Answer to RC1: Comment on esurf-2021-91 from Damien Kuss

June 26, 2022

We wish to thank the referee for his careful evaluation of the manuscript. Please find below the detailed answers. The reviewer's comments are shown in bold and some modifications of the manuscript are emphasized in blue.

General comments

This article is original and particularly interesting with the use of a 2D hydromorphological numerical model in a torrential context. The task is challenging as the study concerns the modeling of a reach of braided river with wandering flows which are by nature random and are therefore particularly difficult to model in a deterministic way.

From a methodological point of view, the numerical aspects are very well described. On the other hand, the study site and the modeled domain deserve to be better described: length, slopes... A longitudinal profile, encompassing the modeling domain, would make it possible to better understand the problem of deposition during floods in link with the weirs and with the decrease in the longitudinal slope. The influence of the solid volume taken inot account, linked with the slope, could be discussed in the results section.

A better description of the study site including length and slopes will be added in the text. The longitudinal profiles extracted from the LIDAR DEM of 2016 and 2019 will be plotted in the description part (Fig. 1).
A discussion will be added in the boundary conditions section regarding the possible influence of the upstream boundary condition on solid discharge, as explained below.

The hydromorphological modeling is carried out taking into account only bedload (with Meyer Peter and Recking formulas). But you mention, by exploiting the data from dredging, that the fraction of the volume transported by bedload would represent only 8 to 16% of total transport (lines 417 to 417). There is an inconsistency:

- **The altitudinal evolutions observed by DoD are compared to the modeled bed evolutions, which only include sediment transport by bedload;**
- **On the other hand, the modeled transported volume is compared to the total volume observed minus the fine fraction (volume transported by suspension).**

In the Lac des Gaves, the deposit consists of an upper layer of coarse material over the first few centimeters, with finer sediment stored below. In the simulations, only the bedload has been taken into account while the difference in altitude between the LIDAR DEM of 2016 and 2019 takes into account the total load. This is one of the reasons why several differences are observed between simulations and DEM evolution. Considering only bedload transport is probably the most wrong in the downstream area of Lac des Gaves where significant deposition of fine sediments has been observed. These aspects have been mentioned in the manuscript already but will be clarified and detailed.
As far as volumes are concerned, the simulations were compared to the dredging volume, but

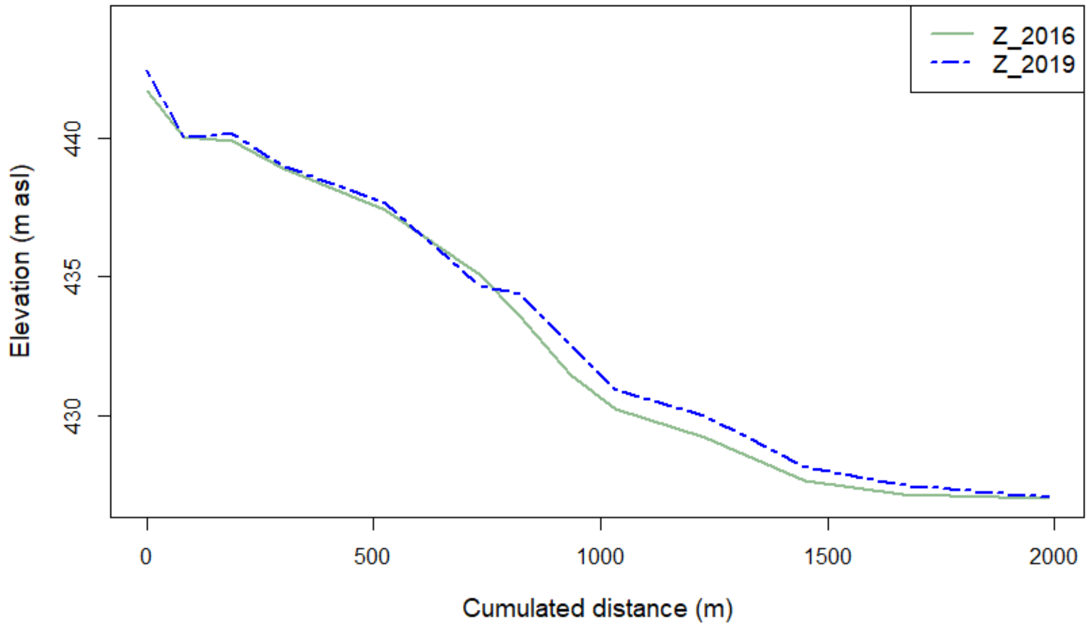

Figure 1: Longitudinal profile evolution following the flood of 2018.

taking into account only a fraction of this dredging volume: between 8 and 16%, which refers to the fraction of bedload transport. This will also be clarified in the text.

The performance of each modeling scenario is evaluated with the BSS score. In a braided river context, the scores obtained are not good (BSS = 0.06). You discuss the representativeness of this metric for such river morphologies. If the metric can be criticized because of the random nature of the wanderings, it would also seem relevant to question the added value of a 2D model compared to a 1D model in such a context. You could precise the configurations where a 2D model is apropriate.
Wouldn't a 1D model have been enough? The choice of a 2D model has been made because it allows a better representation of the hydrodynamics and in particular of the friction with taking into account a spatialization of the water height. Even if the representation of the braiding and of the different flow arms is not the real one, the 2D model has the advantage of a continuity of the dynamics, contrary to the 1D model with interpolation between two profiles and water height projected on the DEM to estimate the extent of the flooded area.
For all these reasons and despite the random nature of the wandering which is difficult to reproduce, we still think that 2D is a better choice than 1D in the Lac des Gaves area. On the other hand, the choice of the BSS criterion is more debatable. Such a discussion will be added in the model section regarding the 1D vs 2D choice and in the final discussion section regarding the BSS choice.

Specific comments Reference Reisenbücchler et al., 2019 at the end of sentence line 19. What does it refers to ?
This is a typo, this reference will be removed.

Line 19 : "They showed". "They" refers to Rickenmann et al. or Reisenbuchler et al. ?
"They showed" will be replaced with "Reisenbüchler et al. (2020) showed".

Line 38 to 40 :

- **a mention could be made of more recent formulas partially based on field data (Recking, 2013 ; Lefort, 2015).**
  The Recking formula will be mentioned at that point. We didn't find a formula from Lefort in 2015 but we will mentioned the one from Lefort (2007).
  although more recent formulas are partially based on field data (Recking, 2013; Lefort, 2007)

- **are bedload transport formulas established in 1d narrow channels directly transposable in 2D models ?**
  The Recking formula that has been implemented is a version compatible with 2D calculation. It will be added in the text.
  We used the version of this formula compatible with 2D calculation and local data (Recking et al., 2016) which is introduced below.

$$\phi = 14 * \frac{\tau^{*\ 2.5}}{1 + (\frac{\tau_m^*}{\tau^*})^{10}} \quad (1)$$

  with

$$\tau_m^* = 0.26 * S^{0.3} \quad (2)$$

  The parameter τ_m^* is a mobility term that defines the transition between partial transport and full mobility Recking et al. (2016), τ^* is the Shields number and S [m/m] the river bed slope.

Lines 40-41 : the slope used for the sediment transport calculation at the upstream boundary condition of the model is a key parameter to perform realistic simulations. It must be apprehended by a geomorphological analysis based on the the longitudinal profile.
As explained, a morphological equilibrium condition has been set at the inlet because of numerical instabilities generated at the level of the boundary cells with other kinds of solid boundary conditions. We agree that this is indeed a strong assumption and studies are currently underway with the new solid transport module Gaia of the TELEMAC-MASCARET modelling system to test the impact of this boundary condition on the simulations.

Line 63 : "The TELEMAC-MASCARET modelling system has been considered well suited to perform 2D morphodynamic simulations on the LDG reach". Why ?
Clarifications will been added to the text.
Indeed, previous studies have shown that TELEMAC/Sisyphe was able to reproduce processes of erosion/deposition accurately in similar configurations (Reisenbüchler et al., 2020, 2019; Cordier et al., 2019). Sisyphe enables the use of different transport formulas (Meyer-Peter and Müller, 1948; van Rijn, 1984) and also take into account various factors influencing sediment transport, such as the effect of the bed slope (Koch and Flokstra, 1981; Soulsby, 1997) on the magnitude of the bedload transport (Riesterer et al., 2016). It also offers the possibility of programming other formulas, both for the parameterisation of friction and for solid transport, a possibility which has been used here to introduce formulations more adapted to the context of mountain rivers.

Line 92-93 : you could add a reference at the end of the sentence.
Reference will be added in the text.

a longitudinal profile would complete the description and would allow to better understand the effects of the two weirs during the floods.

The longitudinal profiles extracted from the LIDAR DEM of 2016 and 2019 will be plotted in the description part.

Lines 101-104 : you could add references concerning the peak discharges.
Reference will be added in the text.

Figure 3 : you could add the reference for each picture
References will be added in the text.

Lines 164-166 : you could add a reference : Rickenmann and Recking (2011) ?
Reference will be added in the text.

Lines 185-188 : please define all the terms used in equation 5
The definitions of Φ and $\tau*$ will be added in the manuscript.
Φ is the dimensionless solid transport, calculated as $\Phi = \frac{q_{sv}}{\sqrt{g(\rho_s/\rho-1)D^3}}$ with q_{sv} $[m^3/s/m]$ the unit solid volume transport: $q_{sv} = Q_{sv}/W$ with Q_{sv} $[m^3/s]$ the solid volume flow rate, W $[m]$ the river width, ρ_s $[kg/m^3]$ the density of the sediments, ρ $[kg/m^3]$ the density of water and D $[m]$ the grain diameter.

$\tau*$ $[-]$ is the Shield number, calculated as $\tau* = \frac{\tau}{g(\rho_s-\rho)D}$ with τ $[N/m^2]$ the shear stress.

Lines 195-208 : note that the recking formula : (a) is mainly base on lab experiments for high shields numbers ; (b) is very sensitive to the choice of the shields mobility parameter. So the avantages of using this formula for intense floods where the shields number exceeds the mobility parameter could be discussed.
Clarifications will be added in the text.
The parameter τ^*_m is a mobility term that defines the transition between partial transport ($\tau^* < \tau^*_m$) and full mobility ($\tau^* > \tau^*_m$) (Recking et al., 2016). The Recking formula was calibrated on field data ($\tau^* < \tau^*_m$) and laboratory data ($\tau^* > \tau^*_m$). It is the value of τ^*_m that gives its shape to the model. Therefore the value of τ^*_m strongly impacts the result, and its determination is difficult, especially for mountain streams. Ideally it should be based on measurements. Failing that, the available data suggest that an estimate is possible (Recking et al., 2016).

Lines 225-226 : it is not clear how you use the dredging data.
Clarifications will be added in the text.
Indeed, coarse sediment dredging data over 11 years were collected upstream the first weir. Using this data, the fraction of bedload of the total sediment transport has been estimated. This is necessary as our model only consider bedload transport when in fact there is both bedload transport and transport in suspension.

Lines 234-235 : "However, the recorded volumes represent both very fine sediments probably transported by suspension and very coarse sediment via bedload transport". The model used in the study takes into account only the bedload transport, Is it right ?
Yes, that's right, the numerical model only takes into account the bedload transport but only 8-16% of the dredging volumes are compared to the simulated volumes as explained in section 5.3. The 8-16% range corresponds to the estimated contribution of bedload to total transport.

Lines 269-270 : you therefore make the assumption of no downstream influence. Yes that's right, we made the assumption of no downstream influence, that is to say dewatered regime for the weir which is most often verified on site.

Line 276 : what do you mean by "instabilities" ? These are numerical instabilities that lead to aberrant erosion or deposit, extremely high and localized on only one or two cells of the boundary. Clarifications will be added to the text. Unfortunately, this generated many numerical instabilities that lead to aberrant erosion or deposit, extremely high and localized on only one or two cells of the upstream boundary.

Lines 276-278 : the slope of the LDG reach is never given. What is slope at the upstream boundary condition ? Is the hypothesis of stable riverbed evolution justified ? What was the observed evolution of the river bed at the upstream condition during the floods ? The bed slope at the upstream boundary condition is 0.018 m/m. As mentionned before, it was difficult from a numerical point of view to impose solid discharge from larger model. Nevertheless, the area of interest of the study is located between the 2 weirs (between 500 and 2000 m on figure 10). In this part, the evolution of the bed is less influenced by the choice of the boundary condition than in the upstream part. Then it can be assumed that the upstream boundary condition on solid discharge has low influence in the area of interest: the upstream condition is located sufficiently far from it to reduce its influence. This is a relatively good assumption for the flood event of 2018 for which little material seems to have come from upstream the area of interest. Of course this will not be true for the flood event of 2013 for which large amounts of sediments have come from upstream. Again, we agree that this is indeed a strong assumption and studies are currently underway with the new solid transport module of the TELEMAC-MASCARET modelling system to test the impact of this boundary condition on the simulations. Discussions will be added in the text on this topic. At that location, the bed slope is 0.018 m/m (Fig. 6). The particularity of this boundary condition is that it delivers sufficient bedload at the model inlet to keep the riverbed elevation at the inlet cross-section constant in time. It has been assumed that the upstream boundary condition on solid discharge has low influence in the area of interest which is the Lac des Gaves: the upstream condition is located sufficiently far from it to reduce its influence. This is a relatively good assumption for the flood event of 2018 for which little material seems to have come from upstream the area of interest.

Lines 286-287 : you could detail what you mean by numerical and physical parameters. The numerical parameters are related to the time step, the type of solver and its accuracy for instance. The sentence will be removed as it's not the purpose of the paper and it may be confusing.

Figure 6 : how do you transform 2D results into 1D longitdunal profile ? There is no transformation: the 1D plot is just an extraction of the longitudinal profile from the lowest bathymetric points of the 2D results. Clarification will be added in the text. The 1D longitudinal profiles of the present paper are drawn from an extraction of the lowest bathymetric points of the 2D model.

Lines 326-327 : "To date, numerical models cannot predict channel migration processes that occur in braided rivers. These phenomena are uncertain and random. A modeler should thus not expect the model to predict channel migration accurately during a flood.". I agree. Butin consequence you should better justify why you have chosen a 2D hydromorphological model for this case study. Clarification on the choice of a 2D hydromorphological model will be added in the text, in the model description section.

The choice of a 2D model has been made because it allows a better representation of the hydrodynamics and in particular of the friction with taking into account a spatialization of the water height. Even if the representation of the braiding and of the different flow arms is not the real one, the 2D model has the advantage of a continuity of the dynamics, contrary to the 1D model with interpolation between two profiles and water height projected on the DEM to estimate the extent of the flooded area.

Lines 331-332 : is the 2019 LiDAR realigned ?
No the 2019 DEM is not realigned, Fig. 7a was obtained by calculating the difference in elevation between the 2 available DEMs, the one of 2016 and the one of 2019.

Figures 10-11 : I regret that the 2016 profile was not drawn with a solid line. it's hard to see the position of the fall. You could also explain how you transform 2D results with a bed level not constant over cross sections in to longitudinal profiles.
The 2016 profile will be drawn with solid line. There is no transformation of the 2D results: the 1D plot is just an extraction of the longitudinal profile from the lowest bathymetric points of the 2D results.

Figure 13 : how do you explain the deposits above the max water level ?
There is no deposition above the maximum water level. The elevation at 439 m at about 130 m cumulated distance corresponds to the topography from the original 2016 DEM that has not been eroded.
Clarifications will be added to the text.
For instance, the elevation at around 439 m at about 130 m cumulated distance in the upstream cross-section (Fig. 13a) and 13b)) corresponds to the topography from the original 2016 DEM that has not been eroded during the simulation.

Figure 14 : the initial profile is missing. It could be a usell information.
The initial cross sections are already plotted, it is the 2019 DEM which is the most recent topography information available from which the restoration scenarios have been simulated (Z_2019 on the figure). Clarifications have been added to the text.
Two restoration scenarios were performed using the LiDAR DEM surveyed in 2019 as the initial topography.
and in the legend of Figure 14.
Z_2019 represents the LiDAR DEM surveyed in 2019 that is the initial topography.

References

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