Review of "GraphFlood 1.0: an efficient algorithm to approximate 2D hydrodynamics for Landscape Evolution Models"

The manuscript presented a numerical hydrodynamic model which incorporates multiple flow direction of water flow on flow depth calculation with an iteration method. Computationally, the model performs better. Geologically, the model is able to produce similar morphological metrics patterns as a similar hydrodynamic model which used a single flow direction algorithm. The transient solutions of the model showing the propagation of the a flood along the channel is also interesting and has potential to be used for more applied problems.

However, I find some problems with the current manuscript that need to be improved to to clarify the model numerical and physical aspects and to sharpen the characteristics of the model.

General suggestions:

- One concern is about the presentation of section 2 and section 3. It leads a lot of confusion regarding the major physical and numerical structure of the GraphFlood model. After reading the Davy (2017) paper, I think this manuscript should be tailored to emphasize its difference with the Davy (2017) model while keeping the core and shared algorithms clear. If I understand correctly, the GraphFlood model is built on the skeleton of the Floodos model but imbedded the graph topological ordering of nodes for water depth calculation with iteration when the water flow direction algorithm is multiple or single flow direction. The iteration method is clearly presented with the chart between line 188 and line 189 and Figure 2 (although only for the D8 single flow direction). However, the multiple flow direction algorithm in the context of this model is not presented at all, or only minorly with Figure 1 but with very limited captions or explanations in the text to understand. I think a comparable figure, similar to Figure 2, showing the multiple flow direction should be made to sharpen the point of the GrahFlood model.

  Section 2 and section 3 used many symbols in equations, text, and figure captions. However, they should be cleaned up to keep consistency and should be explained either in the text or in a summarization table. Right now, different symbols representing same physical parameters are used in the text and equations. For example, the water depth is represented by h in the beginning but later hw is used in figures, text, and equations. Some symbols are missing explanation and they appear in many places in the manuscript. I identified some and pointed them out in the line-by-line comments below. Note that section 4 also has the similar problems of symbols inconsistency. Please check it through as well.

- The other more scientific question is about application to hydromorphometry which is presented in Section 5.3 and discussed further in section 6.3. I find it hard to relate what's

being described in the text of with the supporting figure, Figure 9. The curve segments described in lines 320-323 needs to be indicated on Figure 9 properly. Also, segments indicating different domains were divided with arbitrary cut-off values, why so? Except for the confusion due to presentation style, one scientific question is what is different compared with the Bernard et al (2022) model where single flow direction is used? And another question is how to understand the similarity of s-a(r) curves for the two very different sites where one is flat with low relief, maybe depositional and the other site is steep hillslopes and bedrock channels? These two questions can shed light to landscape evolution modellings of geological scales and tectonic geomorphology studies as also mentioned by the authors. I think this part should be expanded further to demonstrate the important applications of this model. Maybe further analysis is needed to do so, for example, making the s-a(r), or w(r) analysis on the same study site of the Bernard paper with the GraphFlood model. Given that the GraphFlood model outpaces the other models in terms of computation efficiency, it will be better to further demonstrate its geological applicability in terms of the multiple flow direction realization of hydrodynamic laws.

Some minor problems to be fixed:

- Line 52: "…represented by one pixel-wide paths (Figure 2).", Figure 1 should be referred to here.
- Figure 1 captions and key: 1) it is not clear what the black and red arrows in c and d are showing which parameter(s) vector(s). Are they flow velocities showing the relative rate and direction? 2) the symbols, Hw, in a/c and the A in b/d panel need explicit explanation in the figure caption.
- Line 80: "Precipitons increase the water height along their path, bypassing the need to to propagate", typo here, to to
- Line 88-line 90: "A similar approach has been … our new algorithm". I don't see how the multiple flow algorithm suddenly jumps in here after the statement of information integration along 1D flow path. Could you expand to provide more connections with the previous sentence? Also, the abbreviation of multiple flow direction (MFD) should be mentioned here before use it.
- Line 92: GraphFlood is the name of the proposed new model here. It appears in the manuscript for the first time. I suggest making a clear statement that the model is referred to as "GraphFlood" before using it here. Probably the statement should be made even before Figure 1 because Figure 1 used this term already.
- Equation (2), what is *s* in the equation? Line 119, what is *xmax*? Seems *s* is a vector describing the slope (topographic or hydraulic? If hydraulic, what is the exact definition?) of the direction of the steepest hydraulic gradient. Please double check the equation and the explanation of symbols here.

- Line 125: "…the indices ***Xin*** and ***Xout*** to refer…", is it better to say "…the subscript *in* and *out* to refer…"? X here can be mistaken as a new parameter.
- Line 139-141: "In the following, we detail the numerical graph…, we describe the finite …, explain … and validate…". Need grammar check.
- Line 146: "hydraulic surface ($Z + h$)", the symbol Z needs to be explained. Z is topographic elevation?
- Line 150: "…to downstream and *sink filling* a method filling local …", Need grammar check.
- Line 153: "…or Multiple Flow Direction (MFD) DAGs (e.g. Tarboton, 1997; Anand et al., 2020).", there should be a short explanation of multiple flow direction in terms of node and receiver here.
- Line 162-163: "One advantage of GraphFlood is that it can be implemented using existing computational frameworks for DEM analysis and LEM simulation …", meaning the flow direction indexing with the topologically sorted order? More specific details should be provided here.
- Equation (6): the symbol S_{ijmax} need to be explained in the text. It is the maximum slope between the node i and all its receivers?
- Line 185: "The overall process is outlined on algorithm 1.", should the algorithm 1 chart be indexed as tables or figures for clearer citation here? Plus, the symbol h_w in the chart of algorithm 1 is not explained in the text.
- Line 200: "…depth becomes lowerthan an acceptable…", a space is missing between lower than.
- Line 194: "Equation 6 expresses the velocity of a flood wave…", should it be Equation 6 and equation 3 express the velocity of flood wave?
- Figure 2: 1) caption doesn't match with the figure at all. 2) figure 2 should be cited properly in the text, perhaps in section 3.4. 3) Q_w means water flux? The symbol is not explained in the text. *hw* is water depth? If sediment flux is not talked at all in the equations or text, I suggest take out the subscript *w* from *Q* and *h.* 4) it is not clear how iteration 2 is related with iteration 1.1 and 1.2 from the figure. Caption is needed to explain it.
- Line 219 and equation (9): use h* or hw*?
- Figure 3: Will it be better to point out the stationary and transient (numerical) solution curves on figure a? Or explain them more clearly in the captions. Or use line styles or colors to distinguish them.
- Line 274: typo "previoous"
- Line 288: "…flood risk assessment, (Bates, 2022), Bernard et al. (2022) noted that…", both papers made the point?
- Figure 8: need to include the colorbar in the figure. Dark blue is bigger water depth and light blue is lower water depth? It is confusing without a clear colorbar indicating the parameters being colored on the maps.

- Line 298-299: “We instantly increase the input discharge by a factor 3 and …”, does it mean that higher input discharge lasts for all time steps from time 1 to time end? It is a bit unclearly stated here especially compared with figure 8 which shows higher water depth everywhere but migrating flooding extent from time 26s to time 142s. I feel section 5.2 under-described these observations.
- Line 314: I feel the Bernard et al (2022) paper should be cited here for a clear reference of the specific drainage area, $a_s(r)$.
- Line 318 and Figure 9: “For clarity, we use arbitrary thresholds from the s - as(r) plots to determine the transitions.”, 1) what is s? the hydraulic slope or topographic slope? 2) I don’t understand why arbitrary thresholds are used in Figure 9 to divide the different domains…