Dear editors:

Thank you very much for your letter and for the respected reviewers' comments concerning our manuscript entitled "An improved dynamic bidirectional coupled hydrologic-hydrodynamic model for efficient flood inundation prediction" (ID: egusphere-2023-1106). Those comments that the respected editor proposed are all valuable and very helpful for revising and improving our paper, as well as important guiding significance to our research. We have studied comments carefully and have revised the article which we hope meet with approval. There were new lines and page numbers in the revised manuscript. All the changes were marked using red bold in the revised manuscript. We also responded point by point to the reviewers' comments as listed below, along with a clear indication of the revision. Hope these will make it more acceptable for publication.

Reviewer #1:

First of all, sincerely thank you very much for your valuable comments. All your suggestions are very important and have important guiding significance for our writing and research. When revising the manuscript, we considered thoughtfully what you have advised.

1. Comment: The paper presents an interesting approach of coupling hydrologic and hydrodynamic models to improve computational efficiency while maintaining numerical accuracy. However, to demonstrate the superiority of the proposed approach, it is essential to conduct a thorough comparison with state-of-the-art individual hydrology and hydrodynamic models. This will help highlight the advantages and necessity of the coupled modelling approach. It's crucial to show how the proposed method outperforms existing models in terms of both efficiency and accuracy.

In the introduction, the authors should focus more on recent progress in coupled hydrology-hydrodynamic models, especially with respect to their proposed coupling method, which seems different from the common coupling methods. Additionally, a detailed explanation of the non-uniform grid generation should be provided to give readers a better understanding of its significance in the proposed approach.

Response to comment: Thank you very much for your valuable comments. The coupling model can be divided into two types: external (one-way) and internal (two-way) coupling models (see Figure 1).

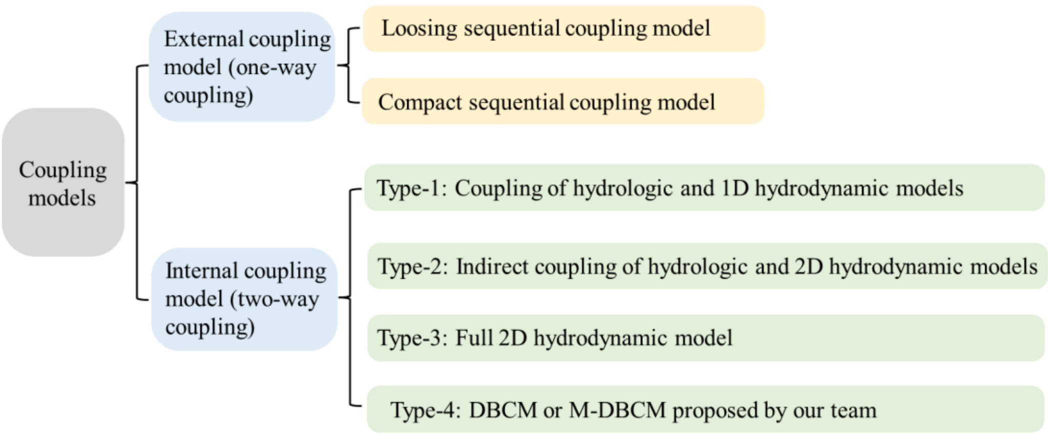


Figure 1 Classifications of coupled hydrologic and hydrodynamic models

One-way coupling models utilize hydrographs obtained from hydrologic models as an input for hydrodynamic models, providing a one-way transition. Usually, the hydrologic model is run first and independently from the hydrodynamic model. External coupling models are powerful tools for watershed flood simulation, in particular large spatial and temporal scale, due to its convenience in model construction. However, the location of the boundary points limits the influence of the upland runoff to downstream waters. The runoff generation on both sides of the river is transferred to limited points upstream of the main stream or tributaries of the river network, resulting in an error in the peak flow rate of the boundary points. Since the flow information is transferred in one-way from hydrologic to hydrodynamic models, the external coupling cannot capture the mutual interaction between runoff production and flood inundation. Moreover, mass conservation of water through the coupling interface cannot be guaranteed.

Two-way coupling models were further divided into four types: the coupling of hydrologic and 1D hydrodynamic models, indirect coupling of hydrologic and 2D hydrodynamic models, full 2D hydrodynamic models, and the DBCM and M-DCBM proposed by our team. The characteristics and applications of different coupling models for flood simulation were detailed as follows.

(1) The hydrologic and 1D hydrodynamic models are calculated synchronously in time in the coupled hydrologic and 1D hydrodynamic models. The flow discharge rate obtained from the hydrologic model is treated as mass source of the 1D hydrodynamic model, while the water depth calculated in 1D hydrodynamic model is fed back to hydrologic model. The coupling of the Mike SHE and Mike11 is a typical example of the coupling of hydrologic and 1D hydrodynamic models. The coupling of hydrologic and 1D hydrodynamic models lacks ability to accurately simulate flood inundation process in 2D regions, such as lakes, reservoirs, complex flows and estuaries where 2D or 3D computations are required.

(2) In order to overcome the lack of 2D hydrodynamic simulation in type-1, the coupling of hydrologic, 1D and 2D hydrodynamic models is proposed. In this coupling type, the runoff first flows into 1D rivers, and then discharge into the 2D inundation

regions, such as lakes or reservoirs. The hydrologic model was coupled with 1D hydrodynamic model, and the 1D hydrodynamic model was coupled with 2D hydrodynamic model. This coupling type is an indirect coupling of hydrologic and 2D hydrodynamic models. For instance, Mike SHE and Mike11 are coupled to form Mike Urban, and Mike11 and Mike21 are dynamically coupled to form Mike Flood. The indirect coupling of hydrologic and 2D hydrodynamic models applied to simulate rainfall-runoff have been reported in many kinds of literature (http://doi.org/10.2166/wst.2017.504; http://doi.org/10.1016/j.jhydrol.2018.07.069; http://doi.org/10.1061/(ASCE)HY.1943-7900.0000485). Compared with type-1, this coupling type has satisfactory and acceptable accuracy and is widely used. However, in these models, the hydrologic model is not directly linked with 2D hydrodynamic model, which is inconsistent with the natural flood processes. In reality, runoff from the uplands may be simultaneously discharged into both 1D channel and 2D inundations, and the hydrologic and 2D hydrodynamic models should be linked directly. Direct dynamic coupling of hydrologic and 2D hydrodynamic model can reflect the flood process more truly. The dynamic bidirectional coupling of the hydrologic and the local 2D hydrodynamic models has been paid much attention.

(3) In this coupling type, only the runoff generation is calculated by the hydrologic model and considered as source term of the continuity equation of 2D hydrodynamic model, and then both the overland flow migration and inundation processes are all calculated by 2D hydrodynamic model. This coupling type is also called full 2D hydrodynamic model (HM2D). The HM2D can be used to simulate the complex flow patterns and achieve satisfactory results. HEC-RAS (version 6.4) was revised and improved in 2023. Figure 2, from the HEC-RAS 2D User's Manual, Version 6.4, Exported - July 2023, shows the multiple 2D inundation regions for floodplains that are connected with the 1D river channels. In HEC-RAS, the flooding process in 1D rivers is simulated by a 1D hydrodynamic model, whereas the flooding process in 2D regions is simulated using 2D diffusion wave equations (DWEs) or 2D shallow water equations (SWEs). The 1D hydrodynamic model is coupled with the 2D DWEs or SWEs. If the 2D regions are discretized into finer grids and the flooding process is simulated using 2D SWEs, the 1D hydrodynamic model is coupled with the 2D SWEs. In this way, the HEC-RAS is similar to Mike Flood. It has high numerical accuracy but is computationally prohibitive for large-scale applications. Conversely, if the 2D regions are discretized into coarse grids and the flooding process is simulated using 2D SWEs, the 1D hydrodynamic model is coupled with the 2D DWEs. In this way, the HEC-RAS is similar to the coupled Mike SHE and Mike 11, which can expand the application scale at the cost of reducing the accuracy.

As the 2D hydrodynamic equations need to be solved in the entire watershed, the HM2D are still computationally prohibitive for large-scale applications, especially in regions where high-resolution representation of complicated topographic features are necessary. Therefore, the HM2D is typically applied to small and medium-sized watershed.

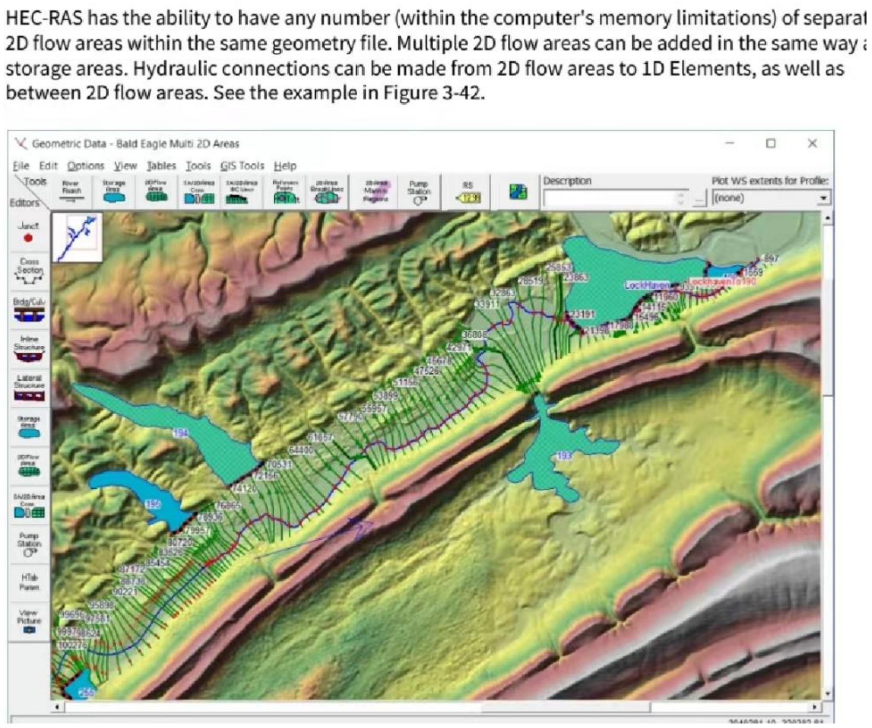


Figure 2 The computational domain of the HEC-RAS obtained from HEC-RAS 2D User's Manual Version 6.4 Exported - July 2023

(4) The DBCM joins the hydrologic and hydrodynamic models into a single modelling framework by combing their code, where the governing equations of hydrologic and hydrodynamic models are reformulated and synchronously solved in a single code base. The information exchange between both portions of the code is performed internally within the same source code and does not involve the exchange of external input and output files. The hydrologic and 2D hydrodynamic model are coupled by a coupling moving interface (CMI), and the inundation and non-inundation regions change with the accumulation of rainfall, which is more consistent with the natural flood process. The DBCM framework was presented in the paper (http://doi.org/10.5194/nhes-21-497-2021). The classification, performance, applications and challenges of different coupling models were detailed by Shen and Jiang (2023). If you want to learn more about this, you can review it in https://doi.org/10.1007/s11069-023-06047-1.

To further improve the computational efficiency, we developed the M-DBCM (https://doi.org/10.3390/w13233454). In the original M-DBCM, the multi-grids were used to divide the computational domain, and the task consists of the following steps:

First, the areas prone to flooding disasters was identified based on two methods. A hydrologic model was used to simulate the flood disasters based on the coarse grids to determine the areas prone to flood disasters. Besides, the areas prone to flood disasters was also identified based on experience. Second, the areas prone to flooding disasters were divided using finer grids, whereas the others were discretized using coarse grids. The grid generation methods were detailed in Shen et al. (2021), if you want to learn more about this, you can review it in Shen et al. (2021)

(https://doi.org/10.3390/w13233454). One limitation is that the grids need to be generated manually, which is highly subjective and uncertain. Therefore, we revised and improved the grid generation method, which is presented in Section 2.1 of the manuscript.

Compared with the Mike series model, the coupling mechanism of DBCM is more consistent with the natural flood disaster. Compared with HEC-RAS, it can save computation time and has better numerical stability.

According to your valuable comments, we have revised the Introduction, where the disadvantages of the existing coupling models was detailed, to highlight the advantages and necessity of the coupled modelling approach proposed in this manuscript. If you are interested in it, you can review it in the Introduction from lines 36 to 91, which was also marked using red bold.

2. Comment: The modelling performance is highly influenced by the underlying mesh generation. Even with advanced adaptive methods using meter-scale data, there can be uncertainties impacting the modelling performance. It is recommended that the authors perform an uncertainty analysis on the mesh generation process to understand its potential effects on the model results.

Response to comment: Thank you for reading this article carefully and making valuable suggestions. There were many mesh generation methods, such as adaptive mesh refinement, static non-uniform grids, and the modelling performance is highly influenced by the underlying mesh generation. In Section 3.2 of the manuscript, cases with different ratios of coarse to fine grids were developed. The computational efficiency and accuracy of different grid generations were evaluated. In future works, we can combine different mesh generation methods, such as the adaptive mesh refinement with the M-DBCM to study the influence of the gird generation on the simulation results. Besides, sensitivity analysis will also be performed to discuss the impact of parameters (such as Manning coefficient, the grid generation, ratio of coarse to fine grids) on the simulation results. Thank you for reading this article carefully and making valuable suggestions, which have important guiding significance for our writing and scientific research work.

3. Comment: The paper mentions the use of a coarse grid. What is the resolution of a coarse grid? What is the ratio between find grid resolution and coarse grid resolution? Will the coarse grid resolution/ratio have a large impact on modelling performance? Understanding the impact of this coarse grid resolution/ratio on the modelling performance is crucial.

Response to comment: In the proposed M-DBCM, the size of coarse grids is an integer multiple of that of a fine grid. The fine grids were first used to divide the areas prone to the flood disasters, and then the coarse girds were used to discretize other areas. As the size of the fine grids varies in different computational domain, the size of coarse grids is also different. In a computational domain, compared with the fine grids, a grid with a larger size is referred to as a coarse grid. In the Section 3.1, the size of the fine grids is 1m ×1m, and the size of coarse grids is shown in Table 1. In the Section 3.2, the size of the fine grids is 0.01m × 0.01m, whereas the size of coarse grids is twice of that of fine grids.

The computational accuracy and efficiency were influenced by the ratio of coarse to fine grids, which was presented in the Section 3.3, where the computational efficiency of different ratios of coarse to fine grids was detailed, please review it from lines 559 to 600 in the revised manuscript.

Besides, the influence of the ratio of coarse to fine grids on the computational efficiency was detailed by Shen and Jiang (2023). If you want to learn more about this, you can review it in this paper (http://doi.org/10.2166/hydro.2023.131)

4. Comment: Providing a detailed description of the hydrology and hydrodynamic components, especially on their treatment of flow variables (e.g., discharge, depth), would greatly enhance readers' understanding of the coupling process at the interface. This information is vital to evaluate the robustness of the proposed coupling approach.

Response to comment: In hydrologic model, a 2D nonlinear reservoir model, including water balance and Manning equations, was used to simulate rainfall-runoff, and the governing equations were listed from Eqs. (7) to (11) in the manuscript. The shallow water equations were solved in hydrodynamic model, we have detailed this in the Section 2.3.2 of the revised manuscript, which was also marked using red bold.

The Finite volume method of conservation scheme was used to discretize the governing equations of hydrologic and hydrodynamic model. A Harten-Lax-van Leer contact (HLLC) approximate Riemann solver was used to calculate the fluxes through the cell interface (see Figure 3).

The governing equations of hydrologic and hydrodynamic models are discretized on structured grids (see Figure 3). The hydrologic model is rational for the continuous non-inundation regions, and hydrodynamic model is rational for the continuous inundation regions. However, since discontinuity existed at the coupling moving interface (CMI), the single hydrologic or hydrodynamic models were not acceptable, which was a challenge for the model calculation. It is necessary to apply suitable numerical schemes to calculate the fluxes through the CMI.

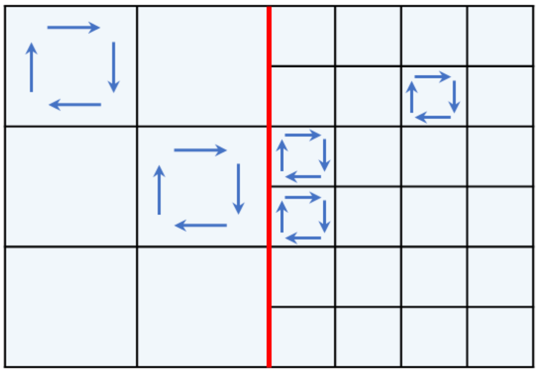


Figure 3 Model calculation at inundation regions, non-inundation regions and CMI

A pair of characteristic waves was used to determine the fluxes calculation methods through the CMI. The characteristic waves were calculated as follows:

$$S_L = u_{i,j} - \sqrt{gh_{i,j}} \quad (1)$$

$$S_R = u_{i+1,j} - \sqrt{gh_{i+1,j}} \quad (2)$$

where S_L and S_R are the characteristic waves; *u* is the flow velocity (m/s); *h* is the water depth (m); subscript (*i*, *j*) and (*i*+1, *j*) refer to the cells in non-inundation and inundation regions, respectively.

If $S_R > 0$ and $S_L > 0$, the fluxes through the CMI were calculated by the hydrologic model, and the CMI may move toward the non-inundation regions. Therefore, the non-inundation regions shrunk, whereas the inundation regions expanded. Only mass conservation through the CMI can be considered in this situation.

If $S_L < 0 < S_R$, the fluxes were calculated by both hydrologic and hydrodynamic models, and the CMI remained unchanged.

If $S_L < 0$ and $S_R < 0$, the fluxes are calculated by the hydrodynamic model, and the CMI may move toward inundation regions. Therefore, the inundation regions shrunk, whereas the non-inundation regions expanded. Both the mass and momentum conservation through the coupling boundary were obtained in the latter two situations. The couplings were detailed in Jiang et al. (2021) (http://doi.org/10.5194/nhes-21-497-2021) and Shen et al. (2021) (https://doi.org/10.3390/w13233454).

The coupling scheme of the hydrologic and hydrodynamic models was detailed in the Section 2.4 (from lines 323 to 350) of the revised manuscript, which was also marked using red bold.

5. Comment: The paper uses small test cases to evaluate the modelling efficiency.

However, it is important to validate the model's performance on larger scales, to ensure its practical applicability. Even the hydrodynamic models working on ~10m-30m can be configured for model run covering an area of several hundred kilometers and quite efficiently.

Response to comment: The proposed model in the manuscript has high computational efficiency compared with full 2D hydrodynamic model. The computational domain was divided using grids with different sizes. The areas prone to flood disaster were divided into fine grids, while other areas were discretized into coarse grids. The hydrologic model was applied to coarse grids, whereas the hydrodynamic model was only solved in local fine grids. Different time steps were accepted in coarse and fine grids. However, the uniform fine grids were used to divide the computational domain in full 2D hydrodynamic model, and the 2D hydrodynamic model was solved in entire computational domain. The performance of the M-DBCM was evaluated by Shen and Jiang (2023). If you want to learn more about this, you can review it in http://doi.org/10.2166/hydro.2023.131

Shen and Jiang (2023) also explained that the larger the computational domain, the more pronounced the improvement in computational efficiency of the model. However, the insufficiency of our research is the applications, due to the difficulty of the data collection including input data, observation data. In future works, we will apply the proposed M-DCBM to watersheds of different sizes. We sincerely hope we have the opportunity to continue our cooperation and publish our study in this journal. Thank you for reading this article carefully and making valuable suggestions, which have important guiding significance for our writing and scientific research work.

6. Comment: The choice of using Fortran for coupling the two modelling components, while the SWMM model is written in C++, raises questions about the rationale behind this decision. The authors should provide a clear explanation for this choice, considering factors like compatibility, performance, and ease of implementation.

Response to comment: C++ and Fortran are widely used in scientific research. There were many differences between C++ and Fortran. C++ is widely used in various domains such as system-level programming, game development, and graphical user interface development. Its flexibility and performance make it a versatile programming language. Fortran is primarily used in scientific computing, numerical simulation, and engineering calculations. It has rich libraries and optimization tools specifically designed for mathematical and scientific computations.

Our team started developing the coupled hydrologic-hydrodynamic model five years ago, when we have a software solving the hydrodynamic model based on Fortran language. It is convenient to develop the coupled hydrologic-hydrodynamic model based on the existing code. Therefore, we developed the coupled model based on Fortran language. We still use Fortran language to ensure continuity in the work of developing model.

However, since the C++ has more advantages than Fortran and is more widely used, we will develop the coupled model based on C++ in future works. It is thus more convenient to discuss the proposed model with other researchers. Thank you for reading this article carefully and making valuable suggestions, which have important guiding significance for our writing and scientific research work.

Reviewer #2:

First of all, sincerely thank you very much for your valuable comments. All your suggestions are very important and have important guiding significance for our writing and research. When revising the article, we considered thoughtfully what you have advised.

1. Comment: The authors present an improvement to the multi-grid hydrological/hydrodynamic SWMM/IM-DBCM model which partitions the model domain into a coarse resolution part (away from rivers) and a fine resolution part (areas susceptible to inundation). The authors present the mesh-generation approach and test the model in 4 configurations with a variable number of grid cells (ranging between 59k-207k cells). Results of discharge are compared to observed values, inundation depth is presented without comparison to observations. Advances are said to stem from improved computational efficiency, the main reason for the multi-grid approach of the model, while retaining an acceptable model performance.

Response to comment: Thank you very much for your valuable comments. SWMM is a direct one-way coupling of semi-distributed hydrological and 1D hydrodynamic models. Since the 1D nonlinear reservoir method is used to simulate the runoff routine, it is difficult to directly coupled with 2D hydrodynamic model. The M-DBCM proposed by our team is the direct dynamic two-way coupling of distributed hydrological and 2D hydrodynamic model.

In the section 3.2, flood process in natural watershed was simulated using the improved M-DBCM. The simulation data was collected from the references, Yu and Duan (2012); Sánchez (2002); Blackmarr (1995). Only the discharge hydrographs were obtained in the observation stations, therefore, we have compared the simulated discharge hydrographs with the measured data to evaluate the performance of the proposed model.

In the proposed model, the inundation and non-inundation regions were changed with the water depth; the hydrologic and hydrodynamic models were coupled through the moving interfaces. Therefore, we have presented the water depth and positions of coupling interfaces in Figure 12 to show the changing process of inundation and non-inundation regions with water depth.

However, our current research work lacks data, especially the measured data used to evaluate the performance of proposed model. In future works, we will collect more data, such as the water depth and discharge to further evaluate the performance of proposed model.

Ref:

[1] Yu C. and Duan J. G., Simulation of Surface Runoff Using Hydrodynamic Model, Journal of Hydrologic Engineering (ASCE), 2017, 22(6): 04017006

[2] Sánchez, R. R., GIS-based upland erosion modeling, geovisualization and grid size effects on erosion simulations with CASC2DSED. Thesis (Ph. D.) --Colorado State University, 2002.

[3] Blackmarr, W., Documentation of hydrologic, geomorphic, and sediment transport measurements on the Goodwin Creek experimental watershed, northern Mississippi, for the period 1982–1993, Res. Rep. 3, Agricultural Research Service, U.S. Dept. of Agriculture, Oxford, MS, 1995.

2. Comment: The state-of-the-art approach to the problem of variable resolution grids is a coarse-resolution hydrological model coupled with a 1D river routing model that activates a 2D model when channel capacity is exceeded. While the authors acknowledge this in the manuscript, they fail to compare their approach to results of such a model chain to demonstrate their advance. Admittedly, producing the same results with such a model chain to use as a baseline is a non-trivial task, but some comparison if not in the same catchment, should be considered mandatory.

Response to comment: Thank you for reading this article carefully and making valuable suggestions. The coupling model can be divided into two types: external (one-way) and internal (two-way) coupling models (see Figure 1). And the internal coupling model can be further divided into four types, as shown in Figure 2.

The coupling of the Mike SHE and Mike11 is a typical example of the coupling of hydrologic and 1D hydrodynamic models, as shown in Figure 2(a). The application of 1D modeling of overland flow is limited when developing precise and reliable flood maps in 2D inundation regions.

To overcome the lack of 2D hydrodynamic simulation in type-1, the coupling of hydrologic, 1D, and 2D hydrodynamic models is proposed. In this coupling type, the runoff flows into the 1D river or pipes first, and the hydrologic model is coupled with the 1D hydrodynamic model. And then, the water in 1D rivers or pipes can overflow into low-lying areas, the 1D and 2D hydrodynamic models are coupled in a two-way manner. This coupling type is an indirect coupling of hydrologic and 2D hydrodynamic models, as shown in Figure 2(b). For instance, Mike SHE and Mike11 are coupled to form Mike Urban, and Mike11 and Mike21 are dynamically coupled to form Mike Flood. The indirect coupling between the hydrologic and 2D hydrodynamic models can be developed by coupling Mike Urban and Mike Flood. The 1D hydrodynamic model is a connection channel between the hydrologic and the 2D hydrodynamic models.

In the Type-3, both the overland flow migration and inundation processes are all calculated by 2D hydrodynamic model, and the runoff generation is considered as the source term of the continuity equation of 2D hydrodynamic model. The type-3 has high numerical accuracy but low computational efficiency.

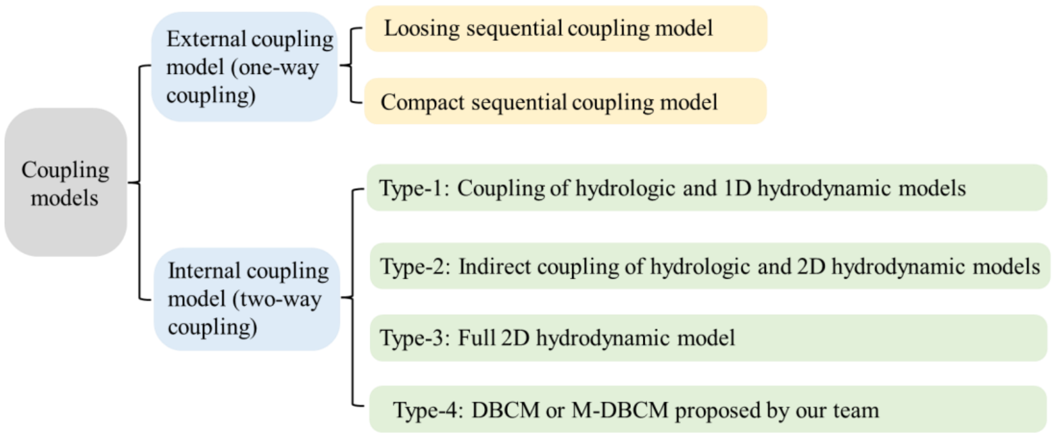


Figure 1 Classifications of coupled hydrologic and hydrodynamic models

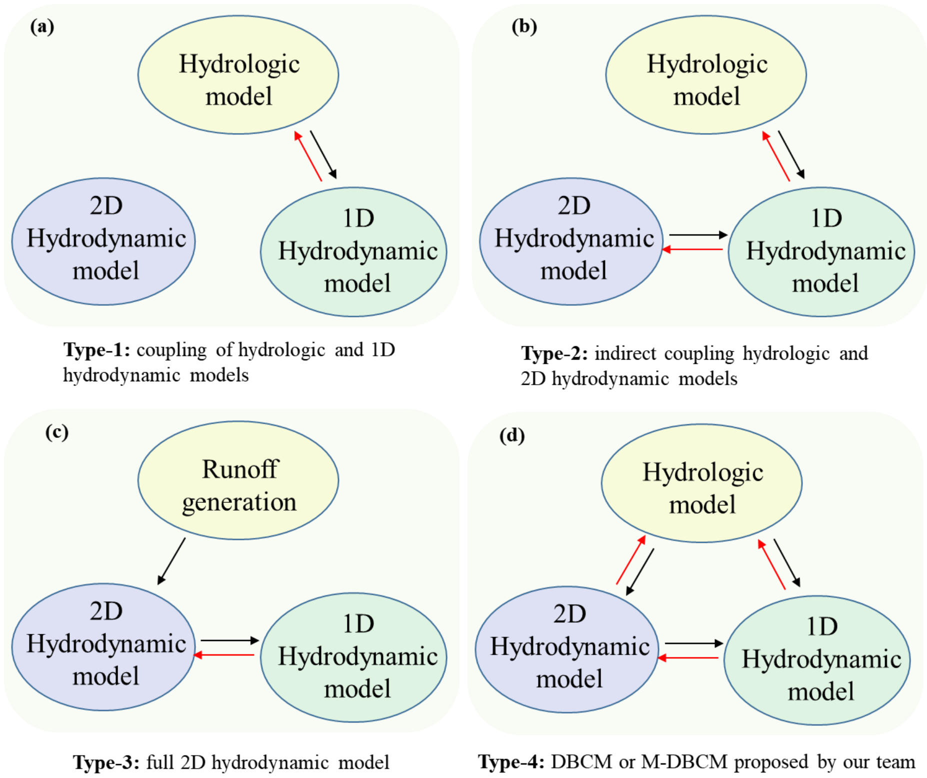


Figure 2 Classifications of internal coupling models

It is observed that existing coupling models can not realize the dynamic two-way coupling of hydrology and 2D hydrodynamic models. The 1D hydrodynamic model was used to link the hydrologic and 2D hydrodynamic models. The runoff flows into the 1D river or pipes first, and the hydrologic model is coupled with the 1D hydrodynamic model. And then, the water in 1D rivers or pipes can overflow into low-lying areas; conversely, the water in low-lying areas can flow to 1D regions in return. The 1D and 2D hydrodynamic models are coupled in a two-way manner. This coupling type is an indirect coupling of hydrologic and 2D hydrodynamic models. In reality, however, water may be discharged into both 1D channel and 2D waterbodies simultaneously, and the hydrologic, 1D, and 2D hydrodynamic models should be linked directly. Direct coupling of hydrologic and 2D hydrodynamic models can reflect the flood processes more truly, which deserves more attention.

Aiming to this problem, we have proposed a coupled hydrologic and 2D hydrodynamic models. In the proposed model, the 1D river channel and 2D inundation regions were not distinguished, and the 2D hydrodynamic model was applied to both regions.

There have been many published papers about the coupled 1D and 2D hydrodynamic models, and our future works may focus on the adding a 1D hydrodynamic model to the proposed M-DBCM, where the hydrologic model is used to simulate the runoff routing, the 1D hydrodynamic model is used to simulate the flood process in rivers and the 2D hydrodynamic model is used to reflect the inundation process in the low-lying inundation regions. Three coupling strategies, i.e., the coupled hydrologic-1D hydrodynamic module, coupled 1D-2D hydrodynamic module and coupled hydrologic-2D hydrodynamic module, are proposed.

However, the direct dynamic bidirectional coupling of distributed hydrologic and 2D hydrodynamic models is the key and important technology to develop the flood simulation models, and it is also the innovation of the M-DBCM. Besides, the multi-grids are used to divide the watershed, and the model can improve computational efficiency while maintaining numerical accuracy, which is the main difference between the proposed model and other existing models.

3. Comment: The authors present model runtimes of the four grid configurations in Fig 13. It is apparent that runtimes scale linearly when comparing the uniform grid case to the variable-grid case (cf case00 to case12). This relationship does not hold, however, in coarser configurations of the multi-grid models (cases 15/10), i.e., the runtime/grid is significantly higher. e.g., going from 105k cells to 59k cells only brings moderate efficiency savings of 10-15%. This shows the limits of the approach, presumably because more time is spent on coupling the coarse and fine grids.

Response to comment: Thank you for your valuable suggestions. We have proposed a parameter to quantitatively evaluate the computational efficiency of the M-DBCM (Shen and Jiang, 2023, http://doi.org/10.2166/hydro.2023.131). We defined the evaluation parameter as the ratio of the simulation time of the M-DBCM to that of the full 2D hydrodynamic model (HM2D), as shown in Eq. (1):

$$C=\frac{\left(1+\alpha_0\right)t_1+t_2}{t_0}=\frac{\left(1+\alpha_0\right)\alpha\frac{A_1}{\Delta x_1^2}\left(\frac{T_{end}}{\Delta t_1}\right)+\beta\frac{A-A_1}{\Delta x_2^2}\left(\frac{T_{end}}{\Delta t_2}\right)}{\alpha\frac{A}{\Delta x_1^2}\left(\frac{T_{end}}{\Delta t_1}\right)} \tag{1}$$

where C is the assessment parameter to evaluate computational efficiency of M-DBCM;

t_1, t_2 are the computation time on fine and coarse grids, respectively (s); t_0 is the computation time of HM2D (s); Δx_1, Δx_2 are the size of fine and coarse grids (m); Δt_1, Δt_2 are the time step on fine and coarse girds (s); A_1, A_2 are the area of coarse and fine grids, respectively; T_{end} is simulation time (s); α and β are the runtime of hydrodynamic and hydrologic models at one calculation node (s), which is depended on computer power and numerical model complexity. Since the hydrodynamic model is expressed by nonlinear hyperbolic equation and hydrologic model is expressed by linear equation, the calculation of the hydrodynamic model is more complicated than that of the hydrologic model, which results $\frac{\beta}{\alpha} < 1$.

The time step ratio of coarse grids to fine grids is equal to the size ratio of coarse grids to fine grids, as follows:

$$\frac{\Delta t_2}{\Delta t_1} = \frac{\Delta x_2}{\Delta x_1} \tag{2}$$

Based on Eq. (2), Eq. (1) can be rewritten as:

$$C = \frac{A_1}{A} + \frac{\beta}{\alpha}\left(\frac{\Delta x_1}{\Delta x_2}\right)^3 \frac{A - A_1}{A} \tag{3}$$

Define $n = \frac{A_2}{A}$ ($0 < n \le 1$), $\Delta t_2 = k\Delta t_1$ ($k \ge 1$), Eq. (3) becomes

$$C = (1-n) + \frac{\beta}{\alpha}\frac{1}{k^3}n \tag{4}$$

From Eq. (4), the computational efficiency of M-DBCM is not only related to the size ratio of coarse to fine grids, but the area ratio of coarse grids to entire domain. If the area of coarse-grid regions are much greater than that of the fine-grid regions, that is, $n \to 1$, the assessment parameter becomes $C \propto \frac{\beta}{\alpha}\frac{1}{k^3}$. It is indicated that the computational efficiency of M-DBCM exponentially improves with the increasing of the area ratio of the coarse grids to entire domain, as shown in Figure 3(a). If the size of coarse grids is much more than that of fine grids, that is, $k \to \infty$, the assessment parameter becomes $C \propto (1-n)$. It is stated that the computational efficiency of M-DBCM improves linearly with the increasing of the size ratio of the coarse to fine grids, as shown in Figure 3(b).

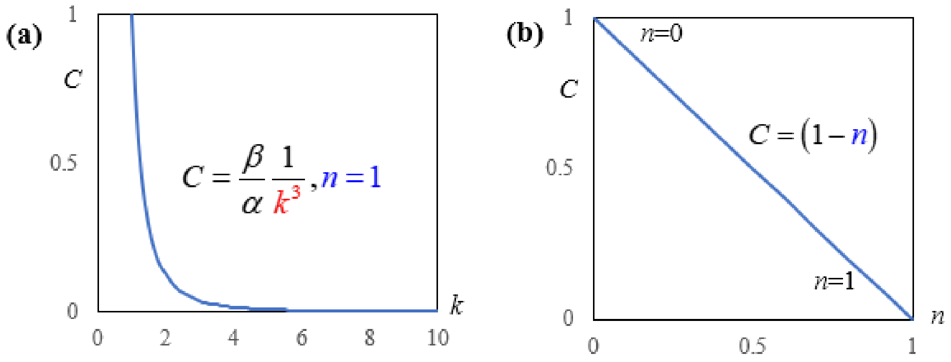


Figure 3 The relationship between the evaluation parameter and the *n* and *k*:(a) the relationship between the evaluation parameter and *n*; (b) the relationship between the evaluation parameter and *k*

We compared the graphs of three functions: $y=1/x$, $y=1/x^2$, $y=1/x^3$, as shown in Figure 4. From this figure, compared with $y=1/x$, in the $y=1/x^3$, the *y* values decrease sharply as *x* increases. It is indicated that the computational efficiency of M-DBCM exponentially improves with the increasing of the size ratio. From this figure, in the $y=1/x^3$, when $x< 10$, *y* values are highly variable; however, when $x> 10$, although the *y* value is decreasing, it is decreasing slowly. It is indicated that a ratio of coarse to fine grid between 1 and 10 may be suitable. We came to this conclusion after carefully reading the reviewers' comments. Thank you again for your valuable comments!

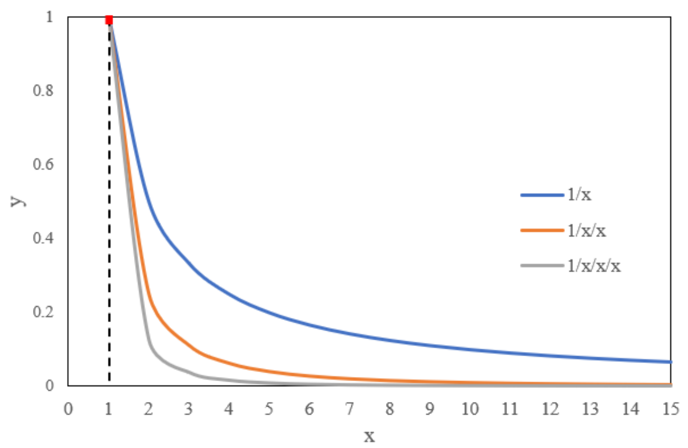
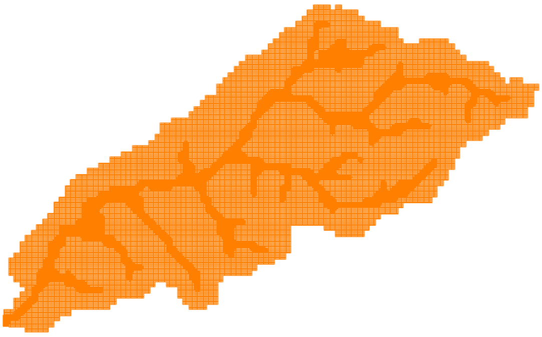


Figure 4 The graphs of $y=1/x$, $y=1/x^2$, $y=1/x^3$

In the original manuscript, different cases were used to divide the Goodwin watershed, as shown in Figure 5. In the case12, case15 and case10, the number of coarse and fine grids are shown in Table 1. The number of fine grids accounts for half of the total number of grids in case12, while the number of fine grids is much greater than the number of coarse grids in case15 and case10. The calculation time of coarse and fine grids is also reported in Table 1. The size of fine grids is the same in all the cases. In case12, the size of coarse grid is twice that of the fine grid, while the size of the coarse grid is five times and ten times that of the fine grids in case15 and case10, respectively.

The number of grid cells ranked from more to less is as follows: case12> case15> case10. It is well-known that the more grids mean longer computational time. Therefore, case12 cost more computation time compared with case15 and case10.



(a) case12

(b) case15

(c) case 10

Figure 5 Grid partition of different cases

Table 1 The computation time of grids with different sizes (s)

	case12	case15	case10
The number of fine grids	42474	42474	42474
The number of coarse grids	42517	7425	2153
Computation time for fine grids	4910.1	4890.32	4761.88
Computation time for coarse grids	243.8	16.28	2.19
Total runtimes	6900	6206	5800

The calculation time for coarse grids is shown in Figure 6. It is observed that the runtime for coarse grids decreases rapidly in different cases, which is related to the number of the coarse grids. In case12, case15 and case10, the number of the coarse grids is 42517, 7425, and 2153, respectively. Therefore, the runtime for the coarse grids decreased rapidly.

However, the number of fine grids is consistent in these cases and does not change with the ratio of coarse to fine grids. The number of fine grids is much greater than that of the coarse grids, especially in case15 and case10. The 2D hydrodynamic model was solved in the fine-grid regions, with a calculation time of about 4800s. It costs more computational time compared with coarse grids. Due to the large amount of calculations involved in fine grids, the time spent on the fine grids accounts for a significant proportion of the total execution time. Therefore, the total computational time of all cases does not differ significantly.

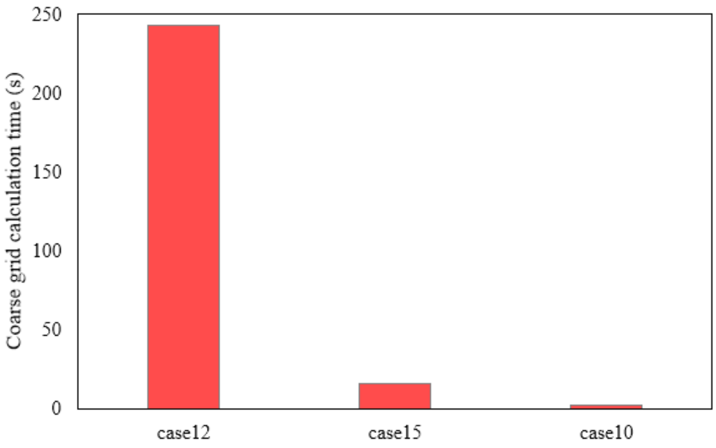


Figure 6 The runtime for coarse grids in different cases

There were two reasons to explain the respected reviewer's question. On the one hand, there were large area of fine grid regions, and the number of fine grids was higher than that of coarse grids in all the cases. The 2D hydrodynamic model was solved in the fine-grid regions, which cost more computational time compared with coarse grids. Due to the large amount of calculations involved in fine grids, the time spent on the fine grids accounts for a significant proportion of the total execution time. Therefore, the total computational time of all cases does not differ significantly. On the other hand, as the respected reviewer pointed, the 1D hydrodynamic model would be added into the M-DBCM. The 1D hydrodynamic model is used to simulate the flood process in 1D rivers and the 2D hydrodynamic model is only used to simulate the flood process in the low-lying inundation regions. The low-lying inundation regions account for a small proportion of the total watershed regions. Therefore, this will greatly shorten the calculation time.

In future works, we will choose many more appropriate watersheds to evaluate the model performance, where the proportion of low-lying inundation regions to the total watershed area can be further reduced. In addition, the 1D hydrodynamic model will be added to the proposed model.

We have detailed the computational efficiency of different ratios of coarse to fine grids in the Section 3.3 of the revised manuscript, which was also marked using red bold. If you want learn more about it, you can review it in from lines 574 to 600. We will be appreciated it if you give us more valuable comments again.

4. Comment: -l.74 -85 unclear, needs proofreading
Response to comment: We have proofread the manuscript thoroughly, especially the lines from 74 to 85 in the original manuscript. Please review it from lines 92 to 101 in the revised manuscript, which was also marked using red bold.

5. Comment: -l.117 Ghost cells need to be defined before

Response to comment: "Ghost cells" is a term used in computational fluid dynamics (CFD). In CFD, the computational domain is discretized into grids, and ghost cells refer to the virtual cells located on the boundaries of the computational domain. In certain cases, to simulate the behavior of the fluid at the boundaries of the computational domain, ghost cells are proposed between the interior of the domain and the boundaries. These ghost cells are mapped to the actual boundaries and allow for the treatment of boundary conditions such as inflow, outflow, and wall conditions.

Ghost cells typically do not participate in the actual computation of the flow field, but they can help determine the physical quantities and boundary conditions at the domain boundaries. By introducing ghost cells within the computational domain, the behavior of the fluid at the boundaries can be more accurately simulated, thereby improving the accuracy of the computed results.

According to your valuable comments, we have defined the ghost cells in the Introduction, from lines 133 to 144 in the revised manuscript.

6. Comment: - l.498 and l.501 "last moment" > in the last time step?
Response to comment: The "last moment" means "in the last time step". We have revised in the revised manuscript, as shown in lines 544 and 546, respectively.