hazards combined to generate the total hazard map? I think more detail is needed to explain this. Note that this is an approach similar to that taken by Lindsay et al (2005) for the "integrated hazard maps" in the Volcanic Hazard Atlas of the Lesser Antilles.

More information has been added to the text for better explanation about this topic.

40. Page 1818 line 8: rewrite as: "In Fig 7a the most likely scenarios. ...are presented together"

Rewritten

41. Page 1818 line 12: This sentence doesn't really make sense, given that "hazard" incorporates a probability of occurrence. Maybe change the beginning to "hazard intensities"

Changed

42. Page 1819 line 10: Give some examples and reference the source of your information regarding "unnecessary over-protective decisions".

We have included a reference where this information has been exposed, but it is still under review: Rosa Sobradelo, Joan Martí, Christopher Kilburn, Carmen López. Probabilistic approach to decision making under uncertainty during volcanic crises Natural Hazards (submitted).

43. In the discussion perhaps mention how the approach taken here differs from other approaches, e.g. BET-VH.

At the end of the Discussion and Conclusions section a brief comparition between HASSET and BET_VH tools have been included.

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44. Figure 1 caption, provide more detail, e.g.: Geological map of the island of El Hierro, the southwestern most island in the Canary island archipelago (see inserts). LP =, LG = etc.

Done

45. Figure 2 caption. Susceptibility to WHAT?? Explain.

More information has been provided in the caption.

46. Figure 3 caption. What do the zones refer to?? How were they defined? Describe in the caption.

A brief description has been written in the caption.

47. Figure 4 caption. Provide more detail! Lava flows from which vents? What do the colours really mean?? Why is the scale a log scale?

VORIS 2.0.1 results for lava flows are given by default as the logarithm of probability of each cell to be invaded by lava. This is because of probability values are so small and they vary in several magnitude orders, for that they are represented as log scale to facilitate its display. See results in: Felpeto et al. (2007) and Martí et al.(2012).

48. Figure 5 caption: What is a Heim coefficient? Not explained here or in the text. What do you mean by "coverage area"??

In order to be coherent with the text explanation, we have changed Heim coefficient by that is explained in the text.

49. Figure 6 caption. What type of scenarios? Using what model? Expand the caption.

We have expanded the caption.

50. Figure 7: explain how the hazards were combined to form the qualitative hazard map. How many hazards superimpose in each zone?

The caption has been expanded and also more information has been provided in the Total Hazard Map section.