Reply to Comments by:

REVIEWER 2

General Comments:

The manuscript evaluates the efficacy of the two available approaches of estimating the velocity distribution of a given discharge passing at the Paglia River reach flow sections in the vicinity of the Adunata bridge subject to the conditions of with and without the impact of the presence of bridge piers on the velocity distributions of the flow estimated at these sections using the entropy theory. These velocity distributions are compared with that of the velocity distributions of the same discharge obtained at these respective flow sections based on the flow fields simulated by a Computational Fluid Dynamics (CFD) model, considered as the benchmark model. The CFD model is set up using different types of observed input data measured and collected based on the recorded water level, velocity measurements made using current meter, rating curves and free surface velocity data collected using the water level and velocity radar sensors mounted on the downstream of the Adunata bridge deck for the three considered past flow events of 2012, 2019 and 2022. Further, the velocity distributions estimated at the studied river flow sections based on the application of entropy theory were assessed using the ADCP measurements made at the section far away upstream of the Adunata bridge. To simulate the velocity distributions at the studied river sections using the entropy theory, the authors have adopted two approaches of using the surface velocities estimated by the CFD model simulations at the considered sections of the considered flow event, *viz*., the use of span-wise simulated surface velocity estimates at the considered river section, and use of only the simulated maximum surface velocity estimate at the same section. Based on the study, the authors arrive at the conclusion that the span-wise estimated surface velocity measurements are needed to effectively capture the sectional velocity distributions close to that simulated by the CFD model at the sections immediately downstream of the bridge where the flow fields are impacted by the disturbance generated by the presence of bridge piers; whereas, the flow sections at far away upstream and downstream of the bridge, where the flow fields of the passing discharge are not impacted by the bridge piers, the velocity distributions estimated at these section using the entropy theory based only on the use of maximum surface velocity information may be sufficient for closely reproducing the CFD model based velocity distributions at these sections.

The study is timely and a needed one to widen the knowledge on the field applicability of the entropy theory for discharge estimation. It can be inferred from the study that when the flow field in a river reach is not impacted by the presence of a structure constructed across a river, then the measurement of maximum surface velocity may be sufficient to estimate the discharge passing at that section using the entropy theory. However, when the river section flow characteristics are impacted by the presence of a structure constructed across the river, then span-wise surface velocity measurements may be required to simulate the actual velocity distribution that prevails at that section which is required for serving the purpose of studying scour around the bridge piers. Therefore, both these different approaches of estimating surface velocity measurements using velocity radar(s) have their relevance to serve their intended practical purposes. The manuscript deserves to be accepted for the stated reasons. However, the authors need to address many comments and incorporate corrections in the manuscript, as given in the following pages, before its publication in the final form.

RE: We thank the reviewer for appreciating the paper and for the constructive criticism and comments, which allow us to improve the paper.

Specific Comments:

(1) Since the manuscript describes the study carried out by the authors and then reported here, it would be appropriate to describe the study in the past tense rather than in the present tense, throughout the manuscript.

RE: Thank you for noting. Some parts of the text were already in the past tense. We reviewed the manuscript and moved to past other parts referring to the specific activities carried out in this study.

(2) Since the main emphasis of the study is related to the velocity distributions of a given discharge passing through many flow sections of the river reach in the vicinity of a bridge, the title of the manuscript may reflect on this aspect, specifically changed as "Estimating the velocity distribution and the discharge passing at different flow sections of a river reach in the vicinity of a bridge using the entropy theory: Insights from the flow fields generated by a computational Fluid Dynamics model."

RE: Thanks for the suggestion. We added "velocity distribution" in the title besides "flood discharge". We note that the title is already long, so it is desirable to add as little text as possible. We acknowledge that the cross-sections we used in the analysis are not located exactly at the bridge, but it is also the common practice that flow and discharge measurements are often carried out from bridge, but not exactly at the bridge section. The sections that are closest to the bridge, in our study, are 50 m upstream and downstream of the bridge, a distance which is about 0.45B, with B the width of the riverbed at the bridge section. These sections are indeed very close to the bridge, particularly considering that, while the water level sensors measure perpendicularly, the remote sensors for surface velocity (such as radar, Large Scale PIV, etc.) have their field of view located some tens of meter upstream or downstream of the bridge. Similarly, when a current meter is operated from a bridge, the drag force moves the current meter downstream at a distance that depends on the height of the bridge with respect to the free-surface elevation and on the drag force of the flowing water. Finally, note that the flow fields predicted by the CFD model show that the velocity distribution varies abruptly at the upstream edge of the bridge (flow contraction), and smoothly in the tens of meter upstream and downstream of the bridge. Accordingly, for the purpose of the study, we remain convinced that the particular choice of looking at cross-sections located 50 m upstream and downstream of the bridge can still be regarded as sections "at" the bridge. We are reluctant to use "in the vicinity" because of the length of the title (which was extended to include "velocity distribution"), and because it makes the title much less fluid than simply "at". We added some text at the beginning of Sect. 3 to explain the issue of cross-section spacing:

> "The sections just upstream and downstream of the bridge are located at a distance of about 0.45B from the bridge, with B the width of the river at the bridge section. This is a short distance, particularly considering that the remote sensors for surface velocity (such as radar, Large Scale PIV, etc.) have their field of view located some tens of meter upstream or downstream of the bridge. The sections far downstream are considered to assess how far the flow field is affected by the presence of the bridge."

Finally, the fact that we also considered two cross-sections further downstream of the bridge is only meant to assess how the disturbances generated by the bridge vary in space. The core of the study is an attempt to answer the question: "how can we estimate the discharge with the entropic theory and measures carried out from river bridges?", which is well reflected by the modified title.

Thus, the title was modified to:

> "Estimating velocity distribution and flood discharge at river bridges using the entropy theory. Insights from Computational Fluid Dynamics flow fields"

(3) Line #38, Explain, what is the secondary current of the second kind?

RE: Secondary flows of the second kind are quite basic features of open-channel flows, which originate at the channel boundaries and streamwise corners because of turbulence heterogeneity. We added some words on this, just before the references in which the matter is clearly explained. Now the text reads:

> "…the presence of banks and of discontinuities of bed elevation in the spanwise directions can generate secondary currents of the second kind because of turbulence heterogeneity (Nikora and Roy, 2011; Proust and Nikora, 2020)."

(4) Line #65, use of some field data! Which field data?

RE: Sorry. We agree that the text was not clear (and annoying too). Indeed, we rewrote and improved large part of the Introduction. In the revised text, now we first introduce different techniques used measure the surface velocity, and then of methods the use these data to estimate the flow discharge.

(5) Line #76, What do you mean by "weak gauging sites?" or is it wake affected gauging sites?

RE: We intended a gauging site with insufficient data to obtain reliable estimates of the flow discharge. This part of the text has been deleted to improve the readability of the Introduction.

(6) Line #89, two European rivers! Specify these two rivers.

RE: In the revised text, this sentence has been removed.

(7) Lines #106-107, severe flooding and high sediment transport! What is the impact of the high sediment rate transport on the flow velocity and its distribution under different magnitudes of sediment laden flood discharge?

RE: The issue of sediment transport and of mobile bed has been also raised by the first reviewer. While the problem of bed mobility is somewhat of second order in view of estimating the flood discharge using non-contact sensors, we agree in that solid transport and morphological changes can really complicate the business in many practical cases. In the specific case considered in the present study, the bed is stabilized by a bed sill about 300 m downstream of the bridge. Historical aerial views show minor changes in the point bar forming downstream of the bridge on the left, reasonably because the bridge structure acts to stabilize the riverbed from (at least) a planimetric point of view. According to the reviewer suggestion, we changed the Conclusions to better remark the possible limitations of assuming a fixed bed. Now the text reads:

> "A main limitation of the present methodological approach relies in the assumption of fixed bed in both the CFD analysis and the application of the entropic model. In natural rivers, bed scouring during sever flood events and the ensuing formation of local deposits, especially close to in-stream structures such as bridges, can alter the bathymetry and, in turn, the velocity distribution and the discharge estimates. In case of movable bed and absence of protection measures (e.g., riprap or bed sills), the uncertainty associated to the local bed mobility has to be evaluated with due care.
>
> Future research ~~will include the analysis of stage-dependent variations of cross-sectional velocity distribution, particularly in case of compound cross-sections that are typical of natural rivers. M~~ on more complex scenarios that still need a comprehensive

assessment, and which could largely benefit from physics-based numerical modelling, will include the case of mobile beds~~, in which the geometrical variability occurring at the passage of floods adds uncertainty to the discharge estimation~~ and the analysis of stage-dependent variations of cross-sectional velocity distribution, particularly in case of compound cross-sections that are typical of natural rivers."

(8) Line #117, "mayo axis", is it "major axis"?

RE: Yes, of course. We fixed the typo. Thank you.

(9) Line #167, it is stated that three different steady flow conditions are simulated using the 3D-CFD model which correspond to the peak flow conditions of flood events occurred in 2012, 2019 and 2022. But in Line #173, it is stated that surface velocity data are not available for the 2012 flood event. So how the 2012 flow event's velocity distribution was simulated using the CFD model for the peak discharge of the 2012 flow event?

RE: We agree that, in the previous version, the use of data (either measured or derived from the 3D-CFD numerical model) was not sufficiently clear, and apologize for that. As a preliminary step, a 2D depth averaged model was setup and calibrated with the rating curve available for the bridge section (Appendix A), in order to obtain reliable water level elevations downstream of the bridge. A 3D-CFD model was then setup and forced with the flow discharge at the inlet and the water stage (derived from the 2D model) at its outlet. The CFD model, which does not require any calibration, was validated using the surface velocity data that were available for the 2019 and 2022 event (Appendix A), not for the 2012 flood event (the instrument was not mounted at that time yet). The 3D-CFD model has been used to derive physics-based flow fields in the vicinity of the bridge. Of the 3D-CFD flow fields, extracted at the four considered cross-sections, the surface velocity distributions were used as input for the entropy model, and the cross-sectional velocity distributions were used to benchmark the results of the entropy model.
The text was changed and improved so that we are confident that in the revised version of the manuscript these aspects are sufficiently clear.

(10) Line #185, define phi(M)!

RE: Thank you for noting. Now all the parameters and functions are properly introduced and defined. Please see also our answer to major point #2 by Reviewer 1.

(11) Line #208, Phi(M) is defined as entropy parameter, and in Line# 74, the parameter M is also defined as entropy parameter. So, a consistent definition of these parameters needs to be given.

RE: Thank you for noting. As reported in the comment above, now all the parameters and functions are properly introduced and defined. $\phi(M)$ is the entropy function and M is the entropy parameter.

(12) Table-2 contents, the second line inside the Table the estimate of M is given as -1.03, what is the physical meaning of a negative M?

RE: The M value is the main parameter the entropic distribution depends on. According to Eq. (2) in the paper, M has a one-to-one relationship with the entropic function, $\phi(M)$, which, being the ratio of the average to the maximum velocity in the cross-section, is always positive. The physical meaning of the entropy function, $\phi(M)$, is clear, as the values it assumes are larger (i.e., close to one) when the velocity distribution is nearly uniform. The magnitude of M can be negative depending on the analytical nature of Eq (2). Overall, it usually happens when the distribution of the cross-sectional flow is far from being uniform, i.e., when the maximum velocity within the cross-section is much larger than its average value. In the present study, this occurs just downstream of the bridge, where the abrupt geometrical variations produce strong acceleration in the flow field.