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Interactive comment

Interactive comment on "Hydrogeomorphological analysis and modelling for a comprehensive understanding of flash-flood damaging processes: The 9th October 2018 event in North-eastern Mallorca" *by* Joan Estrany et al.

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The response of the questions and comments provided by Dr. Jorge Lorenzo-Lacruz will be addressed in a point by point format.

GENERAL COMMENT OF DR. LORENZO-LACRUZ. After a careful reading of this manuscript I have several questions and concerns about the data (rainfall, discharge) and methods (modelling) the authors used for analysing the flash-flood occurred in October 2018 in eastern Mallorca

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Discussion paper

We are very grateful to Dr. Lorenzo-Lacruz for this short comment because it provides an interesting opportunity to underpin the research work carried out by the MEDhyCON Team in collaboration with a multi-disciplinary group of scientists from different academic institutions in Spain and a spin-off from Switzerland. Beyond the continuous streamflow monitoring in the Begura de Saumà River hydrometric station, it is also worth saying that most of the data exposed in this paper was collected in the very intense fieldwork campaign during the fortnight following the catastrophe, in which the MEDhyCON Team was fully collaborating in search and rescue tasks as required by the Directorate General of Emergencies of the Balearic Islands Government to help in finding the last missing victim. We are therefore in a unique position to clarify some questions which have arisen about this particular event.

The research group in Hydrology and Ecogeomorphology in Mediterranean environments –MEDhyCON (http://medhycon.uib.cat) is part of the Institute for Agro-Environmental Research and Water Economy – INAGEA (http://inagea.com) at the University of the Balearic Islands (Spain). During the last decade, we have been working on the installation of a hydrometric monitoring network throughout the island of Mallorca. The deployment of our network was specially motivated by the lack of maintenance and the structural deficiency (cf. Fortesa et al., 2019) of the official network managed by the Autonomous Government of the Balearic Islands. It is important to note that the implementation of this new network by MEDhyCON, in some cases, necessitated taking advantage of some useful abandoned parts of the aforementioned old official network. This research infrastructure has been crucial for going beyond in the scientific assessment of global change impacts on Mediterranean catchments hydrology (see a list of SCI papers published by the Group at http://medhycon.uib.cat/publications.html).

Mallorca is a Mediterranean flood-prone region historically affected by devastating flash floods, which have systematically been well documented but always ungauged (Grimalt and Rosselló-Geli, 2011; Estrany and Grimalt, 2014; Petrus et al., 2018). Under this geographical framework, MEDhyCON research team deployed its hydrometric network in some of the catchments most affected by these catastrophic events. As a result, our hydrometric monitoring network is currently composed of 34 stations (see Fig. 1 of this point-by-point document) with digital probes to measure the water stage by readings of 1 minute intervals accumulating in 15-minute average values. This type of monitoring provides continuous streamflow records.

One of these stations was installed in June 2015 in the Begura de Saumà River hydrometric station, located in Sant Llorenç des Cardassar village (see Fig. 1 of Estrany et al. MS). The small spatial and temporal scales of flash floods, relative to the sampling characteristics of typical hydro-meteorological networks, make these events particularly difficult to monitor and document. A lot of flash flood events occurred in ungauged catchments. Even in those catchments with hydrometric stations, streamflow monitoring can be damaged during these catastrophic events. This was not the case of the worst natural disaster that occurred in Mallorca during the Late Modern period, because the water stage was completely recorded by our pressure probe installed in a bank of the artificial channel where the water stage is the same by “connected vessels” but avoiding potential damage (see Fig. 2 of this point-by-point document). It is a historical landmark, being the first time that real data is recorded in the Balearic Islands in such type of events.

References used in this comment

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Fortesa, J., García-Comendador, J., Calsamiglia, A., López-Tarazón, JA., Latron, J., Alorda, B. and Estrany J.: Comparison of stage/discharge rating curves derived from different recording systems: Consequences for streamflow data and water management in a Mediterranean island. Sci. Total Environ., 665: 968-981. DOI:

10.1016/j.scitotenv.2019.02.158, 2019.

Grimalt, M., Rosselló-Geli, J.. Anàlisi històrica de les inundacions a les Illes Balears. (Translation to English: Historical analysis of floods in the Balearic Islands; following the methodological guide developed by the Spanish Ministry of Agriculture, Food and Environment). Conselleria d'Agricultura, Medi Ambient i Territori del Govern de les Illes Balears, 442 pp + Atlas, 2011.

Petrus, JM., Ruiz, M and Estrany J.: Interactions between Geomorphology and Urban Evolution Since Neolithic Times in a Mediterranean City. Urban Geomorphol., 9–35. DOI: 10.1016/B978-0-12-811951-8.00002-3, 2018.

POINT 1 LORENZO-LACRUZ. The abstract states: "Continuous streamflow monitoring data revealed a peak discharge of 442 cumecs"... but it is not clear if the event was continuously monitored, as in line 226 the authors say "with the absence of direct flow measurement for the Q estimation"; and in line 382 they say that the hydrological monitoring period excluded the October 2018 month, when the flash flood occurred. Therefore, there was no direct measurement during the flash flood and this statement cannot be used neither in the abstract nor in the rest of the manuscript.

Our hydrometric station located at Sant Llorenç des Cardassar provided a complete and continuous water stage recording of the extreme flash-flood event, as we have explained in the previous general comment. We are really surprised by this comment because it denotes a lack of knowledge about one of the basics in surface hydrology: the estimation of river discharges. In a hydrometric station, discharges are traditionally estimated from the continuous measurement of the river's water stage. As is explained in the sub-section 2.3 Discharge data, "the MEDhyCON Research Group installed within the gauge house a Hobo Water Level U20L-04, which measures the water stage by readings of 1 minute accumulating 15-minute average values" (Lines 218-219). Therefore, the continuous measurement of water stage is directly related to the continuous streamflow monitoring.

It is obvious that the hydrological monitoring period also included the October 2018 month, when the flash flood occurred. However, to better assess the hydrological dynamics of the catchment, we structured these hydrological results into two sub-sections. The first one is the 3.1 Catchment hydrological dynamics, where these dynamics were described during almost 4 hydrological years. The second one is the 3.2 Hydrological response of the flash-flood, where the continuous streamflow monitoring allowed evaluating this response with a high accuracy. This structure is also linked with the performance of two different figures for each sub-section where the NHESS readers can directly observe the ephemeral regime during the monitoring period 2015-2018 (Fig. 5 of Estrany et al. MS) and the difference of three units of magnitude in the observed discharge during the catastrophic flash flood if compared with the previous monitored period (Fig. 6 of Estrany et al. MS).

Regarding Line 382 and considering the explanation provided in the previous paragraph, we must however thank to Dr. Lorenzo-Lacruz because the writing could generate confusion to the NHESS readers. We will therefore change the sentence in the revised version of the Estrany et al. MS.

The original version was:

“The hydrological monitoring period in the hydrometric station was from 10th January 2015 to 30th September 2018 (Fig. 5), excluding the October 2018 month when the catastrophic flash flood event occurred (see results in sub-section 3.2)”.

The modified version will be:

“The hydrological monitoring period assessed in this paper by using data from the hydrometric station was from 10th January 2015 to 31st October 2018 (Fig. 5). In addition, the October 2018 month was reserved to develop a singular and deeper study in order to better describe the catastrophic flash flood event (see results in the next sub-section 3.2)”.

POINT 2 LORENZO-LACRUZ. Related to the discharge and following line 226, with the absence of direct flow measurements, the next line explains that the authors applied the two-dimensional hydraulic model HEC RAS 5.0.6. However, where this simulation can be found in the paper? Linked to the previous Point 1 provided by Dr. Lorenzo-Lacruz, it is essential to emphasize that specific discharge measurements, known as gaugings, are needed to establish a relationship between the water stage and the discharge. This is called a stage-discharge rating curve, and its purpose is to translate water stages into discharges (Chow, 1964; Braud et al., 2018).

In the Begura de Saumà hydrometric station we did not perform specific discharge measurements by using direct flow velocity measurements, although during flash-flood events it is not possible to carry out these measurements with traditional tools; i.e., current meters. Therefore, rating curves are often extrapolated for high flows, far beyond the range of gauged values, which leads to very high uncertainties regarding flood discharges. In order to avoid these uncertainties, a two-dimensional hydraulic model was applied as a tool to perform and evaluate the stage-discharge rating curve as well the peak discharge during the event. The 2D hydraulic model was also thoroughly described between lines 224 and 272 and Fig. 3 of Estrany et al. MS. Data used for the DEM and mesh construction, area and length of the studied reach, location of significant structures and hypothesis regarding its hydraulic behaviour, boundary conditions, calculation method and simulations running in order to obtain the stage-discharge rating curve are shown in Fig. 4 of Estrany et al MS. All significant factors and processes regarding the simulation assumptions and hypothesis were also explained.

It is worthy of note that the main scope of our paper is not the hydraulic modelling of the event, it is focused on addressing other features such as the hydrological response of the catchment and its modelling, the damage assessment and geomorphic changes.

Reference used in this comment

Braud, I.. Vincendon, B., Anquetin, S., Ducrocq, V. and Creutin J-D.: The Challenges of Flash Flood Forecasting. In Mobilities Facing Hydrometeorological Extreme Events 1. Elsevier; 63-88, 2018.

Chow V Te.: Handbook of applied hydrology; a compendium of water-resources technology. McGraw-Hill, 1964.

POINT 3 LORENZO-LACRUZ. The peak discharge of the flash flood was estimated through a stage-discharge rating curve (figure 4) calibrated with only two events with values over 1 cumec. Therefore, the estimated value of the maximum discharge is suspicious or may contain a significant error. There is a study made by Lorenzo-Lacruz et al. (2019) (https://doi.org/10.5194/nhess-19-2597-2019) addressed on the same event, and published in NHESS one month ago. In this published article, Lorenzo-Lacruz et al. obtained peak discharges of 306.9 cumecs and 303.4 cumecs with FEST and KLEM models, respectively, and successfully validated it with in situ measurements after the event. As a new contribution, Estrany et al. must discuss the significant difference with the result they have obtained (442 cumecs). Nevertheless, the authors not even mention the article of Lorenzo-Lacruz et al., (2019), in spite of it was published for open discussion three months before Estrany et al. submitted its manuscript for discussion and review.

First of all, the stage-discharge rating curve shown in Fig. 4 of Estrany et al. MS is not the result of a calibration made with only two events with values over 1 m3 s-1. This stage-discharge rating curve was obtained by means of the two-dimensional hydraulic model described in sub-section 2.3, simulating the 2D flow hydrodynamics with the required free surface flow equations; i.e., Shallow Water Equations.

A hydrometric gauging station is located at the beginning of the artificial channelization of the Begura de Saumà River that crosses the village of Sant Llorenç des Cardassar, as was explained in detail within sub-section 2.3. However, in this case, water stage measurements cannot be directly transformed into discharges by using a typical stage-discharge rating curve, despite this being the normal procedure in gauging stations. During the 9th October event, two main factors could have led to wrong results by using this transformation. Firstly, as the flow overbanked the artificial channelization, the cross section used in the traditional stage-discharge rating curve is no longer a rectangular section, although the entire cross section of the flooded area must be completely incorporated into the discharge estimation. Secondly, as it was also carefully explained, several bridges cross the artificial channelization. Specifically, one of them is located 50 m downstream of the hydrometric station (see Fig. 3a and sub-section 2.3 in Estrany et al. MS). This bridge was severely obstructed by vegetation during the event (see inset pictures in Fig. 3 in Estrany et al. MS). The obstruction influenced the channel hydraulics also creating backwater effects that altered the stage-discharge relationships, causing an increase of overflow in sections located upstream of the bridge.

Accordingly, it is not possible to apply a unique theoretical stage-discharge rating curve due to the necessity of having to apply a different approach to compute the stage-discharge rating curve during the flash flood event.. The complete geometry of the study area, including bridges, were implemented in a 2D hydraulic model, being run with different boundary conditions (different discharge values entering the system). In addition, for each of these conditions, the water stage –calculated at the location of the hydrometric station– was retrieved. It can be observed that if the flow depth is below the low chord of the first bridge's deck, the resulting stage-discharge rating curve follows the theoretical expression, according to the channel characteristics. However, once the water stage reaches the first bridge's deck, backwater starts affecting the hydraulic flow behaviour at the gauging station, and the streamflow starts overbanking the channel section. The influence of bridges is therefore well evaluated and represented in the stage-discharge rating curve in our paper, performing a 'jump' in the water stage.

Moreover, during the event of 9th October, the partial blockage of some of the bridge's openings (clearly visible in the post-event pictures in Fig. 3 of Estrany et al. MS) also occurred. One of the main uncertainties regarding the discharge simulation of the flash-flood event is the level or degree of obstruction at each bridge. In this case, we carefully implemented a model calibration parameter, estimated by observing photographs taken just after the event; i.e., 12 hours after, 10th October morning. The calibration procedure was carried out with the maximum water stages measured at significant locations (see Fig. 3b in Estrany et al. MS). With the values described in lines 262 and 263, the simulated water stages matched these ground control points with and error < 5% (even < 1% in the case of the water stage recorded at the hydrometric station). With a small increase or decrease in the flow discharge, these errors are rapidly increased.

Regarding to the discussion proposed by Dr. Lorenzo-Lacruz on the discrepancy in peak discharges between our manuscript (Estrany et al.) and those obtained in the paper Lorenzo-Lacruz et al. (2019), we have carefully read the methods and results sections. Thus, Lorenzo-Lacruz et al. (2019) explained that peak discharge was obtained with FEST and KLEM models (fully distributed hydrological models), being validated with in situ measurements after the event. There is a clear lack of information on this key method issue, although we can assume a hypothetical validation by means of hydraulic modelling of those peak discharges. However, there are some important issues within the model that Lorenzo-Lacruz et al. (2019) used that, from our point of view, invalidate the obtained results.

First, it is stated that Lorenzo-Lacruz et al. (2019) applied a 1D model (Line 231). The software is the same (HEC-RAS) used in our paper, but 1D models are strongly not-recommended for the simulation of flood events. Once the flow overbanks the main channel, this flow can take multiple directions, and hence have varying water surface elevations and velocities in each of the directions. The HEC-RAS 2D Modelling User's Manual (2015) indicates ex professo this recommendation. Therefore, the 1D models only incorporate one main direction of the flow (in this study case, the direction of the channel). However, with overbank flows, a significant second direction is starting to take place.

1. Lorenzo-Lacruz et al. (2019) clearly describes how the water overflowed the chan-

nelization from the beginning of the flash-flood event:

Line 362: “The hydraulic simulation (Fig. 4) shows how water starts flowing through Sant Llorenç town at 1900 h (LT) and, in barely 10-20 minutes, it starts overflowing the artificial channel at several points within the sector between bridge#2 and bridge#3, reaching 365 depth values of about 3 m. The football field locate in the meander between bridge#2 and bridge#3 was completely flooded in less than half an hour”.

2. They also described how the overflows reached the centre of the village which is a complex net of buildings and streets. As a note in urban geography, we must say that the old village where the centre is located was not affected by the overflows. In terms of hydraulics, urban environments are characterized by numerous transitions to supercritical flow and numerical shocks. As a result, the simulation of the flow behaviour during this catastrophic flash-flood event, a 2D model is required (Hunter et al., 2008).

Line 366: “It only takes between 10 and 20 minutes for the peak flow modelled at the entrance of the town to reach the maximum extent of flooded area in the city centre: water covers the entire longitudinal path of the channel through town, with the most affected areas in the vicinities of bridges and river corners”.

Line 372: “Water depth reached almost 1.5 m in the Town Hall square and the surrounding blocks, which are located 150-200 metres away from the main river channel”.

3. Furthermore, they highlighted the need to excessively increase the width of the cross-sections in order to reach the points located in areas affected further away from the channelization (it must be noted that the width of the channel is just 10 m).

Line 267: “The number of cross-sections was limited by the meandering shape of the Ses Planes river at Sant Llorenç and the extraordinary extent of flooding in the city centre (cross-sections wider than 300 m were required to cover the affected areas at some points)”.

Although there is no universal rule to determine whether using a 1D or a 2D model, some practical rules can be applied. For instance, when the cross-section width is longer than 50 times the water depth, a 2D model is recommended. However, if the flow itself is clearly 2D (flow at channel bends, flow with significant velocity differences between channel and floodplain, flow divergence, or flows in urban areas), a 2D model is compulsory (ACA, 2003).

Therefore, it is difficult to understand why the authors chose a 1D model to represent a flooding process that is clearly 2D, and why they affirm that results obtained with that model can be used to validate the peak discharge obtained with the hydrological model. In line 495, Lorenzo-Lacruz et al. (2019) introduced the possible inaccuracies caused by the 1D approach:

Line 495: "In this context, the use of the 1-D approach for analysis of bridge effects may not properly simulate the interactions between bridge and flow, and backwater effects may be underestimated or neglected (Costabile and Macchione, 2015). This seems to not be the case for Sant Llorenç since water velocity greatly increased at bridges, and sections between bridges #2 and #3 were flooded for a longer time, denoting that the model registered the occurrence of intense backwater processes at these bridge locations".

However, 1D models are perfectly useful for simulating flow through bridges, for both low and high water stages. This cannot be the reason why the 1D model should or should not be considered valid. As the flow overbanked the main channelization occupying the urban area, this is the clear reason that a 1D model is not valid to simulate this catastrophic flash-flood event. The difference between Lorenzo-Lacruz et al. (2019) peak discharge –peak discharges of 306.9 m3 s-1 and 303.4 m3 s-1 with FEST and KLEM models– and Estrany et al. MS peak discharge (442 m3 s-1) can be easily explained. Beyond Estrany et al. MS directly measured the water stage by a pressure probe, the use of 1D models underestimate discharges in the case of overbanking flood events, because one of the two main directions of the flow is being neglected (and therefore, not all the water volume flow is estimated).

Additionally, regarding the use of KLEM model, it is also known that the rescaled width function (which is the root of the KLEM model) is sensitive to the method of channel network extraction (Mutzner et al., 2016). This is particularly true if the drainage density is uneven. Lorenzo-Lacruz et al. (2019) used a threshold area method without giving neither the value of the threshold, nor the resolution of the DEM used to extract the network. However, the threshold area method assumes a constant drainage density. The magnitude and the ratio of the hillslope and channel velocities are also determinant and also have a large influence on the timing and peak of the modelled flood (Mutzner et al., 2016). Then of course the calibration of these two parameters helps to obtain a very good agreement with the timing of observed discharge (if existing).

Some other relevant comments can be made about Lorenzo-Lacruz et al.'s hydraulic model:

1. In Line 265 "The HEC-RAS model was set up using 40 cross-sections distributed along the 4303 m of reach length". This separation distance between cross-section performed more than 100 m distance between sections when the recommended distance should not exceed 20-25 m. Lorenzo-Lacruz et al. (2019) explained this selection in:

Line 267: "The number of cross-sections was limited by the meandering shape of the Ses Planes river at Sant Llorenç and the extraordinary extent of flooding in the city centre (cross-sections wider than 300 m were required to cover the affected areas at some points), since cross-sections could not intersect each other".

In our opinion, this confirms the need to use a 2D model, instead of a 1D model that does not accurately represent the geometry of the study area.

2. It was not specified in Lorenzo-Lacruz et al.'s paper how the model assesses the vegetation blockage that occurred in some bridges, especially those bridges located very closed to the hydrometric station, although they do highlight this fact in the paper:

Line 402: “The bridge (pictured in Figure 6), which occupies more than half the flooded section, blocks the water and increases its velocity upstream due to flux accumulation and generation of intense backwater effects caused by bridge clogging”.

Line 511: “Along the study reach, several trees were eroded, transported and deposited downstream, arriving at the first bridge at the entrance of the village”.

3. In Line 282 “The computation time step was set up at 10 minutes (same temporal resolution as the discharge hydrograph) and the output time interval was set at 1 minute”. The computational time step should be determined according to numerical computational criteria, such as Courant’s condition, not to the temporal resolution of the input boundary condition. Computational time step and the temporal resolution of the hydrograph are two completely different parameters. Such a large interval may lead to instabilities and inaccuracies. Furthermore, it makes no sense to retrieve output results in time steps that are smaller than the computational time step.

In view of all these scientific evidences, the hydraulic model used in Lorenzo-Lacruz et al. (2019) cannot be considered adequate to validate any maximum discharge hypothesis.

References used in this comment

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Engineers, U.A.C.O. 2015. HEC-RAS River Analysis System, 2D Modeling User’s Manual. Agència Catalana de l’Aigua. Departament de Medi Ambient 2003. Guia Tècnica. Recomanacions tècniques per als estudis d’inundabilitat d’àmbit local.

Mutzner R, Tarolli P, Sofia G, Parlange MB, Rinaldo A. 2016. Field study on drainage densities and rescaled width functions in a high-altitude alpine catchment, Hydrol. Process, 30: 2138-2152. DOI: 10.1002/hyp.10783.

POINT 4 LORENZO-LACRUZ. Figure 6 show the total rainfall during the flood event. It is weird how the authors distributed the rainfall showing that the highest values were recorded in the western-central part of the basin and not in the headwaters, where the relief is higher (around 400 meters). The figure also shows 13 rainfall radar points for what purpose? to calibrate the rainfall? In Lorenzo-Lacruz et al. (2019) they show a complete reconstruction of the radar data for the same flood event and it is completely different to the data depicted in Figure 6. Lorenzo-Lacruz et al. draw the highest values (up to 400 mm) on the headwaters. This highest rainfall recorded in the upper parts of the catchment would explain why the flash flood also occurred in the surrounding basins (barranc de Sa Canova and s'Ametllerar), which share the headwaters with the studied catchment. Regarding the rainfall estimation process using radar data we would first like to emphasize that in our case we only used the lowest available radar PPI, which performed a vertical inclination of 0.5°. This PPI is justified because we only used the radar data that we downloaded during the event thanks to the Open Data of AEMET (https://opendata.aemet.es/centrodedescargas/inicio). In contrast, Lorenzo-Lacruz et al. (2019) used in their paper two PPI, the one showing a vertical inclination of 0.5° and the one with 1.5°.

It is possible that some of the differences mentioned by Dr. Lorenzo-Lacruz in the rainfall estimations by Lorenzo-Lacruz et al. (2019) and our rainfall estimation emerged due to the differences in the processed data. Furthermore, Lorenzo-Lacruz et al. (2019) decided to implement a technique designed to correct the orographic-blocking of the radar signal to their data. In Estrany et al. MS, we decided not to implement this procedure because we did not detect major blockings to the signal, after calculating the trajectory of the 0.5° PPI and considering the location of the radar. In this sense, it is a bit worrying to observe the radar location that Lorenzo-Lacruz et al. (2019) used because in their Fig. 1 the rain radar is incorrectly located. It seems that they located the rain radar at Palma Airport, but the AEMET rain radar is located almost 25 km faraway, in a site called Cap Blanc. However, at Palma Airport an AEMET radar of the lightning detection system is installed, but the AEMET rain radar is located at Cap

Blanc. This information can be found, for instance, in many messages of the official twitter account of @AEMET_Baleares, the entity which owns and manages the rainfall radar. (https://twitter.com/AEMET_Baleares/status/798930116969644032).

It is also worthy of note that while Dr. Lorenzo-Lacruz mentioned a "complete reconstruction of the radar data" in his comment, we consider more precise the expression "estimation process". We are aware that two different estimation processes can lead to two different estimation quantities, as it occurs with our work. In this sense, and surprisingly for us, Lorenzo-Lacruz seems to assume in this comment that a rainfall episode always shows a strong relief influence. In Mallorca, it is true that an orographic effect can generate an increase over the precipitation total amounts. However, this process is commonly restricted to some synoptic situations in the Tramuntana Range; i.e., northeastern winds (Sumner et al. 1995; Llop and Alomar, 2012). In reality, this process is very effective when the rainfall is heavily influenced by the uplift generated in the surface by the orography, which can or cannot occur during a convective episode. Despite Cuevas-Tascón et al. (2019) explaining how a convergence front in the mesoscale probably existed, the exact location of this convergence front it is still unknown. Accordingly, the convergence front was a key factor in explaining the persistence of heavy rainfall and the total rainfall amount, but it is not possible to assume that the highest amount of rainfall should have been estimated at the higher relief areas of the Begura de Saumà River catchment, as Dr. Lorenzo-Lacruz assumes in his comment.

Regarding the 13 points showed in the Fig. 6 of Estrany et al. MS we want to point out that these points corresponded to the centroids of our rainfall estimation and they were used to generate the map of isohyets as well as to obtain the estimation of rainfall at each time step.

Regarding the following part of comment 4 "This highest rainfall recorded in the upper parts of the catchment would explain why the flash flood also occurred in the surrounding basins (barranc de Sa Canova and s'Ametllerar), which share the headwaters with the studied catchment". We do not fully understand the aim of this comment. It is true that a flash-flood also occurred in surrounding catchments, but with peak discharges much lower than the peak discharge recorded in the Begura de Saumà River (see Fig. 3 of this point-by-point document). The inset figure illustrates the rain fallen the 9th October 2018 in the middle and downstream parts of Na Borges River catchment as well the continuous streamflow calculated from the MEDhyCON Research Group at the (3) Sa Vall and (4) Ses Pastores hydrometric stations. Peak discharges were >10 m3 s-1 during the rain event of 9th October 2018, at least two order of magnitude lower than the peak discharge recorded in the Begura de Saumà River. With such intense rainfall recorded in the upper parts of the catchment as stated by Lorenzo-Lacruz et al. (2019), the MEDhyCON hydrometric station located in Ses Pastores (number 4 in Fig. 3 of this point-by-point document) probably experimented a flash-flood peak discharge of a similar magnitude to the one recorded in the Begura de Saumà River. Nevertheless, the peak discharge recorded by the MEDhyCON gauging station was one order of magnitude lower. In our opinion, this reinforces the spatial distribution of the rainfall obtained in our paper against the one presented by Jorge-Lorenzo et al. (2019).

Furthermore, in this specific part of his comment, Dr. Lorenzo-Lacruz seems to underestimate the possibility of rainfall amounts ca. 150-200 mm to generate flash-flood events. This is quite curious, as in their own paper, Lorenzo-Lacruz et al. (2019) explained –in the sub-section 2.1 Catchment description– the following:

“The Ses Planes torrent has been affected by some severe flood events over the last half century: 12th October 1973, 3rd September 1982, 25th October 1985 and 6th September 1989 (Grimalt and Rodríguez-Perea, 1989). The latter was especially important; 156 mm of precipitation recorded in 2 h generated a flash flood that affected some areas of the town and led local authorities to undertake the artificial channelization of the Ses Planes torrent where it crosses the Sant Llorenç urban area”.

The event of 1989 was general in the eastern part of Mallorca island, generating a flash-flood episode that affected most of the catchments in that part of the island, as explained in Grimalt and Rodríguez-Perea (1989). At the same time, only a few weather stations reported a rainfall amount > 200 mm, and in general, the recorded rainfall was in the range of 100-200 mm.

References used in this comment

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Sumner, G., Ramis, C., Guijarro, J.A. (1995). Daily rainfall domains in Mallorca. Theoretical and Applied Climatology, 51:199-221

POINT 5 LORENZO-LACRUZ. The authors used the hydrological modelling GSM-SOCONT and it is also surprising, since this model is "a semi-distributed glacio-hydrologic model to simulate daily discharge from catchments with glacier cover" (https://www.mathworks.com/matlabcentral/fileexchange/43452-gsm-socont-glacio-hydrological-model). Surface runoff was computed with the SWMM (a conceptual glacio-hydrological model for high mountainous catchments). It seems not to be the most appropriate model for this watershed and for a catastrophic flash-flood analysis or reconstruction. There are other studies addressed in the Mediterranean region in which more appropriate models for flash flood episodes were used (Amengual, A., Homar, V. and Jaume, O., 2015: Potential of a probabilistic hydrometeorological forecasting approach for the 28 September 2012 extreme flash flood in Murcia, Spain. Atmospheric Research, 166, 10-23. Amengual and Carrio, 2017: A Comparison of Ensemble Strategies for Flash Flood Forecasting: The 12 October 2007 Case Study in Valencia, Spain https://doi.org/10.1175/JHM-D-16-0281.1). We are delighted with Dr. Lorenzo-Lacruz for his comment. We also recognize that referring to GSM-SOCONT in the manuscript can be confusing, as the snow and ice contributions are null in this case and only the SOCONT part of the model was used. We will adapt the manuscript and refer to the SOCONT model only, as only the soil contribution of the model is determinant here.

However, we are concerned by the lack of knowledge and interest of Dr. Lorenzo-Lacruz regarding the model used in our study. In the link given by Lorenzo-Lacruz et al. (2019), it is possible to access the paper of Schaefli et al. (2005) where the SOCONT model is described in detail. We quote: "It is carried out through a conceptual reservoir-based model named SOCONT developed by Consuegra and Vez (1996) and similar to the GR-models (Edijatno and Michel, 1989)" and later in the same section: "Several applications of the SOCONT model to non-glaciered catchments (Consuegra et al., 1998; Guex et al., 2002) have shown that this model is able to reproduce all the major characteristics of the discharge such as floods, flow-duration-curves or the hydrological regime". As described in our manuscript, the SOCONT model takes into account infiltration, surface and sub-surface runoff, karstic behaviour, evapotranspiration and flow routing.

Moreover, the GR-models are widely used, in particular in France by national authorities to produce flood forecasts, including Mediterranean areas, see for instance https://webgr.inrae.fr/en/models/hydrological-forecasting-model-grp/. Hydrique Engineers successfully used SOCONT model for flood forecasting in many parts of the World, including flash flooding systems. More importantly, these models are applied in very different hydrological regimes (Mediterranean regions, karstic environments, snowmelt/glaciermelt fed hydrographs in Europe and China). We have therefore tested empirically that this kind of model is very versatile and is perfectly suited to analyse the kind of event described in the paper.

Regarding the other studies focused on the application of more appropriate hydrological models in Mediterranean catchments. Initially, we believe that it is not ethical to only cite those studies developed by some of the co-authors of the paper that you are leading because, secondly, a lot of models are applied and developed in Mediterranean catchments.

Reference used in this comment

Schaefli, B., Hingray, B., Niggli, M., and Musy, A.: A conceptual glacio-hydrological model for high mountainous catchments. Hydrol. Earth Syst. Sci., 9: 95-109. DOI: 10.5194/hess-9-95-2005, 2005.

POINT 6 LORENZO-LACRUZ. Therefore, it is embarrassing to say that the “observed and modelled hydrograph and corresponding peak flow (442 cumecs)” showed in Figure 6 contains major flaws as: i) there is no observed hydrograph, ii) a glacio-hydrological model was used for a small Mediterranean watershed with low elevations and semiarid conditions, and iii) what is more surprising, the peak flow is reached one hour before the peak of rainfall. Is there any reasonable argument to defend such hydrological behaviour? We must again thank to Dr. Lorenzo-Lacruz about a warning on the observed hydrograph, despite the pejorative and abusive language. We address the three main concerns on Figure 6 from Estrany et al. MS, as follows:

i) there is no observed hydrograph. In Figure 6, the observed and the modelled hydrographs are perfectly performed in blue and red lines respectively in Estrany et al. MS (see Fig. 4 of this point-by-point document). In addition, as we have stated in the previous points, continuous streamflow monitoring and the application of a calibrated and validated hydrological model as the GSM-SOCONT represents an accurate and precise methodological approach to investigate the hydrological response of this catastrophic flash-flood event. For this reason, the use of adjectives like “embarrassing” is totally unprofessional and unjustified in science communication and in any context. However, we will modify the width of these lines to improve the performance of one of the main results of Estrany et al. MS.

ii) a glacio-hydrological model used for a small Mediterranean watershed with low elevations and semiarid conditions. As commented in the previous point 5, the SOCONT model is well suited to analyse the event. We believe that Dr. Lorenzo-Lacruz was confused by the GSM part of the SOCONT model applied in our study.

iii) what is more surprising the peak flow is reached one or before the peak of rainfall. Is there any reasonable argument to defend such hydrological behaviour? We have revised the plotted hyetograph that represented the hourly average rainfall derived from all the radar points exposed in Fig. 6 of Estrany et al. MS. We have updated the hyetograph using only the rainfall radar points within the Begura de Saumà catchment. In the updated version of Fig. 6 of Estrany et al. MS, the peak of rainfall is at 19:00 h, 15 minutes earlier than the Q peak.

After this change, variables from Table 1 (rainfall and runoff variables of the flash flood) will be updated in the Estrany et al. MS, despite the fact that the differences do not modify the general patterns of the hydrological response of the catastrophic flash-flood. As a result, the time of maximum rainfall has been moved from 18.00 h to 19.00 h, whilst average total rainfall over the catchment derived from radar images has increased from 240 to 249 mm, IPmax average radar decreased from 46.4 to 45.3 mm h-1, IP average radar increased from 24.01 to 24.91 mm h-1 and runoff ratio decreased from 0.36 to 0.35. The updated rainfall and runoff values must be discussed in the same way as the previous values as changes were insignificant.

POINT 7 LORENZO-LACRUZ. It is at least strange that this study not even mention the work by Lorenzo-Lacruz et al. (2019) “Hydro-meteorological reconstruction and geomorphological impact assessment of the October, 2018 catastrophic flash flood at Sant Llorenç, Mallorca (Spain)”, accepted for publication in October 22nd and published one month ago in NHESS. The study by Lorenzo-Lacruz et al. can be used for discussion about the different results that Estrany et al. obtained on rainfall data, peak discharge, hydraulic and hydrological modelling, geomorphological reconstruction, etc. This is, indeed, the objective of an open discussion journal. Explicitly speaking there is a resemblance of some of the content of this contribution (Estrany et al.) with the contents of Lorenzo-Lacruz et al. (2019). Not only the title and structure of the manuscript are similar, some figures included in this paper show a direct and evident inspiration on the published paper by Lorenzo-Lacruz et al. (i.e.: figure 2 of the published paper and figure 2 of this manuscript; figure 6 and figure 7; figure 9.c of the published paper with figure 8.c of this manuscript). In science, the right of any particular to carry out research freely on any topic is respected, of course, but it is also necessary to cite and mention the work already done by others to avoid plagiarism.

We must again thank Dr. Lorenzo-Lacruz for this last comment –as we pointed out at the beginning of this document– because it represents a very good opportunity to better situate our research within the international scientific audience.

The short comment of Dr. Lorenzo-Lacruz is questioning (see the issues raised in this short comment from the abstract to the end of our manuscript) the validity of our data and therefore our ethical integrity as scientists. Sentences like "(. . .) there was no direct measurement during the flash flood (. . .)" demonstrate that accusations or insinuations of falsifying an investigation are extremely serious and damage up the confidence in our discipline itself, beyond our own reputation.

Furthermore, this barrage of denunciations –openly accusing us of plagiarizing Lorenzo-Lacruz et al. (2019)– is completely and demonstrably false, as we have argued throughout this point-by-point document. However, to shed further light on the evidence, we will provide a chronology of the case:

1. Last April 2019 we started the pre-submission of our manuscript on the NHESS Editorial Platform, detail that can be proven by the NHESS Editorial services, as the natural way for the significant working scientific effort carried out.

2. We were aware of the open discussion of Lorenzo-Lacruz et al. (2019) in the beginning of September 2019, when we had almost finished our manuscript, it was submitted on 13th September 2019. At this point, we had already detected the inconsistencies in the Lorenzo-Lacruz et al. (2019) manuscript. However, in view of the very transparent rules of NHESS –with an open discussion in parallel with a very rigorous peer-review process, we decided to wait until the second round of revision to cite this piece of work

in a “classic way”; i.e., until finishing the open discussion and anonymous reviews.

3. In addition, Lorenzo et al. (2019) was not definitely published by the date of us submitting our manuscript (13th September 2019), the status being “Open discussion”. Thus, we decided to wait for both the definitive publication of Lorenzo-Lacruz et al’s piece of work and the second round of revision of our MS. One of our main aims for citing them in this second round of revision was that Lorenzo-Lacruz et al. (2019) seemed to have based their piece of work on the fact that the Begura de Saumà River was ungauged (see Line 14 –Abstract–, and Line 86 –1. Introduction– of their open discussion MS), which is demonstrably false as we stated in our manuscript and within this point-by-point document.

4. Moreover, the supposed lack of knowledge of our streamflow data was at the very least surprising because the catastrophic nature of the event caused that MEDhyCON Research Group was required by the Emergency Authorities to directly participate in the post-catastrophe management by helping to rescue the last missing victim by applying a rapid mapping of sediment connectivity index and a UAV flight campaign for detecting detailed geomorphic changes. However, rapid mapping was enough to find this last missing victim. This approach is explained with detail in section 3.5 Sediment Connectivity and geomorphic change detection as emergency tools of Estrany et al. MS.

5. In November 2018, the Emergencies General Directorate of the Balearic Islands Autonomous Government required the MEDhyCON Research Group to provide an official report in order to perform a forensic reconstruction of this natural catastrophe. Within this report, MEDhyCON Research Group provided detailed information –although not calibrated– on the rainfall-runoff response during the flash-flood event. These key data were later used in the final report explaining the management of the catastrophic rainfall event that affected the Llevant County of Mallorca. This report was signed by the Operational and Technical Head of the Balearic Emergencies Resources and approved on 18th January 2019 by an agreement of the Balearic Council of Ministers (in Catalan)

(http://www.caib.es/govern/pidip/consells/dadesAcord.do?lang=ca&codi=9188230&extra=N). Specifically, page 7 of the second report (http://www.caib.es/pidip2front/jsp/adjunto?codi=2243620&idioma=ca) illustrates a detailed description of the rainfall-runoff process by using MEDhyCON data from the hydrometric station located in the Begura de Saumà River.

6. Lorenzo-Lacruz et al. (2019) must know these data and such statements are not helping the understanding of the event from the general public and cannot be considered plagiarism of their paper.

7. As we reiteratively stated along this point-by-point document, we are using our own data collected and carefully treated from the pressure probe installed and managed by the MEDhyCON Research Group in a hydrometric station since 2015 being combined with hydrological and hydraulic modelling by experienced scientists.

Regarding the mention of plagiarism on the structure of the paper, we must specify that Lorenzo-Lacruz et al. (2019) and Estrany et al. MS are analysing the same catastrophic flash-flood event in the same catchment. Therefore, the potential similarities between both papers can only be interpreted in terms of the study area. Identically, the NHESS applies a rigorous filter of plagiarism. Hence, the Editorial System did not detect any plagiarism with Lorenzo-Lacruz et al. (2019) in Estrany et al. MS.

In addition, Estrany et al. MS is focused on the following specific objectives (see 1. Introduction section, Lines 103-109): “The specific objectives of this study are to (1) explain the runoff response for elucidating the dependency of flood severity on catchment properties and human influences by using the flash flood Q data from a stream gauge installed in 2015 by the MEDhyCON Research Group; (2) assess the uncertainty of semi-distributed hydrological modelling in such severe flash flood in a karstic environment; (3) investigate the socioeconomic and territorial flood damages linked to hydrogeomorphological processes; and (4) multi-temporally analyse high resolution digital elevation models (HR-DEM) to detect and quantify geomorphic changes by using a UAV and a topography-based connectivity index for a rapid response of post-catastrophe search and rescue tasks".

The specific objectives (methods) of Lorenzo-Lacruz et al. (2019) were stated in the Introduction 1, as follows: "The methodology used for the reconstruction of the event was organized on three main stages: (i) 10 min precipitation has been derived from radar reflectivity observations; (ii) two distinct fully distributed hydrological models have been implemented to accurately simulate the discharge hydrograph; and (iii) a hydraulic simulation has been performed to map the affected areas, including flooding extent and timing, water depth and flow velocity. Some of the geomorphological impacts on the main channel have been also assessed by using very high resolution orthophotographs and digital elevations models for comparison of pre- and post-flooding conditions".

Estrany et al. MS are providing a comprehensive picture of the event from using valuable continuous streamflow discharges very useful to help calibrate the application of hydrological models of extreme flash-floods in karstic environments as well as the application of geomorphic precision approach as a rapid management post-catastrophe civil protection tool. In conclusion, Lorenzo-Lacruz et al. (2019) and Estrany et al. MS are reasonably different perspectives of this catastrophic event.

Regarding the mention about plagiarism on specific figures, it is worthy of note that all these figures were already presented on the "International Seminar on flood risk planning and management in Mediterranean environments" organized by the Institute of Agroenvironment and Water Economy at the University of the Balearic Islands, in March 2019: http://diari.uib.cat/arxiu/Seminari-internacional-sobre-planificacio-i-gestio.cid579735. This seminar was specially organized to assess the Sant Llorenç des Cardassar catastrophe as well as generating a debate among the different public stakeholders aiming at improving the planning and prevention of these catastrophic events. The full Seminar can be viewed on the UIB youtube Channel: https://youtube.com/watch?v=mVjJfmUj0Lcwe.

We can also specifically point-by-point comment each figure that Dr. Lorenzo-Lacruz is accusing us of plagiarising:

a) “figure 2 of the published paper and figure 2 of this manuscript”. It is true that our Figure 2 has some coincidences with Figure 2 of Lorenzo-Lacruz et al. (2019). Specifically, a synoptic weather map of the day of the event and a satellite image were used in both Figures. It has to be considered that the usage of compositions like this are very common in papers focusing in flash-floods episodes. It was not the aim of the authors of the paper to copy any Figure or idea of Lorenzo-Lacruz et al. (2019). Our aim was to use a ‘the facto standard’ composition to facilitate the comprehension of the synoptic situation of that specific day.

b) “figure 6 and figure 7”. Carefully comparing Figure 6 from Lorenzo-Lacruz et al. (2019), we are detecting that our Figure 7f is depicting as background the official flood risk maps and flood delimitation by Copernicus EMS at the Sant Llorenç des Cardassar village, but in the Figure 6a from Lorenzo-Lacruz et al. (2019) this information constitutes the basics of this Figure 6a. Accordingly, the purpose of both subfigures is completely different; i.e., the Fig. 7f from Estrany et al. MS illustrated the damage assessment, showing the location of affected buildings by the 9th October 2018 flash-flood compared with different levels of flood risk. In the case of the Fig. 6a from Lorenzo-Lacruz et al. (2019), it presented the checking of flooding extension of the 9th October 2018 flash-flood and selected return periods of flood risk.

c) “figure 9.c of the published paper with figure 8.c of this manuscript”. As we widely stated through this point-by-point document, almost all data exposed in our manuscript were collected from our hydrometric station and during the very intense fieldwork campaign in the fortnight following the catastrophe, in which the MEDhyCON Team was collaborating with the Emergency Resources to help in finding the last missing victim. The aim of the Figure 8c from Estrany et al. MS was showing the overbank sedimentation estimated after the flash-flood by using our own data; i.e., a DEM performed with SfM from an imagery collected during a UAV flight campaign (15th October 2018) to find the last missing victim. It is also quite curious that the imagery and all data used in Lorenzo-Lacruz et al. (2019) was ceded from a private company or public agencies (see the Acknowledgments of this paper), not being original from the authors.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2019-304, 2019.

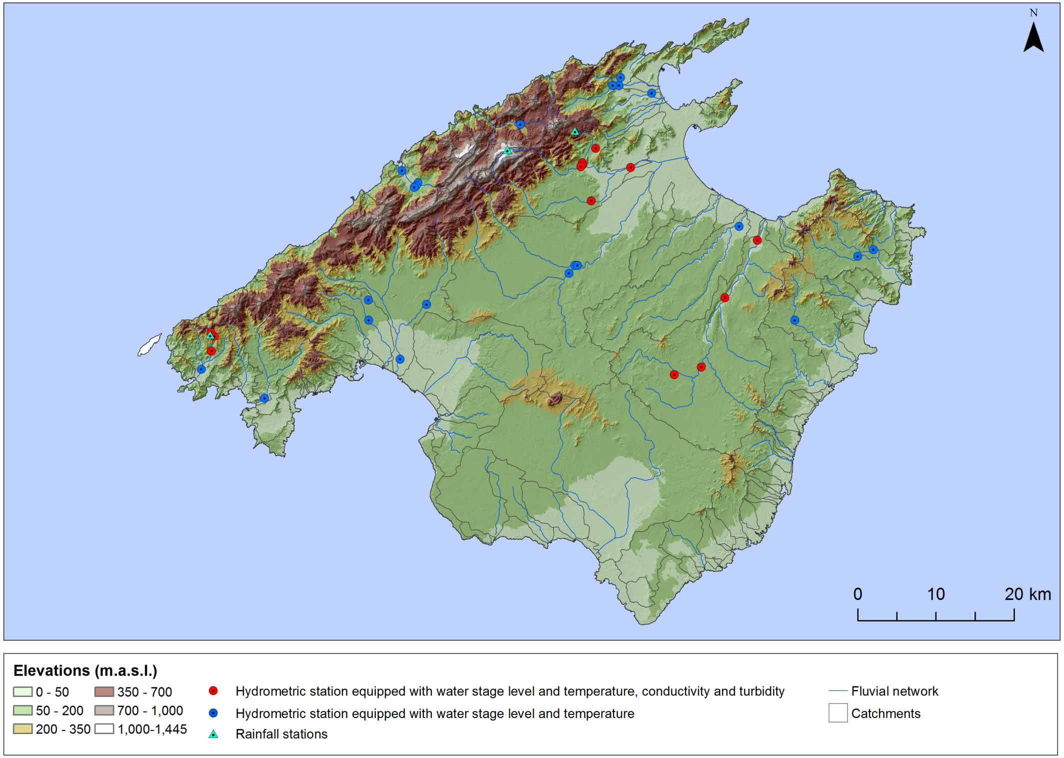

Fig. 1. Hydrometric network deployed by the MEDhyCON Research Team applying continuous streamflow monitoring.

(a) (b)

Fig. 2. Hydrometric station of the Begura de Saumà River. (a) Installation of the digital equipment, 10th June 2015. (b) Data downloading the day after the flash-flood -10th October 2018-.

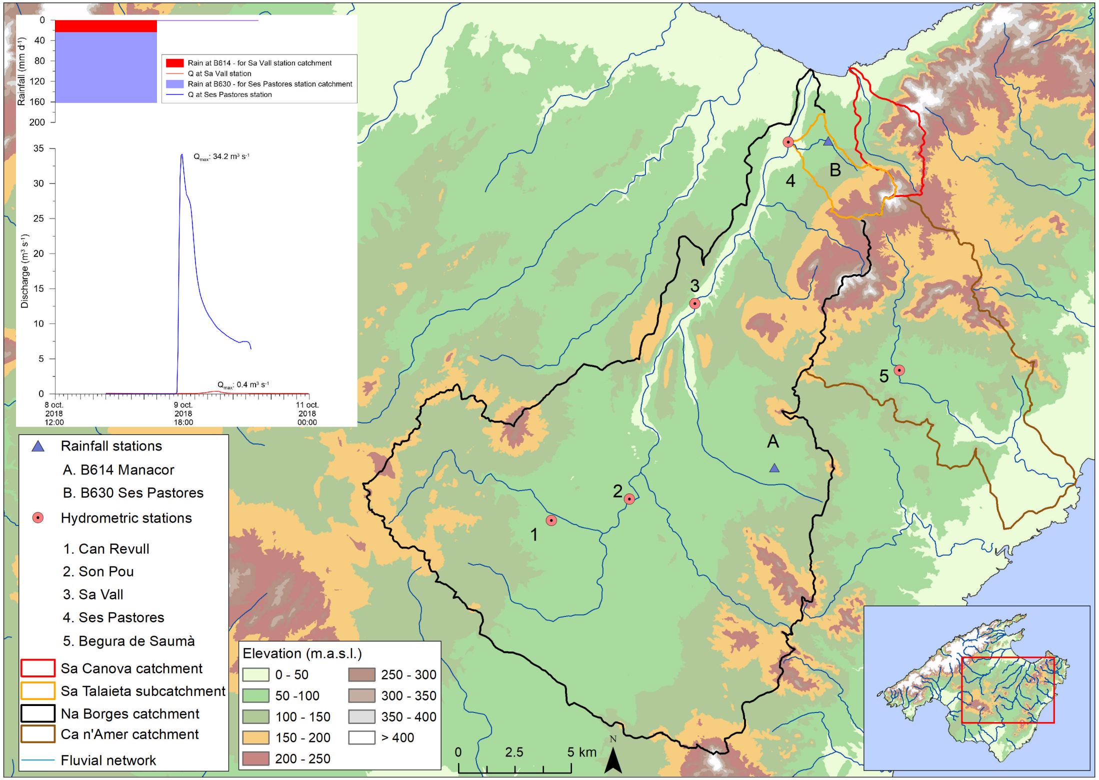

Fig. 3. Map of the north-eastern part of Mallorca Island, showing the catchments commented by Dr. Lorenzo-Lacruz with AEMET rainfall stations and MEDhyCON hydrometric stations.

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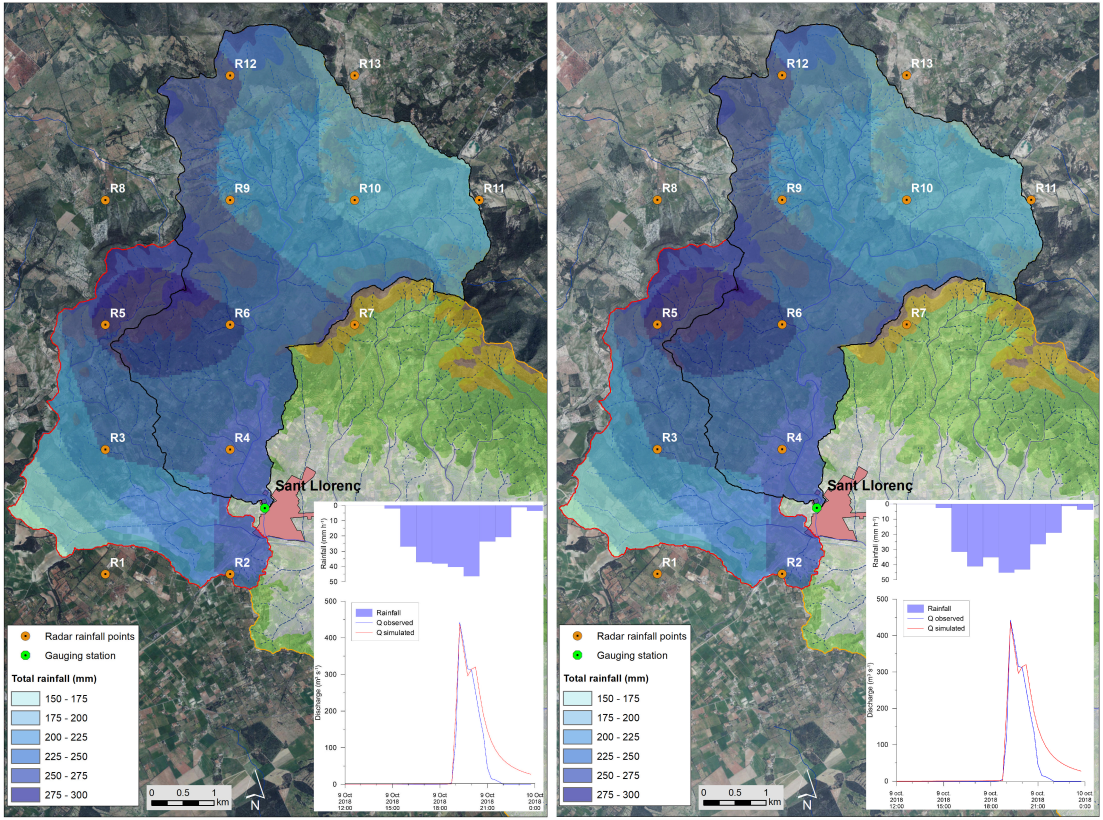

(a) (b)

Fig. 4. Comparison between the (a) Figure 6 of the Estrany et al. version in the Open Discussion stage and the (b) Reviewed Figure 6 that it will be submitted in the reviewed version of Estrany et al.

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