CHyCle 2017

sciforum

Conference Proceedings Paper

Iber as a tool to analyse flooding scenarios

Orlando García-Feal [1,*], José González-Cao[2], Luis Cea[3], Arno Formella[4] and José Manuel Domínguez[5]

Published: 06/11/2017
Academic Editor: Raquel Nieto

[1] Enviromental Physics Laboratory (EPHYSLAB), Universidad de Vigo, Campus As Lagoas s/n, 32004, Ourense, Spain; orlando@uvigo.es
[2] Enviromental Physics Laboratory (EPHYSLAB), Universidad de Vigo, Campus As Lagoas s/n, 32004, Ourense, Spain; jgcao@uvigo.es
[3] Enviromental and Water Engineering Group, Departamento de Ingeniería CIvil, Universidade da Coruña, Campus Elviña s/n, Coruña, Spain; luis.cea@udc.es
[4] Laboratorio de Informática Aplicada, Universidade de Vigo, Campus As Lagoas s/n, 32004, Ourense, Spain; formella@uvigo.es
[5] Enviromental Physics Laboratory (EPHYSLAB), Universidad de Vigo, Campus As Lagoas s/n, 32004, Ourense, Spain; jmdominguez@uvigo.es

* Correspondence: orlando@uvigo.es; Tel.: +34-988-372-255

Abstract: Floods are one of the most dangerous extreme events that can affect people and properties. These events have intensified worldwide over the last decades due to climate change. Therefore, the capability to predict and analyse, in a quick and accurate way, the effects of floods is crucial to avoid or minimize the hazards associated to them. This task can be accomplished by means of numerical tools as Iber, which is a numerical model that uses the finite volume technique to solve the 2-D Shallow Water Equations to obtain water depth and velocity components of the flow under different scenarios. A series of test cases have been reproduced to assess the capabilities of Iber following the document "Benchmarking the latest generation of 2D hydraulic modelling packages" published by the non-departmental public body Environment Agency of the U.K. Government. Results show that Iber is a suitable tool to reproduce accurately different flooding scenarios. A new implementation of the model has been developed by EPHYSLAB. This implementation takes advantage of the modern hardware capabilities and provides significant speedups over the original code. The new possibilities offered by a faster code will be studied.

Keywords: Floods; Numerical Simulation; Iber; Benchmark

---

1. Introduction

Floods are a natural disaster that has affected the humanity along its history. These events can threat human lives as well as infrastructures and economic activities. In addition, climate change also affected negatively these phenomena [1], making the floods more frequent and violent. Numerical tools can help the construction of infrastructures able to resist floods and the deployment of countermeasures to mitigate damages and evacuate people. Therefore, being able to simulate and predict this kind of events is essential to preserve human lives and economic activity, being an important concern for any government.

For all this, the non-departmental public body Environment Agency of the U.K. Government published a report in 2013 [2]. In this document, several 2-D hydraulic flood models are benchmarked. The authors compared the results and performance of different tools with the purpose of helping decision-makers in risk management.

Iber [3] is a 2-D numerical model, developed by GEAMA (Universidade da Coruña) and Flumen (Universitat Politècnica de Catalunya), that uses the finite volume technique to solve the 2-D Shallow Water Equations in order to the water depth and velocity components of the flow under different scenarios. Recently, EPHYSLAB (Universidade de Vigo) also joined the development to improve the speed of simulations by implementing multi-processing techniques.

The aim of this work is to show that Iber is a suitable tool to model floods following the benchmarks defined in [2] and its results are comparable to other commonly used packages.

2. Methodology

The original benchmark published by the U.K. Government [2], consist of 9 different tests and 19 software packages. With the aim of create a brief study, a subset of three representative tests were selected. Four models will be compared using these tests.

Table 1. Summary of hydraulic models employed in this study.

Name	Developer	Version	Underlying equations	Numerical scheme	Gridding
TUFLOW FV	BMT WBM	2012.000b	Shallow water equations	Finite volume	Flexible
InfoWorks ICM	Innovyze	2.5.2	Shallow water equations	Finite volume explicit	Flexible
JFLOW+	JBA Consulting	2.0	Shallow water equations	Finite volume	Square grid
Iber	GEAMA and FLUMEN	2.4.3	Shallow water equations	Finite volume	Flexible

The models chosen to be compared with Iber were TUFLOW FV [4], InfoWorks ICM [5] and JFLOW+ [6]. These packages were chosen due to their popularity [7]; they solve the same 2D Shallow Water Equations and employ similar numerical schemes (Finite Volume) as shown in Table 1.

The tests used for this comparison are shown in the following sections. It should be mentioned that the test names and measure point numbers of the reference benchmark are preserved for easier comparison and reproducibility of the performed experiments. More information about the test specifications can be found in [2].

2.1. Test 1: Flooding a disconnect water body

This is a case to test basic capabilities of a hydrodynamic modelling tool. It consists of a domain of 700 m x 100 m as shown in Figure 1. It starts with an ascending slope from 0 m to 300 m, followed by a descending slope from 300 m to 500 m and then an ascending slope again until the end of the domain. The initial condition is a water level elevation of 9.7 m. The characteristic length of the elements of the grid is 10 m and the Manning's coefficient is set to 0.03 s/m$^{1/3}$ for the whole domain. There is a boundary condition to the left of the domain (marked in red in Figure 1) whose hydrograph is shown in Figure 2. The time simulated is 20 hours and the time series of the water level is measured at the points shown in Figure 1.

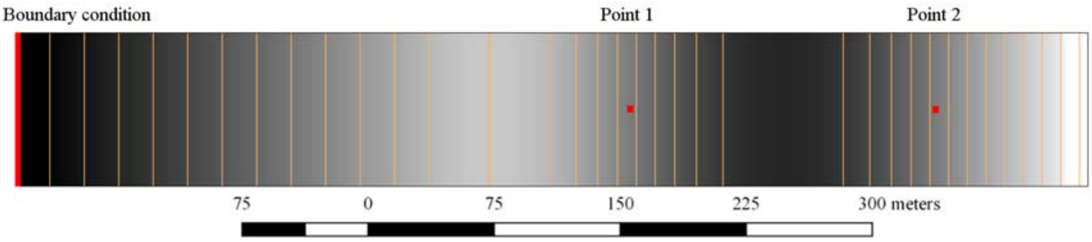


Figure 1. Representation of the simulated domain. White areas represent high terrain elevation.

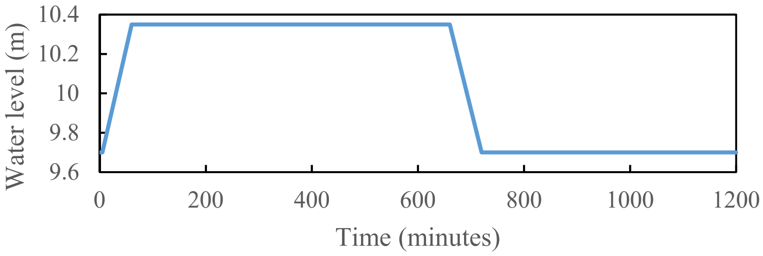
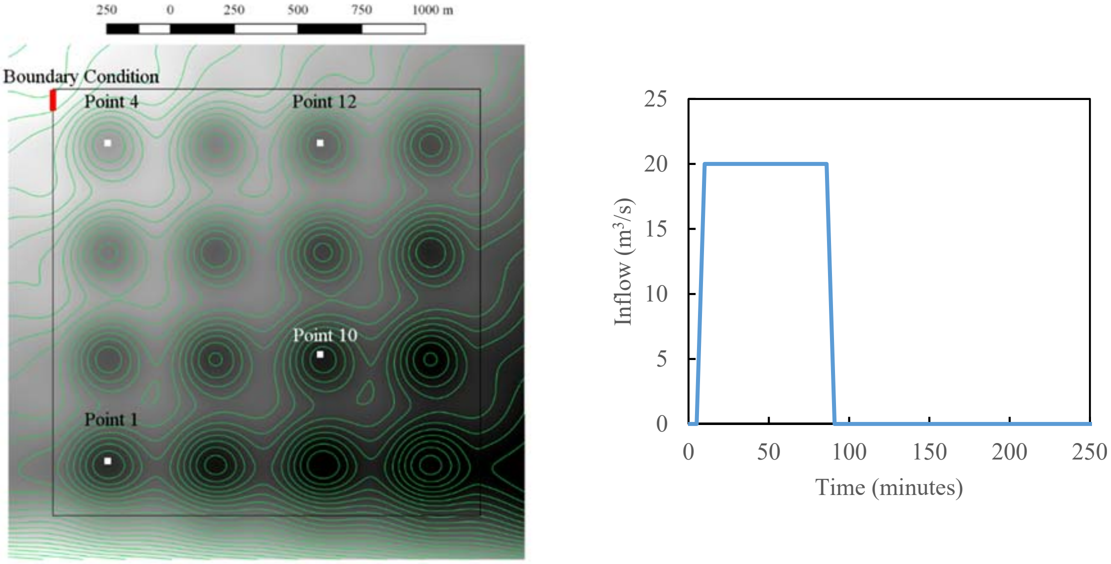


Figure 2. Hydrograph defined for the inlet boundary condition of Test 1.

2.2. Test 2: Filling of floodplain depressions

Test number 2 was chosen to test how models reproduce the flood of several connected floodplains with a complex topography. The final distribution of the water is essential to predict the extension of a flood. The case topography is based on a 2000 m x 2000 m domain with a grid of 4x4 ground depressions and a slight descending slope in down-right direction as shown in Figure 3(a). The characteristic length of the grid is 20 m and Manning's coefficient is 0.03 s/m$^{1/3}$ for the entire domain. The initial condition assumes all the elements dry and the time to be simulated is 48 h. There is an inlet boundary condition marked in red in Figure 3(a) whose hydrograph can be seen in Figure 3(b).

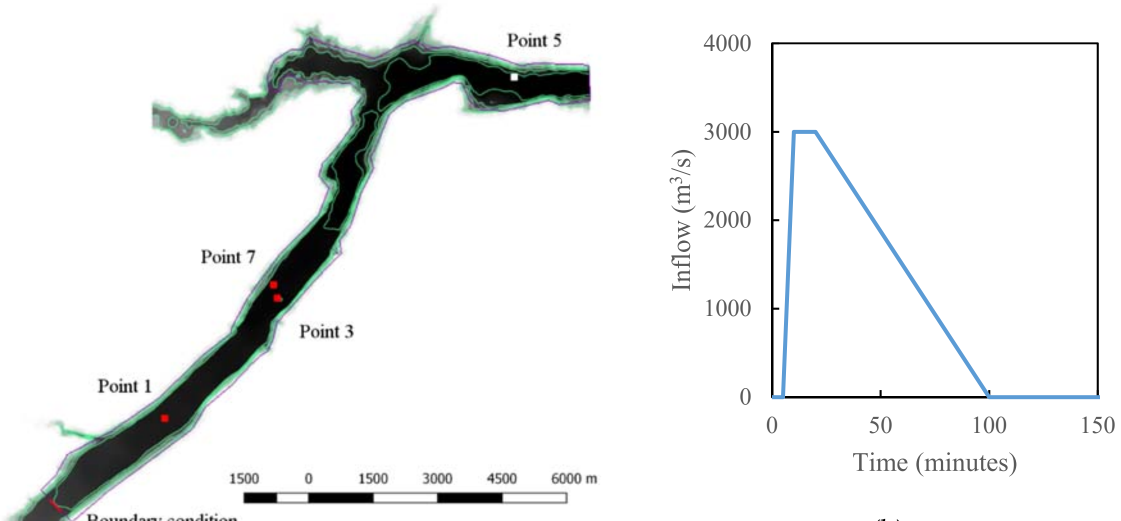


(a) (b)

Figure 3. Setup of the Test 2. (a) Shows the simulated domain; (b) Hydrograph used for the boundary condition.

2.3 Test 5: Valley flooding

In Test 5, a dam break originates a flood that is propagated through a river valley. This case measures the capacity of the model to simulate large inundations and estimate their hazard. The topography of this case is approximately 0.8 km x 17 km as shown in Figure 4(a). The characteristic length of the elements of the mesh is 50 m, Manning's coefficient is set to 0.04 s/m$^{1/3}$ and the initial condition is dry for the whole domain. The time simulated is 30 hours. There is an inlet boundary condition marked in red in Figure 4(a) that follows the hydrograph shown of Figure 4(b).



(a)

(b)

Figure 4. Setup of Test 5. (a) simulated domain; (b) Hydrograph used for the boundary condition.

3. Results and discussion

In the following subsections, the results obtained for the chosen models will be analysed.

3.1. Results for Test 1

Figure 5 represents the water depth at the end of the simulation performed by Iber. As shown in Figure 6, the results obtained with Iber are equivalent to those obtained with the other codes, as expected in a basic test. The water level measured for Point 1 and Point 2 is almost the same after 2 hours aproximately.

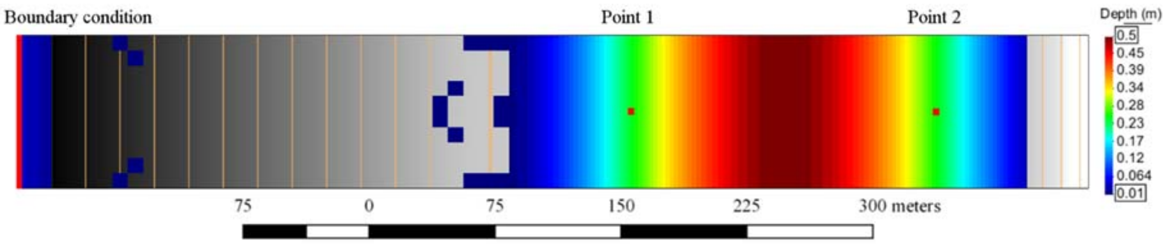
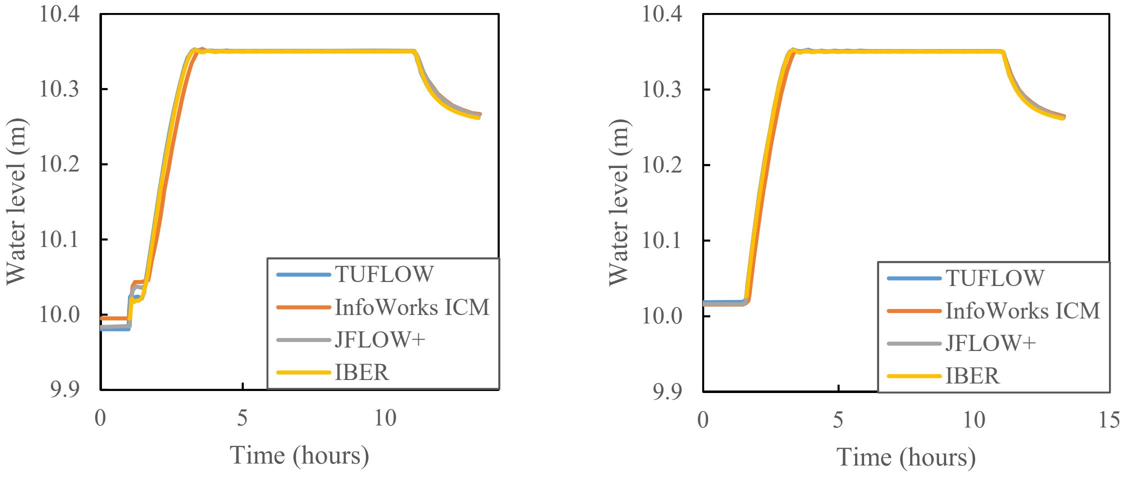


Figure 5. Water depth in Test 1 at simulation time t=20 hours.



(a) **(b)**

Figure 6. Time series of the water level for Test 1. (a) Measurements for the Point 1; (b) Measurements for the Point 2.

3.2. Results for Test 2

Figure 7 shows the water level after the Iber simulation was ended. It can be appreciated that 11 out of 16 floodplains were inundated.

The water level evolution for the selected points is shown in Figure 8. Although the original benchmark used up to 16 points, for this case, four of the most representative points where chosen.

- Point 4 (Figure 8(a)): Iber performed very similar to JFLOW+ and TUFLOW.
- Point 1 (Figure 8(b)): there are small differences in the water arrival time. JFLOW+ and InfoWorks performed similarly but in TUFLOW simulation the water arrives faster than in those models being even a bit faster in Iber. However, the final water level is similar in all cases.
- Point 12 (Figure 8(c)): the differences in the arrival times are similar to those shown for Point 1, but there are also small water level differences. The faster models also show higher final water levels. In any case, the differences are small ~2 cm (0.2 % of maximum water level).
- Point 10 (Figure 8(d)): this point shows the highest differences among the four analysed models. The final water level is similar, but a bit lower for Iber (once again just 1-2 cm with respect the other models). In addition, there are also significant differences in the arrival time. Iber is the fastest model although it is similar to TUFLOW and InfoWorks. On the other hand, the flood takes several hours longer in the JFLOW+ case than in the rest of the cases.

To summarize this case, all the selected models performed similarly. They all showed floods in 11 out of 16 floodplains with similar water levels at the end of simulation. However, significant differences in the arrival time of some floodplains were found. These differences were also noted in the original benchmark [2] and attributed to the very weak flow between floodplains.

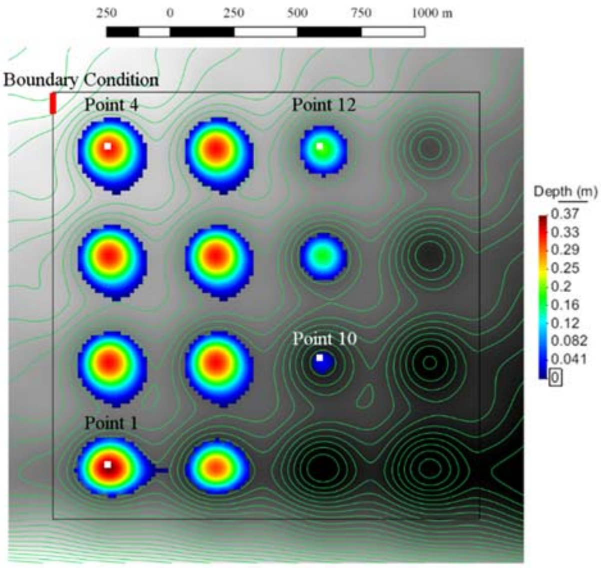
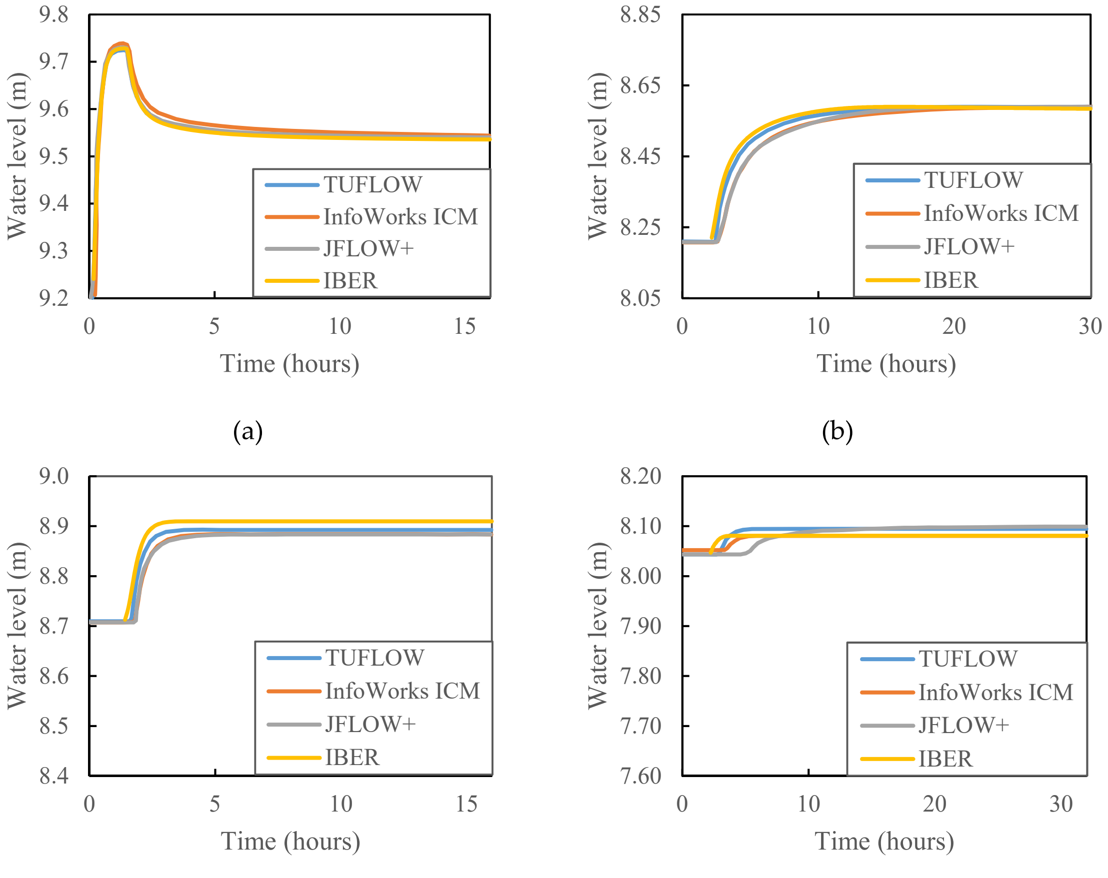


Figure 7. Water depth in Test 2 at the end of the simulation (t=48 hours).



(a) (b)

(c) (d)

Figure 8. Variation of the water level for Test 2. Measurements for Point 4 (a); Point 1 (b); Point 12 (c); and Point 10 (d).

3.3. Results for Test 5

The final water depth simulated by Iber can be seen in Figure 9. Results are very similar for all models (Figure 10). The arrival time at the end of the valley (Point 7, Figure 10(d)) show small differences, over 30 minutes between TUFLOW and JFLOW+, InfoWorks and Iber are placed in the middle. Water level is very similar without significant differences among models.

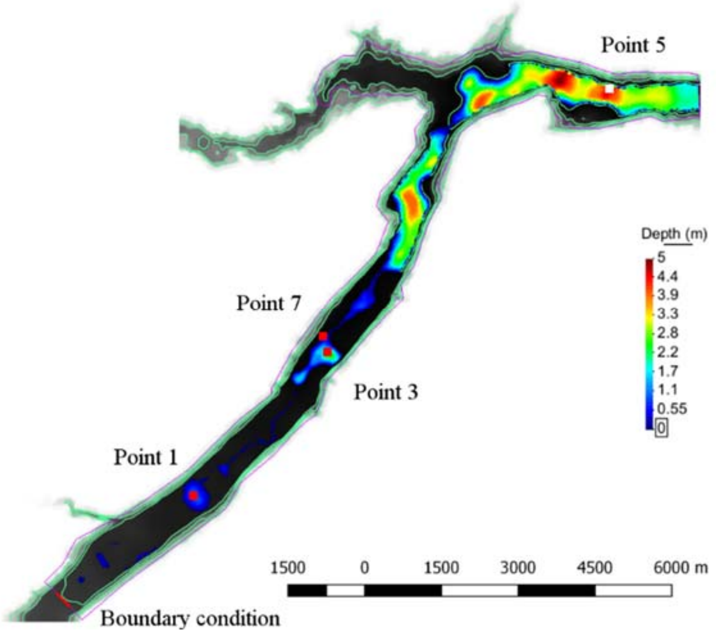
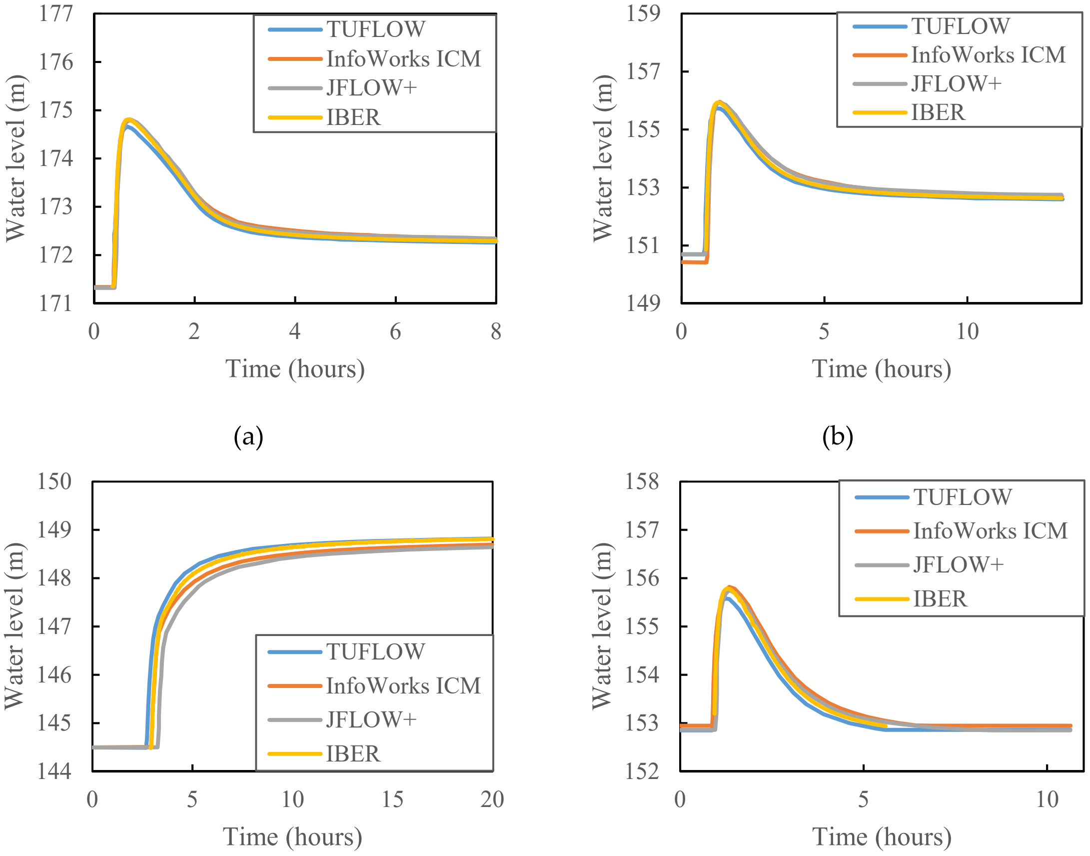


Figure 9. Water depth in Test 5 for simulated time t=30 hours.



(a) (b)

(c) (d)

Figure 10. Time series of the water level for Test 5. Measurements for Point 1 (a); Point 3 (b); Point 5 (c); and Point 7 (d).

3.4. Performance

In this section, the proposed models will be analysed in terms of computation speed. The system used to perform the Iber simulations features an Intel i7-4770 CPU and 16GB of RAM. The hardware specifications used for the other packages can be found in [2]. All models used a similar resolution grid. Iber uses adaptive time stepping but with a maximum time-step of 1 second by default. This parameter can be tuned in order to improve run times, but it can lead to some precision penalty in certain cases. For this work, default time stepping was used. Iber uses by default a first order numerical scheme, although a second order or DHD numerical scheme [8] can also be used when needed. Only a first order scheme was employed in this case.

Iber was developed in Fortran and designed to run in single-thread scenarios. Due the evolution of the hardware market to parallel computing, it was partially parallelized with OpenMP. This can reduce computation time on some simulations but the results are suboptimal.

Table 2. Summary of run times.

Name	Multi-processing	Test 1 run time (s)	Test 2 run time (s)	Test 5 run time (s)
TUFLOW FV	Yes – 12 CPUs	2.1	26	67
InfoWorks ICM	Yes – GPU	9	11	9
JFLOW+	Yes – GPU	28	10	22
Iber	No	41	414	605
Iber OpenMP	Partial – 4 CPUs	29	311	1116

In Table 2, the run times for the different models and cases are shown. Iber is clearly the slowest model among the four analysed models. However, it is faster than other codes not analysed in this work but considered in the original benchmark [2] like ANUGA [9] or UIM [10]. Using the multi-processing option in Iber could save up to 25% in run-time with four CPU cores, it can be useful for some cases but the speed-up is limited and it can be even counterproductive in others. The maximum time-step parameter could also be tuned to save a significant amount of time, but in this case, the default option was used.

4. Conclusions

Iber has shown to be an useful tool to simulate different flooding events. It was tested for different scenarios, providing a precision similar to other widely used hydraulic modelling tools. Iber offers an implementation comparable to some existing codes in terms of speed. However, it lags behind new developments that make an efficient use of multi-core CPUs and GPUs. To address these issues, a new version of Iber is being developed in C++. This new version will be able to run in CPU and GPU to achieve significant speed-ups. With these improvements, Iber will be able to achieve greater precision by using finer grids to simulate bigger domains, allowing flood hazard simulations at a reasonable computational time.

Acknowledgments: This work is partially supported under projects IMDROFLOOD (Water JPI - WaterWorks 2014), and Programa de Consolidación e Estructuración de Unidades de Investigación Competitivas (ED431C 2017/64 co-funded by European Regional Development Fund (FEDER).) and Risc_ML (Interreg Program, European Regional Development Fund, ERDF).

Author Contributions: O. García-Feal and J. González-Cao conceived and designed this work. O. García-Feal and J. González-Cao carried out the numerical simulations. L. Cea, A. Formella and J.M. Domínguez analysed the results. O. García-Feal, J. González-Cao, L. Cea, A. Formella and J.M. Domínguez wrote the paper.

Conflict of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study, in the collection, analyses and interpretation of data, in writing of the manuscript and in the decision to publish the results.

Abbreviations:

CPU: Central Processing Unit
DHD: Decoupled Hydrological Discretization
EPHYSLAB: Environmental Physics Laboratory
ERDF: European Regional Development Fund
FEDER: Fondo Europeo de Desarollo Regional
GEAMA: Grupo de Enxeñeria da Auga e do Medio Ambiente
GPU: Graphics Processing Unit
OpenMP: Open Multi-Processing
RAM: Random Access Memory

References

1. Houghton, J.T.; Ding, Y.; Griggs, D.J.; Noguer, M.; van der Lindern, P.J.; Xiaosu, D. *Climate Change 2001: The Scientific Basis*. Cambridge University Press: Cambridge, United Kingdom, 2013.
2. Néelz, S.; Pender, G. *Benchmarking the latest generation of 2D hydraulic modelling packages*. Environment Agency: Bristol, United Kingdom, 2013.
3. Bladé, E.; Cea, L.; Corestein, G.; Escolano, E.; Puertas, J.; Vázquez-Cendón, E.; Dolz, J.;. Coll, A. Iber: Herramienta de simulación numérica del flujo en ríos. *Revista Internacional de Métodos Numéricos para Cálculo y Diseño en Ingeniería*, **2014**, vol. 30(1), pp. 1-10.
4. TUFLOW FV Science Manual. Available online: https://www.tuflow.com/Download/TUFLOW_FV/Manual/FV_Science_Manual_2013.pdf (accesed on 2 11 2017).
5. InforWorks ICM Product Information - Overview. Available online: http://www.innovyze.com/products/infoworks_icm (accesed on 2 11 2017).
6. Crossley, A.; Lamb, R.; Waller, S. Fast solution of the Shallow Water Equations using GPU technology. In Proceedings of the British hydrological society 3rd international symposium, 2010, Newcastle, pp. 13-19.
7. Néelz, S.; Pender, G. *Desktop review of 2D hydraulic modelling packages*. Environment Agency: Bristol, United Kingdom, 2009.
8. Cea, L.; Bladé, E. A simple and efficient unstructured finite volume scheme for solving the shallow water equations in overland flow applications. *Water Resources Research* **2015,** *51*(7), pp.5464-5486.
9. ANUGA User Manual Release 2.0. Available online: https://github.com/GeoscienceAustralia/anuga_core/raw/master/doc/anuga_user_manual.pdf (accesed on 2 11 2017).
10. Chen, A.S.; Djordjevic, S.; Leandro, J.; Savic, D. The urban inundation model with bidirectional flow interaction between 2D overland surface and 1D sewer networks. NOVATECH 2007, 2007, pp. 465-472.