Challenges in modelling ice floods on the Ningxia-Inner Mongolia reach of the Yellow River, China

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We would like to thank the Reviewer 1 for taking time in reading and suggesting modification to the paper.

Answers to specific comments of the reviewer follow:

Comment 1:

The article, " Challenges in modeling ice floods on the Ningxia-Inner Mongolia reach of the Yellow River, China " by C. Fu, I. Popescu, C. Wang, A. E. Mynett, and F. Zhang undoubtedly focuses on an important and actual problem that follows from the title. The article is constructed logically well. The purpose is stated clearly and methods are well-founded. The authors describe in details the object of research and the current state of the art in ice flood modeling demonstrating a good knowledge of advanced modeling techniques. Results obtained in accordance with the intended purpose and well interpreted by provided figures. To obtain these results, the authors use the sensitivity and Uncertainty analysis. Conclusions quite meet the declared objectives.

Authors' answer: We would like to thank the reviewer for evaluating the article as well-founded from the point of view of the objective and clarity of the presentation. We do address all the comments raised by the reviewer bellow.

Comment 2: *However importance and relevance of the work is limited only by its practical application, from a theoretical point of view it is of no interest. This follows from the approaches that are used by the author. Despite the understanding of current approaches (knowledge of which was demonstrated in a review of the article) the authors use a not very modern approach, namely the one-dimensional model. The main questions arise precisely because of the rationale for the choice of the model and set up. Initially, it is clear that the one-dimensional model can not solve the problems associated with flooding in full.*

Authors' answer: With the above comment authors have realised that the explanations we give in the rationale for the carried out research carried is not completely clear. Allow us to elaborate here. Indeed the work is limited by its practical application, however the choice of the 1D model is given by the availability of data at YRCC. Currently there is no DEM available for the Ningxia-Inner Mongolia reach. Data that was available allowed for development of a one dimensional model. As the data collection continues a more complex model will be made available, by extending the existing model to a 1D2D one. Moreover it was very important to use such a model in forecast conditions, in order to determine what are the possible times to have ice-formation and consequently flooding. With the help of such predictions decision makers can take appropriate measures to reduce the risk of flooding. Flooding during cold season is very important, however the main aim of the paper was to determine when ice is formed, and to possibly eliminate flooding, by forecasting the ice formation. Flooding extent was a secondary aim of the study and due to data availability just a 1D model was sufficient to be used.

Comment 3: *Moreover the description of the model YRIDM is practically absent and there is no reference on it. The authors say only "The YRIDM is based on the RICE and RICEN models, and designed taking river ice processes into account... It consists of three main components, the river hydrodynamics, thermodynamics, and ice dynamic modules. (p 12303*

paragraph 5)" Further hydrodynamic equations are given only. If YRIDM different from RICE and RICEN, it is necessary to dive all of the equations, or give a reference, but if it's just an adaptation of the existing models, why hydraulic equations are presented only?

Authors' answer: Thank you reviewer for pointing out this omission from our description of the model. Indeed we will add in the manuscript all the equations that are different in YRIDM model as oposed to RICE model, as we are detailing bellow, in the answer to this comment. We will leave out the equations that are the same, including the 1D saint Venant equations.

River ice phenomenon includes formation, evolution, transport, accumulation, dissipation, and deterioration of different kinds of ice. The ice formation phenomen is a complex combined effect of the river hydrodynamic and thermodynamic processes, which are under the influence of meteorological and hydrological conditions.

The river ice processes are evolving in time in three main time periods; the freeze-up period; ice-covered period; and breakup period.

Apart from the equations of one-dimensional flow, water temperature distribution along the river is an important factor for the ice formation, during the freeze-up period. The YRIDM model is simulating the ice dynamics, by describing the skim ice formation and frazil ice as it is in teh RICE model. Skim ice formation is based on the empirical equation, developed by Matousek (1984). Frazil ice along the river channel is described by the mathematical model defined by Shen and Chiang (1984).

Another important element in describing the ice dynamics is the static border of the ice formation. Svensson et al. (1989) defined a critical value which shows the formation of static border ice. This critical value is used by the YRIDM model. Finaly the other elements of the ice dynamics are the growth of the border ice, the undercover accumulation, erosion of the ice, and erosion of the ice cover due to thermal growth.

We would like to emphasize that though YRIDM is based on RICE model, there is a major diference in how the break-up of the ice is checked in the two models. In case of RICE the critical value of discharge for which the break-up appears is a constant value that has to be

determined before using the model, by experiments on site, while in the YRIDM model the critical discharge is determined by the follwoing empirical equation:

$$Q \geq \frac{9.5 * a * h_i}{\sum T_{a+} + 1}$$

Where Q is discharge (m^3/s); h_i is the ice cover thickness when air temperature varies from positive values to negative ones (m); a is the breakup coefficient (a = 4 for mechanical break-up and a = 22 for thermal break-up); T_{a+} is the average daily accumulated positive air temperature, measured from the day when air temperature turns positive.

Moreover the basic equations for ice transportation model are different in the two models: YRIDM uses convection-diffusion equation between ice run and floating ice, while RICE uses a two-layer mode for the surface ice transportation.

Comment 4: *Unfortunately I did not find any scientific novelty in current version of the manuscript. Right now it looks like a publication of a new data only.*

Authors' answer: Authors would like to mention that they do not agree with this comment. Tracking ice formation from observations and combining with numerical model predictions for advanced warning, requires proper understanding of all scientific issues that play a role. In case of the Yellow River, ice floods impose a threat every year, which is why the Yellow River Commission is putting considerable effort in verifying theoretical formulations with actual field measurements in order to better understand the scientific mechanisms that play a role. Transforming this knowledge into an Early Warning System that can help save lives is a scientific issue in itself. We might not have emphasized this in the paper therefore we will make this point more clear in the final version of the manuscript.

Comment 5: *It is not obvious and should have explained why initial roughness of ice cover is not included in the number of the sensitivity parameters.*

Authors' answer: The reviewer is right, indeed theoretically roughness should be a sensitive parameter. The roughness of ice cover can be indeed computed based on the end roughness of

ice cover and the decay constant. However authors have checked the user manual of the YRCC model (YIRDM), and noticed that the initial roughness of ice cover is implemented as a constant, not as a variable. The constant has been determined by YRCC and this is the reason why initial roughness of ice cover is not included in the number of the sensitivity parameters.

Comment 6: *Authors correctly identify deficiencies of the model "the model cannot simulate an ice jam breakup during the breakup period (p 12308 paragraph 5), the model ignores the effect on the water body mass balance due to changes in the ice phase, the model cannot work when the water level exceeds the height of the embankment (p 12308 paragraph 20)". In addition, for the forecast of ice floods it is not enough to know the discharge and water levels. Flooded area and the rate of it increase are the main characteristics. But for solutions of these problems will likely not be enough of these general propositions, as "the YRIDM should be improved so that it has the ability to deal with the problem (p 12309 paragraph 20)" and "the model can be further improved, for example, the one-dimensional models extended to two-dimensional models(p 12311paragraph 5)".*

Since according to the authors "the ice dams and jams lead to dike-breaking and overtopping on the embankment (p 12294 paragraph 5)" and "This is the key problem to be solved on the Ning-Meng reach of the Yellow River (12302 paragraph 25)", for forecast of ice floods it is necessary to use other more advanced models such as DynaRICE (DynaRICE Hung Tao Shen, Li Gao, Tomasz Kolerski, and Lianwu Liu (2008) Dynamics of Ice Jam Formation and Release. Journal of Coastal Research: Special Issue 52: pp. 25 – 32.)

or

Debolskaya, E.I, 'Numerical Modeling of Ice Regime in Rivers', Hydrologic Systems Modeling, Vol. 1, Encyclopedia of Life Support Systems, Eolss Publishers, Oxford (UK), 2009. P.137-165. http://www.eolss.net .

Therefore, if "the purpose of this paper is to apply the YRIDM to the Ning-Meng reach of the Yellow River to examine the accuracy of the model (p 12296 paragraph 5)", it can be considered achieved.

Authors' answer: The authors would like to make clarifications regarding the purpose of the model. The accuracy of the model is an important issue indeed and we are glad to see that this

goal has been properly presented in the paper. However the accuracy is just one step in order to achieve the overall objective of the modelling; i.e. to use such a model to help decision makers, during winter times, when flooding events may happen due to the ice regime on the Nang Menxia reach.

Indeed a 2D model would be a better representation of the flooding event, however at this moment, no 2D bathymetry data, and 2D bed elevation data are available at YRCC.

A data driven model is currently available at YRCC, which aims to build a relationship between input and output (detailed bellow). Input data for the data driven model are: the thermal factors (air and water temperature); and the output data: ice run date, freeze-up date, breakup date, the highest water level and ice flood peak discharge during the breakup period.

This data driven model is in its initial building phase and measuring campaigns are scheduled to take place in the next years. The limitation of this data driven model is that specific physical processes of river ice can not be fully understood and represented, therefore the use of a physical based model, even in 1D form is very useful for the understanding of the processes.

We did checked the references suggested by the reviewer and we will make proper reference to them in the description of the model, making it clear why the use of the 1D model was the most logical to be used at this particular moment.

Comment 8: *However second goal/conclusion "A secondary objective is to examine the possibility of applying the YRIDM to forecasting ice flooding in support of decision making (p 12296 paragraph 5)", / "once the model has been calibrated, it can be used to forecast the ice regime to support decision making, such as on artificial ice-breaking and reservoir regulation (p 12310 paragraph 25) " requires significant additional explanation.*

Authors' answer: Thank you for pointing to us the need to elaborate in this issue. As mentioned in the paper there is a need to forecast the ice flood in the winter season for 10-15 days ahead, in order to be able to either artificialy break the ice or operate the releases from reservoirs upstream. During freeze-up period, operating reservoirs to decrease the releases, causes decrease of peak discharge during the breakup period. Through such measures the occurrence of mechanical breakup of the ice can be avoided.

The 1D model has the advantage that if forecasts of the meteorological data are given for 10-15 days, and they are used as hydrological and hydraulic input into the model, the ice regime for the leading time of 10-15 days could be predicted, and support decision-making. It is important to emphasize that the model objective was not to be used to determine the flood extent, but to determine the ice regime, that could lead to a flooding event. Decision makers could try to prevent the formation of ice, through field campaigns that will break the ice and eliminating it, avoiding flooding.

The new manuscript will have this objective clearly emphasized and explained.

Comment 9: *Technical corrections:*

7.1. Tables 1 and 2 can be combined. Need to explain the lack of dimension of measurement units.

7.2. There is no reference in the text to work. Shen, H. T., Su, J., and Liu, L.: SPH simulation of river ice dynamics, J. Comput. Phys., 165, 752–771, 2006. and vice versa (Shen et al., 2000) (p 12297 paragraph 20) is not in list of reference

Authors' answer: We will take note of the technical corrections on the revised version of the manuscript, i.e. tables will be merged, dimensions explained and references will be properly corrected.

The supplement to this comment is a file containing the comments that are available on line, therefore all answers are in this document.

All our responses to the questions raised by the referee will be included in the revised version of the manuscript.