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Interactive comment on "Hydrological control of large hurricane-induced lahars: evidences from rainfall, seismic and video monitoring" *by* Lucia Capra et al.

Lucia Capra et al.

lcapra@geociencias.unam.mx

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Responses to V. Manville.

We would like to thank the reviewer for the comments and constructive suggestions made to improve the present work. Please find below the reviewer's comment and authors' replies to these comments.

Title. The reviewer suggests to mention rainfall-runoff simulation into the title. -We agree and we modified it as follow: "Hydrological control of large hurricane-induced lahars: evidences from rainfall-runoff modellin, seismic and video monitoring"

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1(line 31). How do you define lahar size? By peak discharge, and if so where? Or by peak seismic amplitude by using this as a proxy for lahar volumetric discharge, even though the seismic energy output of a lahar is a function of many factors including volumetric discharge, sediment concentration and sediment grain-size distribution.

R1: Yes, we used the amplitude as a proxy for lahar volumetric discharge. On previous published works at Volcán de Colima (Vazquez et al., 2016), the size of lahars has been classified based on their seismic response (amplitude, validated with image data) and duration. With available images, the maximum pick discharge was calculated and assigned to the maximum amplitude recorded form the seismic station. We agree that it is not always possible to correlate the amplitude of the seismic signal with the flow depth, but based on real time data gathered at Colima, there is a quite good correlation for those large events (See. Fig. 5 Vazquez et al., 2016). The figure below extracted from Vazquez et al., 2016, clearly point to a correlation between lahar amplitude and flow discharge.

To better state this concept we slightly change the text at line # 183 as follow:

In particular, for lahars at Volcán de Colima a correlation between the maximum peaks in amplitude and the maximum peaks in flow discharge was found (Fig. 5 in Vázquez et al., 2016). Fluctuation in seismic energy along the vertical component reflects variation in flow discharge.

2 (line 37). This sentence is unclear, there appear to be some key words missing. Some kind of couple

R2: Here we refer that based on rainfall data of Manuel and Patricia hurricanes, which show a very similar behavior, a “synthetic” rainfall curve has been designed (in accumulated percentage). If the amount of rain can be estimated prior to an event, this curve could be used to run a rainfall-runoff simulation to try to have a possible forecast. The sentence was modified as it:

A theoretical rainfall distribution curve was here designed based on the rainfall/time distribution of hurricanes Manuel and Patricia. Then, weather forecasts can be used to run simulations prior to the actual event, in order to estimate the arrival times of main pulses, usually characterized by block-rich fronts, which are responsible for most of damage to infrastructures and loss of goods and lives.

3(line 44). Hurricanes and cyclones are not globally distributed.

R3: We modified the sentence as suggested:

"In recent years hurricanes have had catastrophic effects on volcanoes in the tropics troughs the triggering of lahars (sediment-water gravity-driven flows on volcanoes)."

3A(line 55). Mt Ruapehu is not a tropical volcano, despite its rich rain-triggered lahar

R4: The Mt. Ruapehu reference was deleted.

4 and 6 (line 164 and 188). Insert the full date.

R4 and 6: The full date for Patricia and Manuel date of landfalls were added. The sentence was modifies as follow:

In contrast, in 2015 the MgMS site was destroyed by pyroclastic flows during the 10-11 July explosive activity, and in October 2015 the new station was still under construction. Hurricane Manuel (category 1), hit the Pacific coast on 15 September 2013 causing several damage to mountainous region in Guerrero state, triggering several landslides that caused up to 96 deaths and left several villages cut of, as while thousands of tourists were trapped at Acapulco and Ixtapa international airports.

6A (line 200). The sentence was modified as suggested.

R6A: Hurricane Patricia on 2015 was considered as the strongest hurricane on record to affect Mexico. The system began to develop on 18 October over the Pacific Ocean, strengthened into a hurricane shortly after 00:00 GMT on 22 October and early on 23 October it reached its maximum category of 5, before losing strength as it moved

onto the Sierra Madre Occidental range. Landfalls occurred around 23:00 GMT on 23 October along the coast of the Mexican state of Jalisco near Playa Cuixmala, about 60 km west-northwest of Manzanillo.

7(line 234). This sentence reads like there are three zones, unless you are combining the channel and terraces into one. Clarify please.

R7: The sentence was clarified: The watershed of La Lumbre and Montegrande ravines were subdivided into two main zones: 1) the unvegetated upper cone and the main channel that both consist of unconsolidated pyroclastic material with large boulders embedded in a sandy to silty matrix, and 2) the vegetated lateral terraces.

7A (line 279). Move this sentence to line 173.

R7A: This sentence was moved as suggested (se answer to point 1)

8 and 9 (line 311-329). Move the underlined text down to line 316 and move the indicated block of text to line 316 before the insertion.

R8 and 9: The sentece was modified as follow:

Finally, analyzing the simulation in the Montegrande ravine for the 11 June 2013 event, it is possible to observe a different behavior. The lahar starts as less than the 10% of the total rain is accumulated, and the main lahar pulses perfectly correlate with the peak rainfall intensities, and only the last largest pulse correlates with the watershed peak discharge. For la Lumbre watershed, in 2015 a clear correlation between peak rainfall intensities and simulated watershed discharge is not clear. For the Patricia event, along the La Lumbre ravine, first slurry flows also starts after 40% or total rainfall, but main lahar pulses fit better with the simulated peaks watershed discharge.

10. A critical weakness of using the 40% of total rainfall threshold is that it is difficult to know when this point has been reached when it is still raining, unless you have a great deal of faith in your weather forecasts. Do you have accurate predicted total rainfall and distribution curves for these events that could be run through your simulator and

compared with the actual lahar events?

R10: We agree with the reviewer. Here we are only pointing to the evidences get from data here presented (not from the simulations!) that after 40% of the total rainfall first lahars are detected for all the analyzed events. This corresponds to an amount of accumulated rainfall of 100, 120 and 160 mm of rain for Jova, Manuel and Patricia respectively. This evidence points that after at least 100 mm of rains had accumulated (measured in real time from raingauges) lahars can occur. The early warning system will be based on rainfall-runoff modeling results. For the Patricia event the trajectory and time of landfall was quite well predicted, and data about the amount of rainfall were also provided. The text was modified as follow:

For the Jova, Manuel and Patricia events, lahars started after the 40% of total rain had accumulated (corresponding to c. 100, 120 and 160 mm of rain respectively), and apparently the timing for the initial pulses correlates well with the peaks of the rainfall intensity for the Montegrande ravine, while for La Lumbre ravine they better match with the peak simulated watershed discharge.

11 (line 335). This implies that there is no lag time between the peak rainfall intensity measured 6 km away on another volcanic edifice and the arrival of the lahar peak at the detectors.

R11: As observed for the Hurricane Jova, rainfall data from the station at Montegrande and La Lumbre ravine are almost identical (more than 8 km away). This means that the rainfall behavior is quite constant over a large area during a hurricane. Similar behavior is observed for Patricia event, by comparing the Nevado station with the raingauge at Ciudad de Colima. So even if data here used for the Hurricane Patricia are from a station located 6 km away from Volcan de Colima, we are considering that the rainfall intensity was quite homogeneous over these two volcanoes. The Figure R2 (see below) will be added as an extra panel to Fig. 3.

12. How long does it take to run Flo-2d, could it be run in real-time by feeding in the

incoming rainfall intensity data?

R 12: For the simulation here performed, using a 20 m DEM in resolution, each simulation took no more than 30 minutes at our facility so yes, it could be possible to run simulation in real time as data are acquired.

13. Clarify. R13: The phrase was slightly modified as follow:

The observed difference between Montegrande and La Lumbre ravines can be correlated with the different areas and shapes of the two catchments. In fact, due to its elongated shape (KG = 1.7) and small area (2 km2), the Montegrande watershed shows a quicker response between rainfall and discharge, with a rapid water concentration at different point along the main channel (Fig. 1b).

14. So the simulation cannot duplicate the initial hydrophobic behaviour?

R14: No, with the parameter here used, even changing the SCS to 95% (almost impermeable) the simulation was not able to reproduce water discharge at the time the lahars were detected. This is probably again related with the initial abstraction that is fixed by the program based on the CN value (see comment below and responses to reviewer RC2).

15. I'm assuming that these catchments are ungauged, so there is no way of calibrating the simulated discharge produced by the rainfall-runoff routing model?

R 15: Yes the reviewer is correct, direct measurement of watershed discharge is not available. Also based on the comments by the other reviewers we added a section to try to validate the simulation using the video images recorded by La Lumbre monitoring station. Apparently first stream flows are detected at the same time the simulated watershed discharge curve increases. Please refer to response to reviewer RC2 for more detail on this point.

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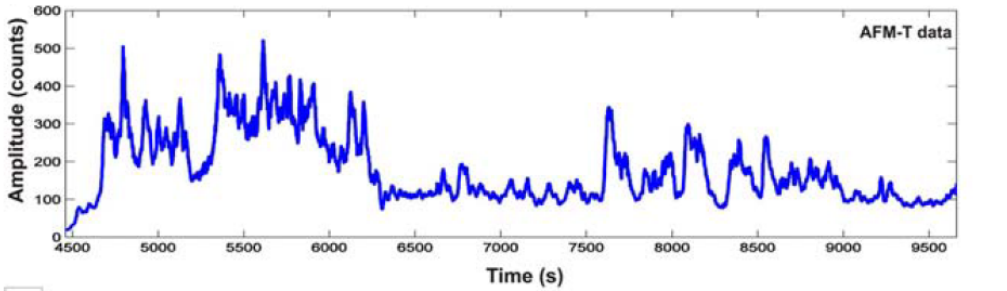

Fig. 5 Plots of the data recorded during the 11 June 2013 lahar from 17:30 to 19:00 (local time). a Envelope of the AFM-T signal (the seismic amplitude is in counts). b Comparative plot where the *green line* describes the discharge curve in m^3/s and the related values of superficial velocity in m/s (*yellow line*), both obtained from the recorded images. *Black arrows* indicate the main features of the flow, as observed in Fig. 4

Fig. 1. Figure 5 from Vazquez et al 2016

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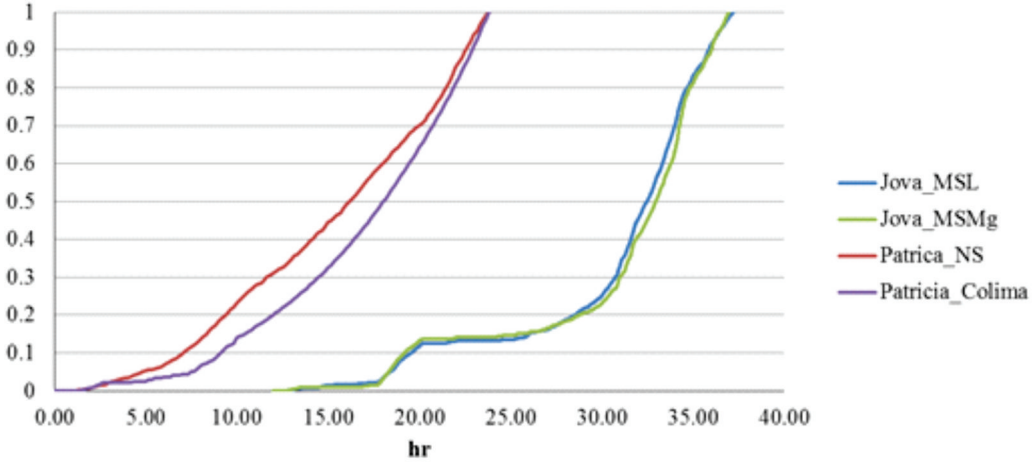

Fig. R2. Normalized rainfall of the Jova and Patricia event as gathered form different stations, pointing to a quasi-stationary rainfall behavior.

Fig. 2. Figure R2

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