Review of nhess-2019-27
"Characteristics of a Hailstorm over the Andean La Paz Valley"
by Marcelo Zamuriano, Andrey Martynov, Luca Panziera, and Stefan Brönnimann
Submitted to *Natural Hazards and Earth System Sciences*, February 2019.
https://doi.org/10.5194/nhess-2019-27

Summary
On 19 February 2002 a severe storm hit La Paz Valley, causing 69 casualties. Unfortunately there are only few low-resolution observations available, mainly from satellite or from a low space-and-time resolution network of stations (reporting mainly daily accumulated rain).

Because of that scarcity of observed data, the case study is tackled using WRF simulations (with 2 km in the inner domain) and applying some sensitivity tests, to highlight the important factors that favored this severe storm. Tests include smoothing or removing orography, warming or removing the Titicaca lake and suppressing heat fluxes. It is found that all these tests affect -more or less- the results.

Major comments

- First of all, the authors must clear that the insights found on the mechanisms underlying the development of this storm are indeed insights on how the WRF simulations works, more than on how this specific storm really evolved. In fact, the observed data are so few, that while the authors can state that the control run has a general agreement with the low resolution satellite-derived observations, they can't prove that the local-scale features evolved following the details simulated by WRF, since there are no radar data, no lightning data and no hail data to compare with. Also, there is no clear comparison with the only available precipitation data, that is, *"The most important rainfall quantity was therefore registered around La Paz next to the mountain slopes (with measured values of around 50 mm)."* I assume that 50 mm of precipitation is the *daily* accumulated value, while the simulations data of Figure 10 show only 3-hours accumulated rainfall, with maximum peaks of about 20 mm. That is not a good forecast if what reported by Hardy (2009) is true, that is, that there were 39.4 mm in only one hour.

- While there is much emphasis on hail, from the title of the paper to the tentatives *"to investigate the physical processes leading to the hailstorm formation"*, in the presented material there is really no specific information on hail and in particular on what would favor a severe hailstorm instead of, for instance, a severe storm not characterized by much hail (that is what one would expected from the analysis of only one case study). The Hailcast module

is coupled into WRF, but I can't find anywhere any clear Hailcast result, like, for example, a map of simulated maximum hailstone diameters. Only a small blue line (very hard to note) is overlapped in Figures 4 and 10, to show hailstone "around 5 mm" or "between 4 and 6 [mm]" of diameters, which seem too few for evaluating the hailcast forecast. Lastly, how important was the hail aspect for the damaged produced by this storm and, in particular, for the 69 casualties? I suspect that the flood aspect (with saturated terrains and steep slopes) could have been more important. In conclusion, maybe that emphasis should be given more on the flash-flood aspects than on hail (and the title changed). Otherwise, the key role of the hail should be better highlighted.

- The material is not presented in a very linear form and there are many repetitions, like for example between Section 4 Discussion and section 5 Summary and Conclusions. I encourage the authors to remove most repeated material and to merge together sections 4 and 5.

- Figures are really too small and very difficult to understand. I suggest to put only one "large" figure per page. Please add at least one map of hail simulated by Hailcast.

Because of these major comments, I kindly ask for a major revision.

Minor comments

Abstract: *The iconic hailstorm*
"iconic" is an appropriate term? I would remove it here and during the whole manuscript.

1, 19: *taking into consideration Bolivian farmers perception of extreme events*
Is it pertinent?

1, 20: *Andean farmers perceive an increase of the frequency and intensity of storms and hail*
How much scientific can be such statement?

1, 25: *was described as an unprecedented crisis*
Maybe crisis is not the best word to use here.

2, 1: *(that resulted in 69 casualties*
How they died? Because of flood, wind gust, giant hail?

2, 5: *the knowledge is taken from local peoples perception of hail frequency and intensity*
That is too few to write a paper on "hailstorm".

2, 5-7: *The lack of formal physical process knowledge about local thunderstorms formation over this region is evident as we take as example the explanation given by the SENAMHI about the*

plausible mechanisms for this particular cell formation.
I don't think that criticizing SENAMHI explanation is relevant here. If their explanation *"might sound trivial for a super-cell formation"*, also your explanation that convective cells *"were triggered by a mix of low level wind convergence, surface heating and orographic forcing"* (page 10, line 8) might sound trivial to others.

Introduction: In this section I would expect some explanation about literature studying hailstorms cases, like for example the work by Kunz et al. (QJ RMS 2016), if emphasis on hail will be maintained. Also some references to orographic precipitation studies could be added, like for example seminal works from Rich Rotunno, Robert Houze, Daniel Kirshbaum and others.

3, 4: *1745 LST*
I searched in Internet for what means LST and it is the "Local Sidereal Time", while you probably was reffering to the "Local Time" (LT). Please correct all LST and describe the relation between LT and UTC time for your specific location.

Figure 3a: I can't really see the observed rainfall distribution. Maybe you can plot the accumulated values at each SENAMHI station located in that area?

4, 16: *We study the role*

4, 21: *We assess the presence of the main ingredients for a hailstorm to occur (moisture, instability and lifting)*
First of all, that language is more appropriate for a cookbook recipe than for a scientific article. Second, if there are -unfortunately- some people that oversimplify the thunderstorm forecasting problem to such a level, they do it for thunderstorm in general, not specifically for "hailstorm". So, please, describe some general features of the environmental conditions that favor thunderstorm development and, if you have any evidence, of specific conditions that instead favor hailstorm formation. Otherwise, simply list the parameters that this study investigates.

4, 23-24: *The low level moisture transport vectors were calculated following*
$IVTU = \frac{1}{g}\int_{SFC}^{200} qud\,p$
... It is calculated from the surface SFC up to 200 hPa.
I really can't understand how can you call it "low level" moisture transport if it is calculated up to 200 hPa!

Figure 2a-2d: Please define what are "sensor count"?

4, 27-28: *the presence of low level water vapor is not well captured in this band but its corroborated with infra-red image at 12μm (not shown).*
Why infra-red at 12μm should provide information on low level water vapor?

6, 8-9: *We note that the models rainfall spatial distribution corresponds very well to the clouds locations in Fig. 2a-b)*
While there is a general agreement, I would not say that forecast and observation fits "very well". Can you provide any verification measure of the agreement between observations and forecasts?

6, 14-15: *Thus WRF is able to simulate the event with its most important features.*
Not so sure, also because you do not have enough observations to describe in detail the event features.

6, 20: *(with measured values of around 50 mm).*
In 24 hours? What is the WRF forecast in the same period and location? Is 50 mm in one day an exceptional rain value? BTW, what is the rain climatology for that location and period of the year?

6, 24: *The analysis of the large scale characteristics and the few observations available provides insufficient information about the three basic ingredients for a thunderstorm: moisture, instability and lifting.*
Maybe it is better to remove it, since it does not add any useful information.

6, 28: *in order to explore the chronology of the precipitation.*
"chronology" is appropriate?

7, 3: *A closer look to the maximum radar reflectivity*
A closer look to the simulated maximum radar reflectivity.

7, 6: *even hailstones of around 5 mm are simulated at the centre of the two formed cells.*
Is it the Hailcast maximum diameter? Or the mean diameter? How it compares with observed hailstone diameters (e.g. from media report) and with the locations were hail was reported? Why not showing also a full map of hail diameters as simulated by Hailcast?

7, 11: *comes from the Amazon avoiding the cordillera obstacle*
"avoiding" is the appropriate term?

Figure 5a-c: Reference vectors are 50 [kg $m^{-1}s^{-1}$] ?

Figure 5d-f: Reference vectors are 3 [ms^{-1}]?

7, 29: *in the proximity if the rain-band*
in the proximity of the rain-band

8, 2: *the atmosphere is saturated until 400 hPa with important wind shear favoring hail and graupel formation*
Can you add a reference to support the hypothesis that wind shear favor hail and graupel formation? In figure 6f I can see a strong directional shear at about 500 hPa, but for example also in figure 6e

there is a strong directional shear at about 550 hPa, even if wind directions are completely different. So, the important issue was really the wind shear or rather the wind direction and intensity absolute values?

8, 7: *and wind shear from surface to 6000 magl (Fig. 7a-c)*
How you define wind shear? Is it the "bulk shear"? I.e. taking the magnitude of the vectorial difference between wind at 6 km and wind at 10 m? Please explain.

8, 13: *Nevertheless, convergence is not enough to explain deep convection.*
Is that a scientific explanation?

9, 9: *showing that breeze and orographic lifting are enough for producing rainfall.*
Is that a scientific explanation?

9, 17: *leaving the cordillera storm free with isolated hailstorms*
Sorry, can you rephrase?

10, 6: *following the thermo-topographic circulation.*
Can you explain better?

10, 13-14: *This propagation allowed both cells to join each other resulting in a precipitation band. This auto-propagation mechanism has been observed*
Please, can you explain better?

10, 17-21: *The presence of sufficient wind shear... as shown in Fig. 7f.*
This part seems not much relevant with the experiments described. I suggest to remove it or to move it to Section 3.

11, 5-6: *satellite information and reanalysis suggests that this severe event was in fact part of a mesoscale convective system.*
That option was never analyzed nor mentioned before the Conclusions. Please remove it or discuss it with supporting facts already in the previous sections.

11, 20-21: *And the surface heat flux suppression (NOHEAT) highlights the importance of surface energy fluxes for atmospheric instability.*
Isn't it a trivial result?

11, 22-23: *highlights the complex interaction between large scale circulation, orography and local features in the formation of hailstorms over the tropical Altiplano.*
Sincerely, I have not found any specific information that can explain why a hailstorm was formed, instead than a thunderstorm (or supercell) not particularly characterized by hail.

11, 23-24: *A semi-comprehensive scheme of participating mechanisms can be found in Fig. 11.*

Please, explain how figure 11 describes this (participating?) mechanisms in details or remove this figure.

11, 29-30: *the proposed mechanisms of this hailstorm formation should be confirmed by high resolution observations*
You already said that these observations are not available.

Regards.