We thank reviewers for their thorough review of the manuscript and the constructive suggestions. The comments and suggestions are answered sequentially following the order of reviewers' questions and comments.

Response for HESS-2020-75 Reviewer #2
A new form of the Saint-Venant equations for variable topography

R2C1

Line 42. In commenting eq. (4) the Authors should explain what they intend for "associated depth consistent with the above definition"

Response to R2C1:

Agree. We have modified the text as shown below

> *Beginning Line 42: where S_R is an arbitrary reference slope and ha is an "associated depth" that will defined in §3.2, below. For an introductory exposition, ∂ha/∂x is merely the residual implied for a given ∂η/∂x and arbitrary S_R. Applying eq. (4) to eq. (1) provides:*

Note that in this introductory section we are trying to make things clear without providing the full details that are in the Methods

R2C2

Line 185. The manuscript should better explain why the interest is to "non-trivial definitions of $z_R(x)$ that are close to $S_0(x)$ but are guaranteed smooth". This may appear to be in contrast with the circumstance that the mathematical re-formulation of the momentum equation is equivalent for any choice (close or not) of z_R (x) (for the purposes addressed in the paper, at least for any choice providing Lipschitz smoothness).

Response to R2C2:

Agree. We have modified the text as shown below.

> Beginning Line 199: However, this form with ∂η/∂x for the entire pressure term is known to cause numerical stiffness issues for large ranges in η; e.g., the elevation change of a river from its mountain source to a coastal plain (Liu and Hodges, 2014). Using the conventional S_0 in eq. (2) reduces this problem as the range of h_0 is inherently confined to the local water depths rather than the underlying topography. In the RS method, the range of h_a is tied to the range of water depths and the selection of z_R; thus, for present purposes we are interested in non-trivial definitions of z_R that are (i) close to z_0 to maintain a small range of h_a values, and (ii) provide smooth $S_R(x)$. Arbitrary z_R that are far from z_0 or non-smooth are of little interest as they hold no theoretical or practical advantage over the eq. (1) approach implied by $S_R(x) = 0$.

R2C3

Line 210. The discussion here ("approximating cubic B-splines to the $z_0(x)$. . .") may suggest the idea that some choice of z_R (x) could be better than other ones. I think that a comment is needed.

Response to R2C3:

Agree. This is the same point as R1C6, answered above.

> See new text beginning Line 242 and new text beginning line 503 as provided in answer to R1C6, above.

<u>R2C4</u>
Line 471. The Authors should add in the revised manuscript a comment on the potential benefit provided by “automatic generation of approximate splines for large river network”: is that essential for the successful application of the proposed methodology? Why?

<u>Response to R2C4:</u>
Agree: We have modified the discussion of splines in two places in response to R1C6 and R2C3. These revisions include the discussion noted here. The following text specifically addresses this point

> *Beginning line 506: Our results indicate that approximating cubic B-splines are adequate for producing smooth z_R for the tested geometries, and the solutions are robust to the selection of z_R as long as S_R is smooth (Yu et al., 2019b). However, it is likely there are limitations to applying the RS method in large-scale river network simulation that will make it difficult to use a simple globally-applied knot spacing. Such networks might consist of 10^4 to 10^5 reaches spanning wide geographical regions with a variety of topology and inconsistent data availability. Some reaches may have well-defined cross-sections at close spacing, other reaches might be poorly documented (Hodges, 2013). Thus, it seems likely that a method for automatically generating approximating splines (or some other form of smoothing) would be useful, but such an advance arguably requires a method for quantitatively evaluating the “goodness” of a particular set of $z_R(x)$, which remains an open question. We speculate that simple window filtering techniques may be adequate for river databases such as NHDplus, but further investigation and examination are needed to better understand the interplay between the smoothing scales and the numerical solution using the RS method for large networks.*

<u>R2C5</u>
Please proofread the manuscript. For instance: Line 65. “an” should read “a”. Line 473. Broken sentence? Line 266. “Being” should read “begin”.

<u>Response to R2C5:</u>
Agree. Proofreading has been done. We’ve corrected the addressed places and we appreciate reviewer’s carefulness.

<u>R2C6</u>
Please double check the notation list. For example, momentum coefficient is in the notation list but not in the equations. Similarly, velocity and average velocity. Reference slope is not in the equation. Reference Slope is not in the notation list.

<u>Response to R2C6:</u>
Agree. We’ve edited the notation list by adding/removing the missing/unnecessary notations. We appreciate reviewer’s thorough review.