INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Team Cosivie

COuplage de modèles pour la SImulation numérique de problèmatiques enVIronnementalEs

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THEME NUM

Activity Report

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Table of contents

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2. Overall Objectives

2.1. Introduction

Created on 2000, COSIVIE team is interested in the modeling and the numerical simulation of water flows problems. Its research efforts are mainly oriented to the development, the theoretical justification and implementation of numerical approximation methods adapted to these problems. Moreover, it investigates the coupling of these models within an integrated information system under the WEB (IISW), with the most recent tools in visualization, treatment, consultation, indexing and structuring of data. This IISW, considered as a major part of a Decision Support System (DSS), is consequently subject to validation on real cases in connection with professionals and end-users in this research field.

These problems related to water resources constitute a high priority field for the man, characterized by the reduction of this resource at the planetary level, its intensive use as well as its related various risks (pollution, flood, etc). Whether it is to preserve water for irrigation, to manage a watershed, to build a dam to alleviate flood risks, to reload or depollute a ground water aquifer or to oxygenate a lake to eliminate eutrophication, any effort to develop a solution for these problems, must be based on an approach that considers all cause and effect relationships, evaluates in a systematic way the various alternatives, and consequently, offers a global vision of the main different components of the studied ecosystem:

- physical and numerical modeling,
- numerical simulation (PDE[1] analysis, algebraic solver, DTM[2], HPCN[3]),
- DBMS[4], GIS[5], vision, experimental data,

[1]Partial Differential Equations
[2]Digital Terrain Model
[3]Hight Perfomance Computing Network
[4]Data Base Management System
[5]Geographical Information System

- evaluations of impact, socio-economic data and indicators, etc...

Each one of these fields is itself a wide potential research domain. Nevertheless, within the framework of Cosivie, we are interested, from the research point of view, only in the numerical modelling and algorithmic aspects in addition to the integrated information system concept. The other aspects are considered as tools to control and to use for a better valorization of the developed software. The objective is thus to associate, in the framework of integrated architectures, the numerical simulation models existing or to be developed with the most advanced data pre and post processing tools. The trend is to go towards the construction of virtual simulators for physical systems able to take into account all the complexity of the modelled phenomena. The validation and the calibration of these simulators constitute also one of the tasks to be ensured. This component implies a real collaboration with professionals of the sector, holders of terrain measurements. The information extracted from these measured data of the real world characterizing the physical phenomenon will allow to corroborate the numerical simulation output with reality by taking into account geometrical, morpho-dynamic, hydro-meteorological data, etc.

On the water resources thematic, we focus our interest on the free surface flows type problems (floods, inundation, water reservoirs, estuaries, fluvial and torrential regime), infiltration (porous media, aquifers, pollution). These problems are mainly governed by unsteady non linear PDE in three-dimensional domains, with eventually a free surface. In addition to the mathematical and numerical modelling aspects of these problems, arises also the deal question of data treatment for modelling watersheds, numerical terrain models, etc. The interactive coupling between the developed models of numerical simulation and the tools of pre and post processing of data, existing or to adapt, provides a suitable appropriate answer to the question. The team Cosivie works relates thus to the two following components:

2.2. Specific component

This first component having applicative character relates to the modeling and the numerical simulation of environmental problems and more particularly the flows and the water management. This part is supported mainly by the work undertaken previously within Euro-Mediterranean projects (ESIMEAU, CRUCID and WADI) as well as by emerging new research fields made possible thanks to the results of the generic component.

The mathematical and numerical Modeling of the considered water problems require a thorough knowledge of the physical phenomenon, essentially governed by the conservation equations of the fluids mechanics (Navier-Stokes, Euler, Saint-Venant) to which are added closure turbulence models. A particular effort is carried on the initial and boundary conditions, in order to restore acceptable physically models, and on the multidimensional and/or multi-models aspects for realistic applications. In this context, works related to modeling are focused on the following applications:

- Unsteady water free boundary flow in rivers (floods, inundations, breaking dam, pollutants and sediment transport), or in estuaries (densimetric media, fresh or salt water, tides, thermics, turbidity, silting, etc...).
- Unsteady water-air 2D/3D multi-scale diphasic flows, with free boundary (treatment by aeration via air bubbles injection of water reservoirs subject to eutrophication phenomenon, optimization of injectors location and injected air quantity, etc).
- Watersheds at the hydrological scale (rain-flow transformation, characterization of the physiographical parameters - rainfall, infiltration, soil rugosity, etc - floods, interaction between numerical simulation and vision by computer, optimization and control of dam location, breaking dams...).

2.3. Generic component

This second component of fundamental character, concerning the research and the development of approximations methodologies and techniques for the studied models in the first component, is focused on the following themes:

- The numerical analysis of continuous problems and approximation methods of PDE with optimization techniques in the finite element/volumes framework, based on a priori and posteriori error estimators and indicators. We notice that this last point will permit on the one hand a significant improvement of the result quality for a pre requested accuracy and on the other hand a better understanding and handling of the coupling of multidimensional models and multi-models towards effective intensive and real computing applications. This implies specifically a very good control of mesh generators and viewers tools.
- In closed relation with the previous theme, algorithmic analysis and the development of parallel programming tools under MPI, to reduce the computing time but also to permit larger computations related to real cases. Besides the need of high performing processor, requires a high level knowledge of the compilers, the data and the instructions flows in order to handle and to improve the data coherency, the tasks dependencies, the communicating overhead convenients and the granularity gain.
- The concept development of software architecture and integrated system in a client/server mode and via the Web: Integration of treatment tools for data, for existing or forthcoming heterogeneous documents database related to water resources and to the environment. This system has to be accessible, diffusable on the Web, and above all exploitable as support in taking socio-economic and socio-politic decision, as well as to the production of informations and knowledge for simulation and modelling purposes.

3. Scientific Foundations

3.1. Introduction

COSIVIE team considers the physical problems inherent to water in order to analyze and to model them at the physico-mathematical level, to examine the related mathematical aspects, to approximate numerically the concerned operators and to establish the associated error estimates. For that, we develop stable numerical resolution schemes in a finite elements/volumes context, as well as robust numerical solvers. These schemes are then implemented within an integrated computation framework using HPCN facilities and including information technologies tools and techniques (GIS, data warehouse, vision, etc) in a convivial software environment serving as simulator.

What characterizes such a simulator, is its software architecture based on the possibility of integration software elements (software component) coming from different sources independantly as much as possible of the existing hardware and operating informatics systems. It implies the integration and the interactivity between various but complementary tools. Instead of huge multifunction tool, it is based on the selection or the development of a set of technologies allowing, by assembling within a data warehouse (see Figure 1), the conception of an integrated information system adapted to the specific needs of the users and to the available computing facilities.

This implies pluri-disciplinary collaborations that are not paradoxically widespreaded, while nevertheless the Applied Mathematics are not specialized by technical domain. For example, the multi-phase flow in porous media yields to the same systems of equations modelling an oil flow or a groundwater aquifer. The two corresponding simulators will have many elements in common. The Applied Mathematics allow to unify and to generalize the tools. An effort on ergonomy and adaptation is nevertheless necessary to switch from a domain to the other. An earlier conceptual analysis and an open data warehouse organization will minimize

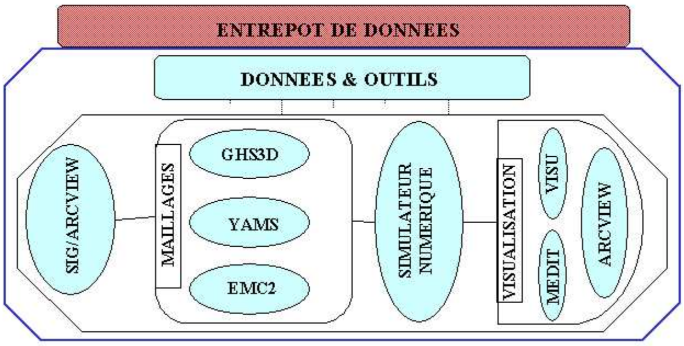

Figure 1. Data warehouse

considerably this work. The necessary counterpart to this pluri-disciplinary approach is the construction or the acquisition of tools adapted for a given sector from general or specific ones developed for other sectors. This allows a strong capitalization of the obtained experience and an effective transfers as well as new research fields emerging in the concerned disciplines. The information system concept through its post and pre-processing tools (GIS, DBMS, & Vision) permits on the one hand to extract in an automatic way necessary information for the simulation models and on the other hand to verify and to calibrate eventually in real time the results of these simulations by corroborating them with extracted or identified parameters. The integration data-models goes therefore in the direction of a better adequateness between the developed codes and the physical reality. From this general perspective, the subjects research of COSIVIE are oriented around the described axis below.

3.2. Modelling and Numerical simulation

The numerical simulation models evolved nowadays towards a more realistic representation of physical problems that they approximate by considering the modelling under a multidisciplanry approach requiring a good knowledge of the threated physical phenomenon. The development of such models is based certainly on mathematical modelling techniques but also on the continually growing of computing facilities provided by information technologies. The approximated physical models in our applications are essentially governed by the conservation equations of the fluid mechanics (Navier-stokes, Euler, Saint-Venant) completed by adequate constitutive laws, state laws, turbulence models and initial and boundary conditions following the considered case; a carefull effort on these phisycal aspects is also deployed in order to obtain physically admissible relevant models. The approximation of a given problem leads to privilege some variables and laws and to take in the weak sense the others. These choices, usually transparent in the continuous problem, become decisive for the simulation results quality. These choices are often linked to physical considerations, to numerical stable schemes and to computing faisability and facilities. Our prior approach consists in identifying the most important variables being able to be calibrated by the numerical pre or post processing tools, available or to be adapted or developped specifically.

The numerical simulation strictly speaking, calls for the use of techniques related, essentially, to approximation methods of PDE's and optimisation techniques. From the computational point of view, these methods necessitate a perfect control of the algorithmic programming tools as well as a powerful and large computing capacities for running the inherent numerical codes. In addition, it is required specifically the control of sophisticated mesh generators systems and graphical viewers (GAMMA project).

3.3. Algorithmic techniques and intensive computation

During the simulations of fluid flows scenarii at real scale, one is confronted to large size problems and consequently to important CPU times. In addition, if we consider for this kind of allpications the requirements of having real time responses and the distributed data access, it becomes essential to include in our approach the use of tools and technologies related to HPCN, mesh adaptation techniques and coupling multi-models and multidimensional models. Around this thematic, the research activity of COSIVIE is focused on the following two aspects:

3.3.1. Mesh adaptation, multi-models and multi-dimensional model coupling

The complexity of real simulation configurations encourages us to elaborate mesh adaptation techniques in order to improve the numerical models, as well on the level of the optimal quality of a response for a required precision as on its cost. The use of these approaches, associated to error indicators, based on the research of optimal size of meshes, allows to guarantee acceptable error upper bounds for the variables of the considered problem. There are various types of error indicators in the literature. However, the residual and geometrical error indicators seem currently to be the most efficient, in the sense that they are on the one hand easy to implement numerically and on the other hand they do not require information on the solution of the continuous problem. In this context, one underlines that error indicators techniques constitute a promising tool of decision for the choice of the flow model, its dimension or its data input requirements. Another promising axis concerns the multidimensional coupling between surface water flow models (1.5D and 2.5D Saint-Venant, 2D and 3D Navier-Stokes), which will be essential for real simulations of flood scenarii. This reveals important difficulties related to the boundary conditions which are also of multidimensional nature. Another research activity, carried out within COSIVIE, relates primarily to the coupling model-model, model-data, data-multi-models via a posteriori estimators. An effective way for implementing such techniques requires, in addition to a fine physical modeling in particular in hydrology, an analysis combining several aspects among which the most dominating are:

- Analysis of hydro-meteorological data.
- The cartographic support including the watershed DTM, vegetable cover, the characteristics of infiltration, streaming and evapo-transpiration as well as other layers of information, in particular of hydro-geological type.
- The transformation Rain-Flow via models of deterministic and/or stochastic type.

Due to the non accessibility or rather the high uncertainty of the data input of the simulation models, a particular effort will be directed towards the study of coupling multi-scale problem between the hydraulic and hydrological models and the numerical modelling aspects of the boundary and initial conditions.

3.3.2. Parallel computing

The parallelization of the existing codes or the ones under development and their implementation on parallel machines will reduce certainly the computing times but also will permit on the one hand to increase intrinsically the size of the treated problems and on the other hand to simulate several cases: consequently, this will improve the model calibration. Indeed, for a given method, the accuracy is often improved by the increase of unknowns number. In addition, these accurate solutions can thus be used as reference solution for the validation of a different and more economic approach of the considered problem.

A first stage consists to take again the already established algorithms, to analyze them and then to decide on the parallelisation strategy to implement. The implementation on parallel machines uses the protocols of standard communication MPI/PVM or HPF and libraries of parallel algebraic solvers, available in general in the public domain, indeed, this cost-effective choice is motivated mainly by the portability of the codes from the networks of workstations, on which the developments are done, until the supercomputers and their re-use. These standards are adopted and installed by the majority of the manufacturers for their level of diffusion, universality and portability in the field of the HPCN, as well as for their availability, in the public domain. Moreover, we notice that the acquisition of the HP V2250 (16 proc RISC Pa 800 8Go RAM) by our team permits to lead simultanuously both distributed and shared memory programming. Indeed, this machine is a true parallel computer from its internal cross bar architecture, its shared memory and especially by its dedicated buses for the I/O between the various processors; this last point missing really in a distributed memory virtual parallel machine, in general constituted of cluster of stations or PCs under Internet network. This was checked by the comparison between 2 architectures, the parallel server V2250 and a network of stations under Unix or of PCs under Linux or WinNT configuring a virtual parallel machine; the obtained results show that the real (or elapsed) time performances are clearly improved on the V2250 and this independently of its shared memory.

3.4. Software Architecture and Integrated System

Planning and management of water resources is a highly complex and tedious task that involves many aspects including data acquisition and treatment, multi-processes and therefore multi-models, numerical modeling, optimization, knowledge data warehouse, analysis exploitation issues, etc. As mentioned before, we have developed a client/server Web Integrated Information System (WIIS) dedicated to the management and the modeling of the hydrous resources. This system is an infrastructure of development, perennial, open, modular, robust, effective and convivial offering a complete dynamic and configurable environment. The WIIS architecture consists in two levels: the first one contains general modules such as viewers, GIS, grid generators, data warehouse, simulators, etc, and the other one is domain specific and includes all the relevant modules tackling numerical modelling for the water related physical application under study, i.e. hydrology, hydraulics, hydrodynamics floods. The realization used intensively the JAVA technology and client/server architecture under Web including in particular an Information Indexation and Research System (IIRS). This IIRS operates on a thesaurus based on substitutes of documents under XML structure of the data warehouse characterized by strongly heterogeneous and distributed contents. In such a way, this WIIS allows on the one hand to extract, prepare, handle, manage and analyze in an automatic way necessary information to the models of simulation and on the other hand to analyze, exploit, interpret, display, manage, communicate, check and calibrate if required in real time the results of these simulations by corroborating them with extracted or identified parameters. The Prototype I the WIIS has been validated and tested within the EC WADI project on concrete cases as Foum Tillicht (Morocco) and Nahr Beyrouth (Lebanon) for the localization of potential dam sites and the prevision of natural inundation in addition to Oued Soummam (Algeria).

4. Application Domains

The COSIVIE workprogram is directed towards an identified target applicative domain: the water resources and their management. It is supported by European and bilateral programs with the partnership of professionals from the water sector. However the approach oriented to the development of a " simulator " is generic, its transposition towards other application fields is relatively easy. One can quote closed fields such: regional planning (coasts, watershed, etc...), transport of pollutants, sediments, etc. But one can also quote connexe fields like the dynamics of populations, the study of living species in the considered media (halieutics species), the management and the modelling of energetic resources, etc.

5. Software

We give below a list of developed or ported /adapted software in COSIVIE:

- **NS2DCA-(u-p)**: (see section 6.1) Software solving 2D Navier-Stokes equation in velocity-pressure formulation, using the characteristics method for the time discretization and finite elements P1/P1 bubbles for the spatial approximation. At each time step, we have to solve characteristics scheme and Quasi-Stokes type problem. The resulting linear system is solved by a preconditioned conjugate gradient-Uzawa method, with Cahouet-Chabard preconditioner. Intermediate linear systems are also solved by the same method with the incomplete Cholesky preconditioner. This software offers several options:
  - Semi-compressible alternative, consisting in solving a transport equation on the density by the characteristics method.
  - Diphasic alternative for treatment of water-bubbles air flow, taking into account the effect of bubbles by the means of correction terms, starting from di-phasic models; these terms are a source term representing Archimedean force and a term, related to the void fraction of bubbles in air, intervening on the level of convection and diffusion factors.
  - Free surface alternative, calculating the void fraction of the water by the characteristics method, from a transport equation, and allowing thereafter to update the fluid domain at each iteration in time.
- **NS3DCA-(u-p)**: It is INRIA software (ex-M3N), consisting in solving 3D Navier-Stokes equations by the same techniques as NS2DCA-(u-p) software.
- **NS2DCA-(ω, ψ)**: Software solving 2D Navier-Stokes equations in vorticity-stream function formulation. The time discretization is performed with the characteristics method. Stabilized C0 finite elements are used for the spatial approximation.
- **SV2DCA**: (see section 6.2) Software dealing with St-Venant equations, written in the non conservative form, in water depth-velocity formulation. It is adapted from NS2DCA-(u-p) software and integrates a module handling free surface, based on wetting drying elements criterion.

We give now a list of important softwares used and/or adapted to the needs of COSIVIE team:

- **FESWMS:** FESWMS Finite Element Surface Water Modeling System software comes from the public domain. It consists in solving St-Venant equations, written in the conservative form in water depth-velocity formulation, linearised by Newton method and discretized by finite elements P1 for the water depth and P2 for the horizontal velocity. The time discretisation is performed by the Cranck-Nicolson scheme. The LU linear solver is combined to the frontal method, which allows to reduce the necessary space memory for storage.
- **EMC2:** EMC2 is INRIA software (ex-M3N) for editing meshes and contours in 2D. It permits to generate interactively a two-dimensional mesh by defining the geometry, discretizing contours and affecting sub-domains reference numbers, to take into account the boundary conditions and material properties. These meshes, formed of triangles or quadrangles, are of grid or Delaunay-Voronoi type. It is also possible, to edit a mesh by adding, removing or moving the vertices, and by applying transformations: symmetry, rotation, etc. This software uses library F3D under X11 and its portage under MS-SDK was carried out (COSIVIE).
- **VISU:** VISU is a software developed at INRIA (GAMMA project) for the visualization of meshes or numerical results. It presents various interactive menus, which allows to define the 2D/3D visualization parameters (decoration, iso-values or vectors plotting, etc.), to read various topological databases and solutions, to associate them in windows for visualization) and to define curved or surfaces "functions" in 2D/3D with various parameterization types. This software uses library F3D under X11 and its portage under MS-SDK was carried out (COSIVIE).

- **ARCVIEW:** ARCVIEW is a commercial geographical information system (GIS), presenting a certain number of functionalities such as visualization, exploration, spatial analysis of data, the consultation of databases stored in tables related to software and in particular another databases. ArcView has Avenue as language, or pre-compiler BASIC depending on the version; it was developed by ESRI and it is available under Windows and Unix.
- **GHS3D:** GHS3D is an automatic tetrahedral mesh generator developed at INRIA (GAMMA project), allowing to create volume meshes for domains defined by a mesh surface discretisation. Resulting meshes can be viewed using VISU or MEDIT. GHS3D is based on an important input: the surface mesh of domain, provided by assembling its components which can be generated by EMC2 or YAMS.
- **YAMS:** YAMS is INRIA software (GAMMA project) intended for the mesh generation of curved surfaces. The data is a surface triangulation or quadrangulation, to which are applied topological and geometrical modifications. The goal is to obtain a simplified or enriched mesh corresponding to the boundary of a given domain. Its output can be viewed by VISU or MEDIT.
- **MEDIT:**(see 6.5) MEDIT is INRIA software (GAMMA), permitting to visualize any conform or not conform mesh (2D, 3D or of surface) (in the finite element context), in a graphic window which is clean for him and possibly several grids in independent chart windows. The user will be able to act on the visualized object either by changing its appearance, or by carrying out transformations (rotation, translation, cut, zoom...). This software uses OpenGL technology and its portage under MS-SDK was carried out (COSIVIE).
- **IIRS:** Information Indexation and Research System Xml based assisting the user in his search for information. This IIRS operates on a pertinent thesaurus based on substitutes of documents under XML structure of the data warehouse characterized by strongly heterogeneous and distributed contents. The IIRS allows the integration of data resulting from multiple heterogeneous sources, the storage of data, the management of their temporal dimension and their non-volatility.

6. New Results

6.1. Introduction

The results related to the reporting period concern works on:

- new numerical approaches for Navier-Stokes equations, adapted to targeted problems,
- multidimensional models of rivers flows and their automatic coupling by the means of a posteriori estimators,
- the development of parallel algorithms under MPI,
- The construction of an integration prototype of software binding a DBMS, GIS, mesh generators, 2D Navier-Stokes and St-Venant codes and visualization tools for the post-processing.

They were concretized in 2004 by 3 accepted publications and 1 submitted to international journal, and 8 communications with referees. The number of achieved theses related to these topics is 4 ([43], [12], [48], [47]) and there are 7 theses currently in progress. In parallel, the E.C. WADI project required a particular effort: 9 reports).

6.2. Numerical Simulation of the eutrophication mechanic treatment

Keywords: *Navier-Stokes*, *characteristics method*, *finite element*, *multi-scale*, *water-air bubbles diphasic flow*.

Participants: M. Amara, F. El Dabaghi, M. Abdelwahed, Ch. Kada Kloucha, M. Hassine, S. Benziada, F. Mezali.

A lake eutrophication phenomena is observed throught a progressive degradation of water quality. This is caused mainly by the climatic variations and in particular thermal ones, when dissolved oxygen concentration reaches a critical low level: less than 3mg/l (see [43],[5]).

For restoration or prevention techniques against lake eutrophication, the dynamic aeration process is one of the most promising techniques (see figure 2). It consists in injecting air in the bottom of the lake in order to create some dynamics and aerate the water. The numerical simulation of this process leads to many difficulties coming out from the complexity of the two phase water-air bubbles flow model (see [14], [28], [27]) and the higher 3D computing costs resulting from the domain size.

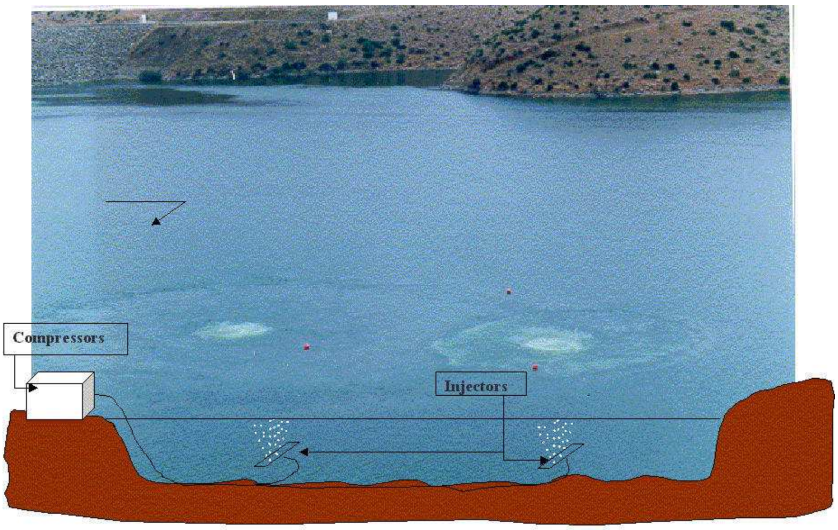

Figure 2. Schéma du processus d'aération d'un lac

Another component of this work, in the Phd thesis framework of Kadakloucha, is to take into account the free surface. We are interested essentially in the effect of the wind on the free surface in order to treat more accurately the dynamics of the lake and consequently the trajectories of the air bubbles injection. Our approach consists in considering a global flow domain, containing water and a part of the atmospheric air, governed by the navier-stokes equations and by a transport equation on the void fraction of the water in this domain for modelling the effect of the free surface (see [34], [21]). On the air-water interface, one considers the impermeability of the surface as boundary condition. Currently, we restrict the study to the 2D flow representing a transversal cross section of a lake. The modeling of the moving free surface, with respect to the time requires the addition of a transport equation for its description. For the numerical resolution of this model, we adopt an Eulerian approach (see [29], [17], [30]) that consists in using a fixed mesh, with a Lagrangian transport of the water domain. In fact, one will introduce a characteristic function in order to determine the position of the water in the space during the time. This function must satisfy a transportation equation in a global domain where water is confined. The time discretisation by the characteristics method leads to successive resolution of two convection problems and a quasi Stokes like problem. For the spatial discretisation, we use the mixed finite element P1+Bublle/P1 (see [15]). A numerical test was done on a rectangular domain. The mesh is more refined in the neighborhood of the free surface at time t = 0 (see figure 3). The domain has a length of 250m and a width of 30m, the distance between the initial free surface and the bottom is 25m. The mesh is constituted of 3450 nodes and of 6487 triangular elements. The number of unknown is of 19874 for the velocity and 3450 for the pressure. Neumann type conditions are considered on the free surface and the outflow boundary, and Dirichlet conditions on the inflow boundary for the velocity. The pressure is prescribed at the free surface.

We plot on figures 4 the isovalues of velocity at times t=100, 200, 300, 400, 550, 800s. The small prescribed velocity on the inflow boundary of 1m/s allows, as one can notice it on figure 6, to generate small perturbations of the free surface. Indeed, this first test validates our modelling approach of the free surface due to the wind effect (see [30]). In the second test, for simulating the aeration process effect, we use instead of air injector, a semi circular obstacle at the bottom (see figure 5) to avoid expensive computations (see [43] and [1]); indeed, this test permits to evaluate the effect on the surface of the perturbation initiated by the fluid itself, as equivalent to the injector effect. For the same boundary conditions of the first test, we plot the isovalues of the velocity at times t=300, 600, 650, 700, 750, 800s (see figures 6). We observe that the approach remains valid and stable. This preliminary and methodological validation for taking into account the free surface in two steps allows us to investigate in a forthcoming work the extension to the problem with injectors and then to use the diphasic code.

6.3. Numerical Simulation of fluvial and torrential flows

Keywords: *Navier-Stokes*, *Saint-Venant*, *coupling*, *estimators*, *finite element*, *multi-scales*.

Participants: M. Amara, F. El Dabaghi, B. Nakhle, N. Guelmi, A. El Kacimi, H. Henine, K. Ider, X. Louvert.

In this research axis, we are interested in the flow rivers simulation from the hydrodynamic point of view. 3D Numerical simulation being not possible on all a river, two approaches are proposed:

- the first, concerns St-Venant representations type, using type 2.5D or 1.5D model,
- the second investigates the automatic coupling of 1.5 D and 2.5 D St Venant models by the a posteriori estimators.

In this context, St-Venant approach is adopted and developed in the framework of Nakhle Phds thesis and the postdoc of El Kacimi. One calls upon the method of the characteristics (M.O.C.) for the time discretisation of St-Venant equations written in the non-conservative form, in the water depth-velocity formulation. The use of M.O.C. (see [13],[18],[34], [20]) is more appropriate for such kinds of flows, where the convection dominates the diffusion; indeed, this approach, consisting in discretising the Lagrangian derivative along the characteristics trajectories, leads to a stable upwind scheme, and consequently larger time steps are possible for accurate results. From a numerical point of view Cahouet-Chabard type precondionner is adapted for such flows. Preliminary results in this sens are the subject of communications in ([46]). The study of theoretical aspects related to this problem are in progress. From numerical analysis point of view, a priori error estimates are established and validated on various test cases (see [13], [19]). A drying-wetting criterion module, handling free boundary aspects, is developed and integrated in SV2SCA simulator.

6.3.1. Academic numerical tests

For illustration, we present some numerical results, using SV2DCA in the case of subcritical flow over 3 different geometrical domains(see [34]):

- rectangular domain, having 100m length and 10m width.
- rectangular domain, having 100m length and 10m width presenting cylindrical obstacle, at 30m from the outflow.

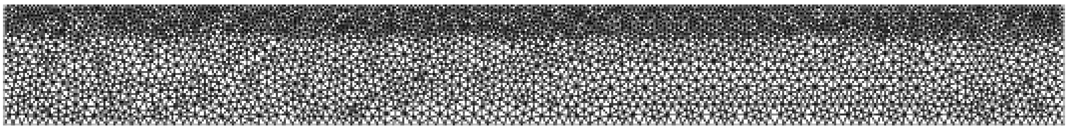

Figure 3. Initial global domain and mesh

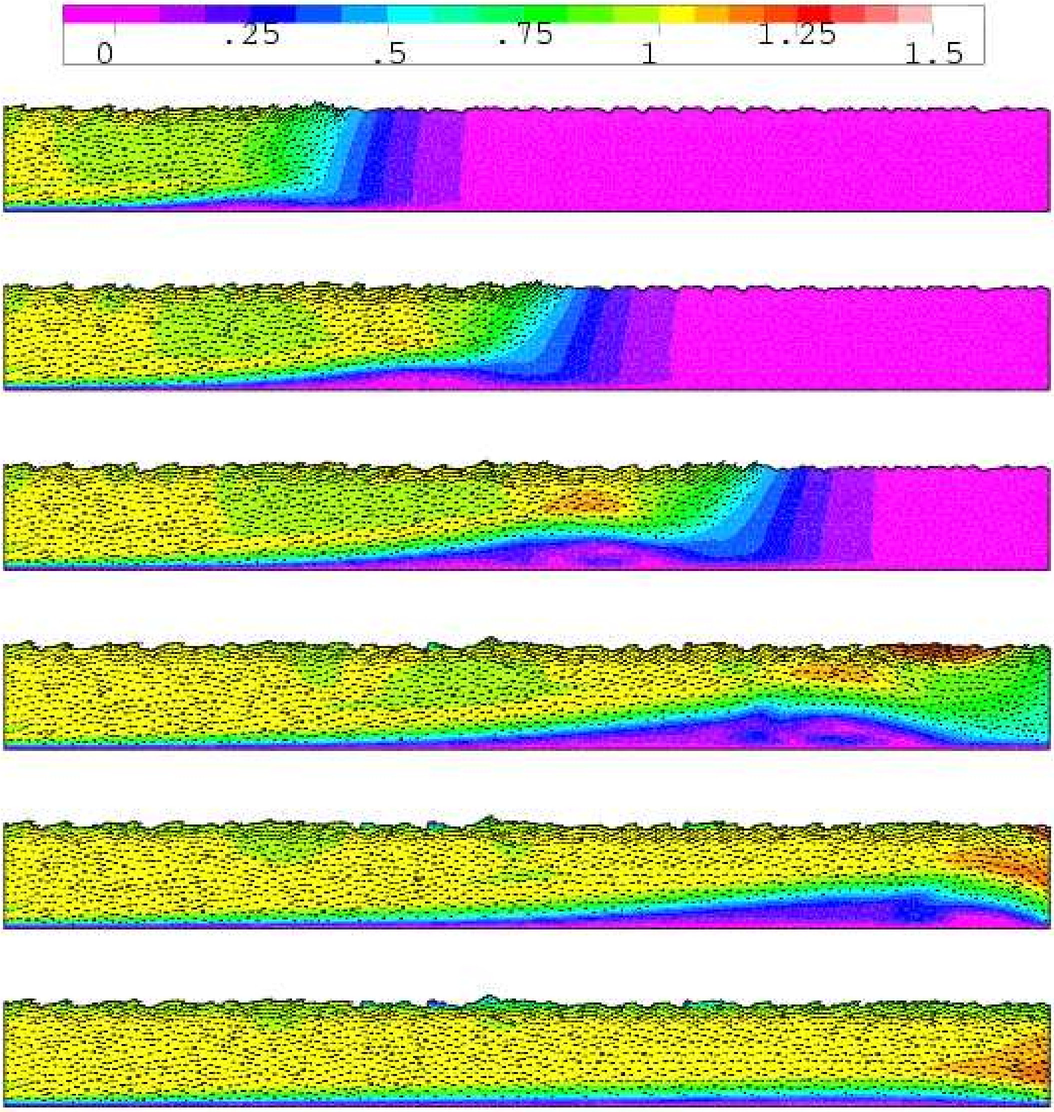

Figure 4. Vectors and isovalues of the velocity for t=100, 200, 300, 400, 550 et 800s

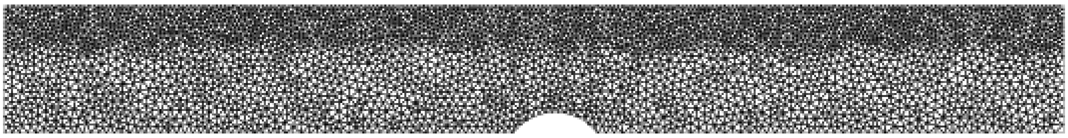

Figure 5. Global domain with circular obstacle and mesh.

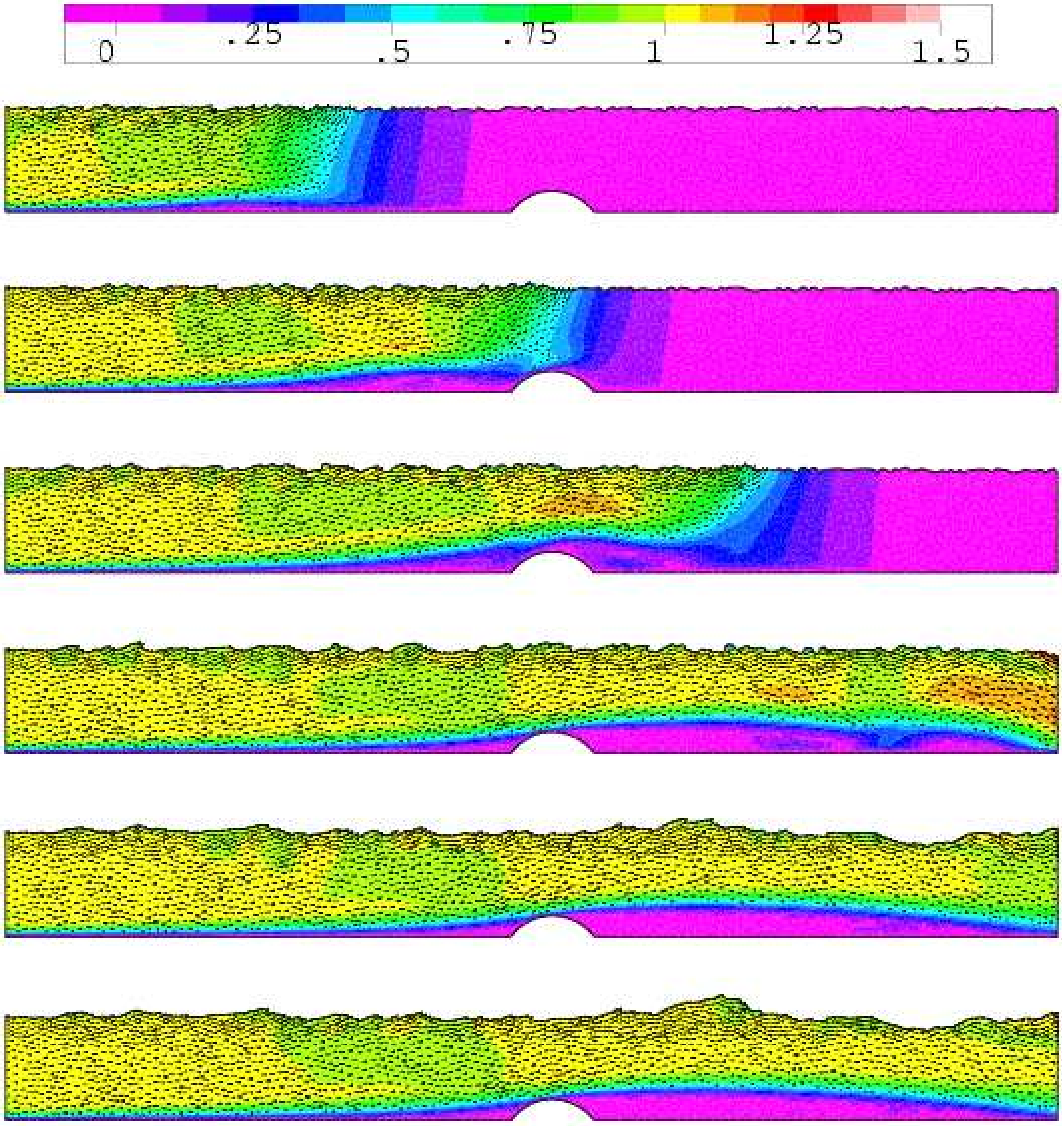

Figure 6. Vectors and isovalues of the velocity for t=100, 200, 300, 400, 550 et 800s.

- prismatic channel, with trapezoidal section having 100m length, 5m height, 20m width on the top, and 14m on the bottom

For the 3 cases, we perform for each one three different scenarii with a simulation time $t \in [0, 200]$ and a inflow flux illustrated in Figure(7) and described below:

- a constant flux of 5 m^3/s for $t \in [0s, 50s] \cup [100s, 200s]$
- a variable parabolic flux for $t \in [50s, 100s]$ with 5 m^3/s at $t = 50\ s$ and $t = 100s$ and a maximum at $t = 75\ s$ of respectively 7.5 m^3/s, 10 m^3/s and 20 m^3/s ($1^{rst}, 2^d, 3^{rd} scenario$)

For all the simulations below, we fix $\Delta t = 1$ and the Reynolds number $Re = 100$. Following the three choices of the profile flux (see figure 7). Tables 1, 2, 3 illustrate respectively the minimum and maximum values of the water depth and the velocity obtained by the calculation in the 3 test cases mentioned above.

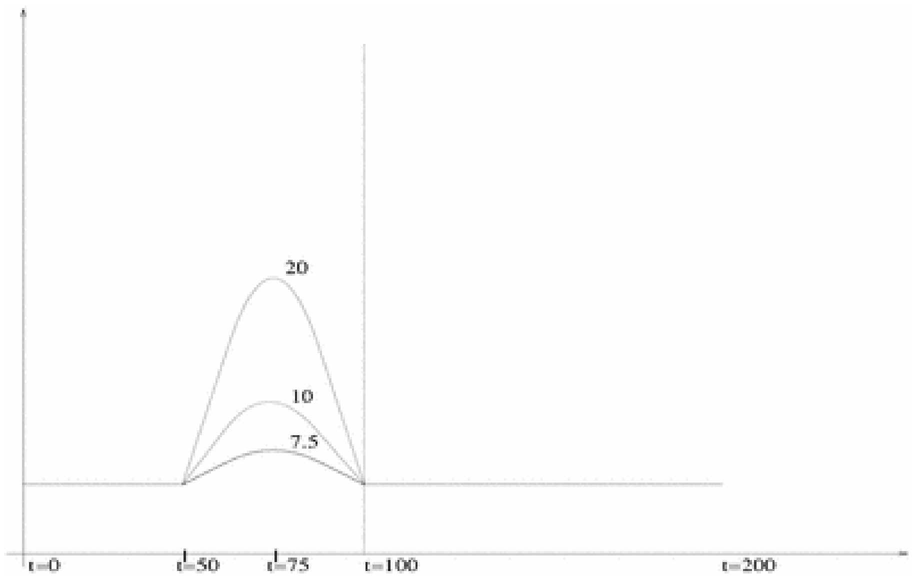

Figure 7. Flux variation

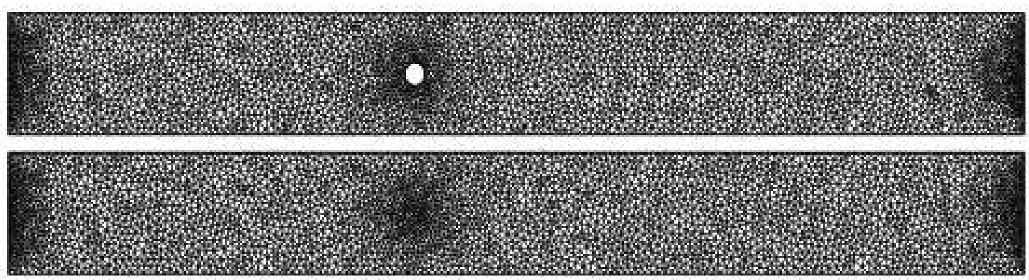

Figure 8. Meshes of the rectangular domain, with and without obstacle

-Rectangular channel without obstacle

The triangular finite element mesh corresponding to this case (see figure 8) contains 3667 vertices and 6952 elements. We present respectively on figure 9 at times (t=50s, 75s, 95s, 120s, 160s, 200s) the iso-values of the velocity and the water depth, in the case of the flux having a maximum of 10 m^3/s at $t = 75s$.

Table 1. Used data, min and max values of the water depth and the velocity.

Debit Max(m^3/s)	$\Delta t(s)$	Re	$H_{min}(m)$	$H_{max}(m)$	$\mathbf{u}_{min}(m/s)$	$\mathbf{u}_{max}(m/s)$
07.5	1.	100	0.922	1.080	0.000	1.116
10.0	1.	100	0.857	1.131	0.000	1.494
20.0	1.	100	0.724	1.335	0.000	2.765

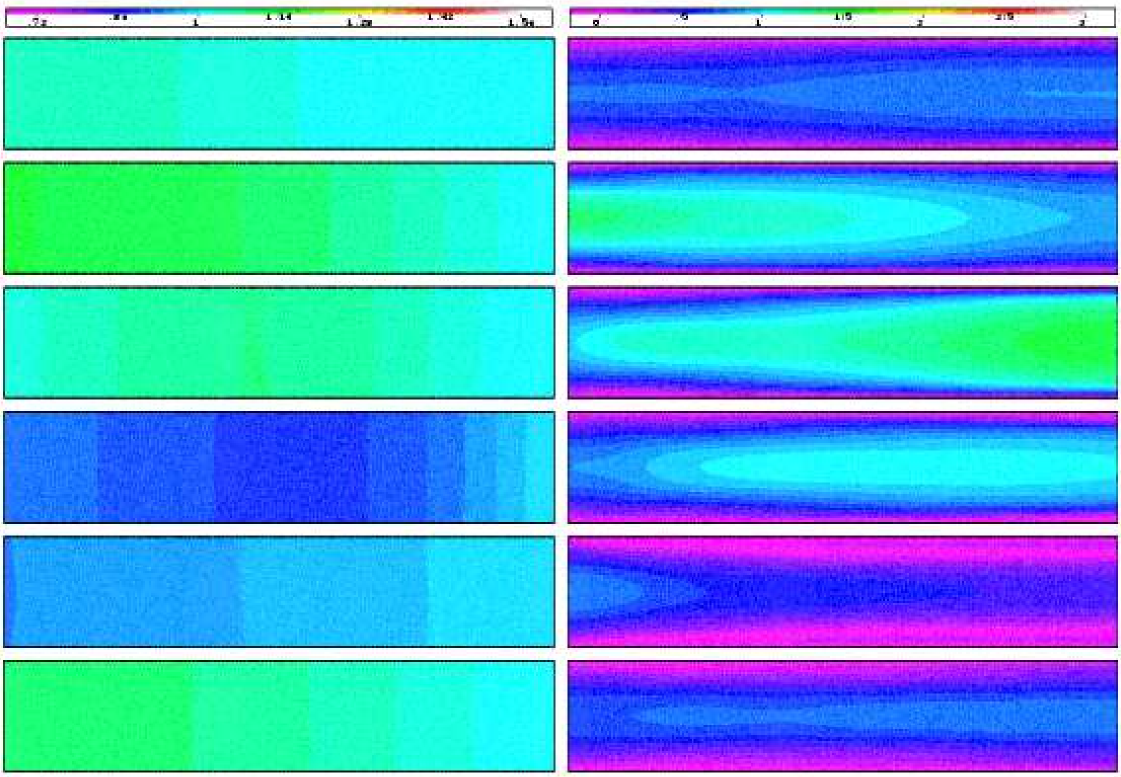

Figure 9. Iso water depth (left) and velocity: t=50,75,95,120,160,200; flux [5-10] m^3*/s.*

-Rectangular channel with obstacle

The triangular finite element mesh corresponding to this case (see figure 8) contains 3647 vertices and 6994 elements. We present respectively on figure 10 at times (t=50s, 75s, 95s, 120s, 160s, 200s) the iso-values of the velocity and the water depth, in the case of the flux having a maximum of 10 m^3/s at $t = 75s$. We observe that the presence of the cylindrical obstacle creates circulations of the fluid (see figure 11) and consequently increases the velocity in the obstacle neighbourhood.

Table 2. Used data, min and max values of the water depth and the velocity.

Debit Max (m^3/s)	$\Delta t(s)$	Re	$H_{min}(m)$	$H_{max}(m)$	$\mathbf{u}_{min}(m/s)$	$\mathbf{u}_{max}(m/s)$
07.5	1.	100	0.890	1.126	0.000	1.359
10.0	1.	100	0.814	1.230	0.000	1.705
20.0	1.	100	0.669	1.542	0.000	2.869

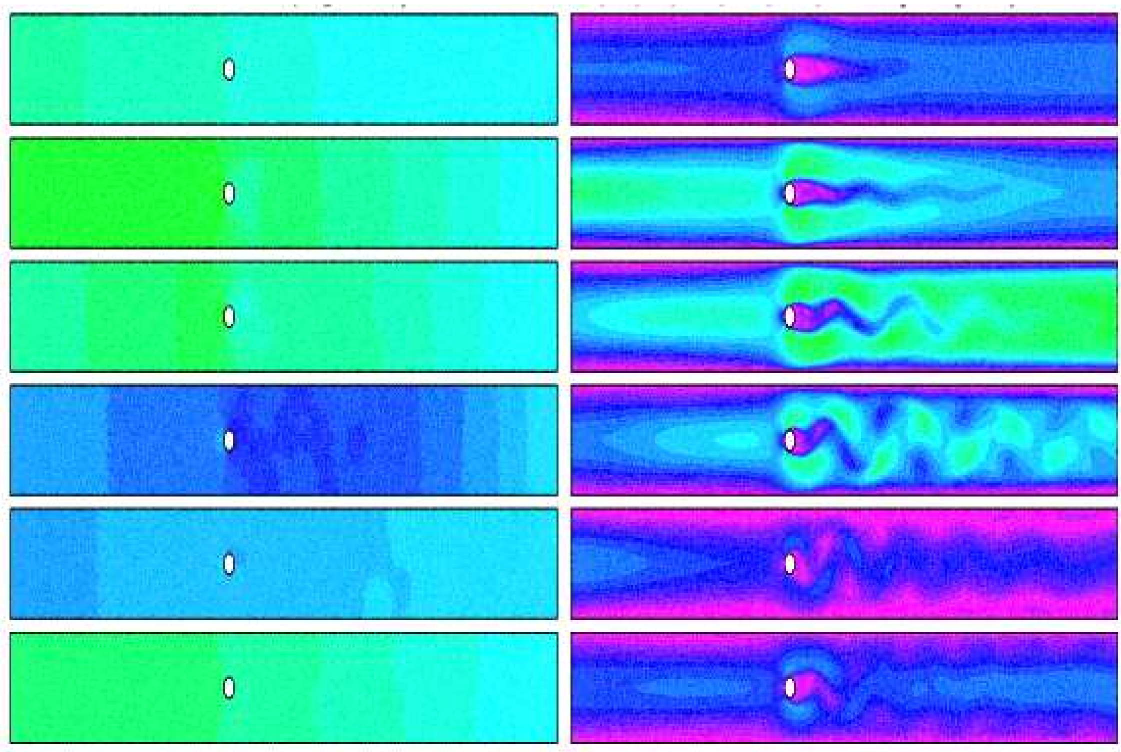

Figure 10. Iso water depth (left) and velocity: t=50,75,95,120,160,200; flux [5-10] m^3*/s ; with obstacle*

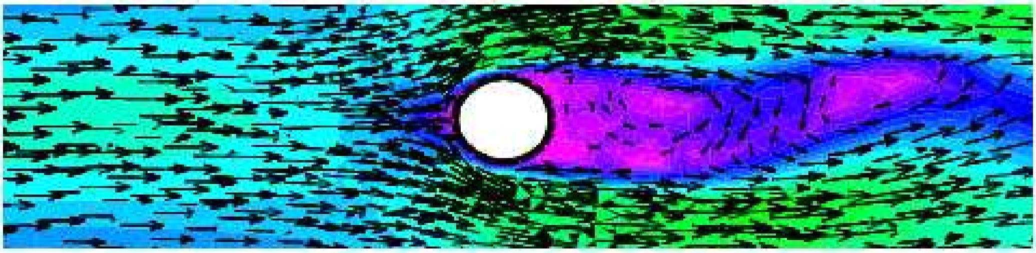

Figure 11. Zoom near the obstacle

-Prismatic channel with trapezoidal section

The triangular finite element mesh corresponding to this case (see figure 12) contains 5292 vertices and 10256 elements. Figures 13 and 14 illustrate respectively at times (t=50s, 75s, 95s, 120s, 160s, 200s) the iso-values of the velocity and the water depth, in the case of the flux varying respectively from 5 m3/s to 10m3/s, and from 5 m3/s to 20m3/s (see Figure 7). We observe that the maximum of water velocity increases slowly, by comparison with the preceding results, when the flux increases (see Table 3, figures 13 and 14). This is justified by the geometry of the fluid domain, having a bigger width allowing the water to spread out and consequently to slow down.

Table 3. Used data, min and max values of the water depth and the velocity

Debit Max (m^3/s)	$\Delta t(s)$	Re	$Z_{min}(m)$	$Z_{max}(m)$	$\mathbf{u}_{min}(m/s)$	$\mathbf{u}_{max}(m/s)$
07.5	1.	100	0.000	1.547	0.000	0.498
10.0	1.	100	0.000	1.646	0.000	0.607
20.0	1.	100	0.000	2.131	0.000	0.950

Figure 12. Mesh of the prismatic channel, with trapezoidal section

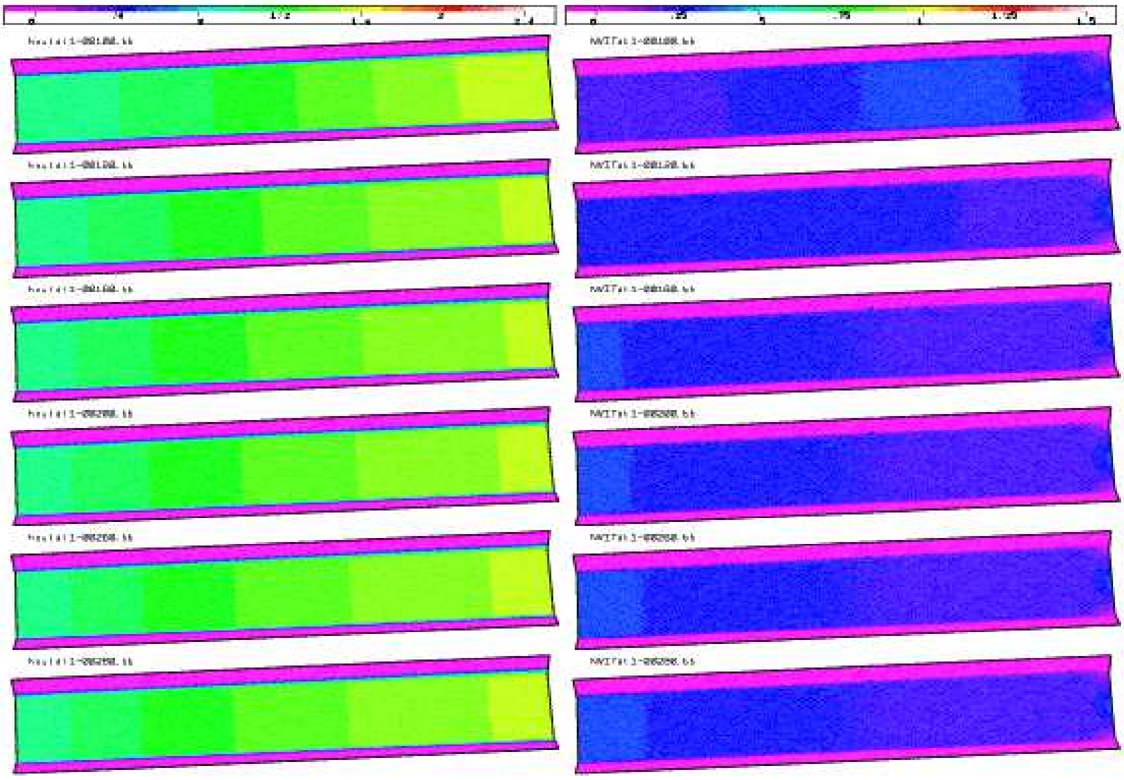

Figure 13. Iso water depth (left) and velocity: t=100,120,160,200,260,280; flux [5-10] m^3/s

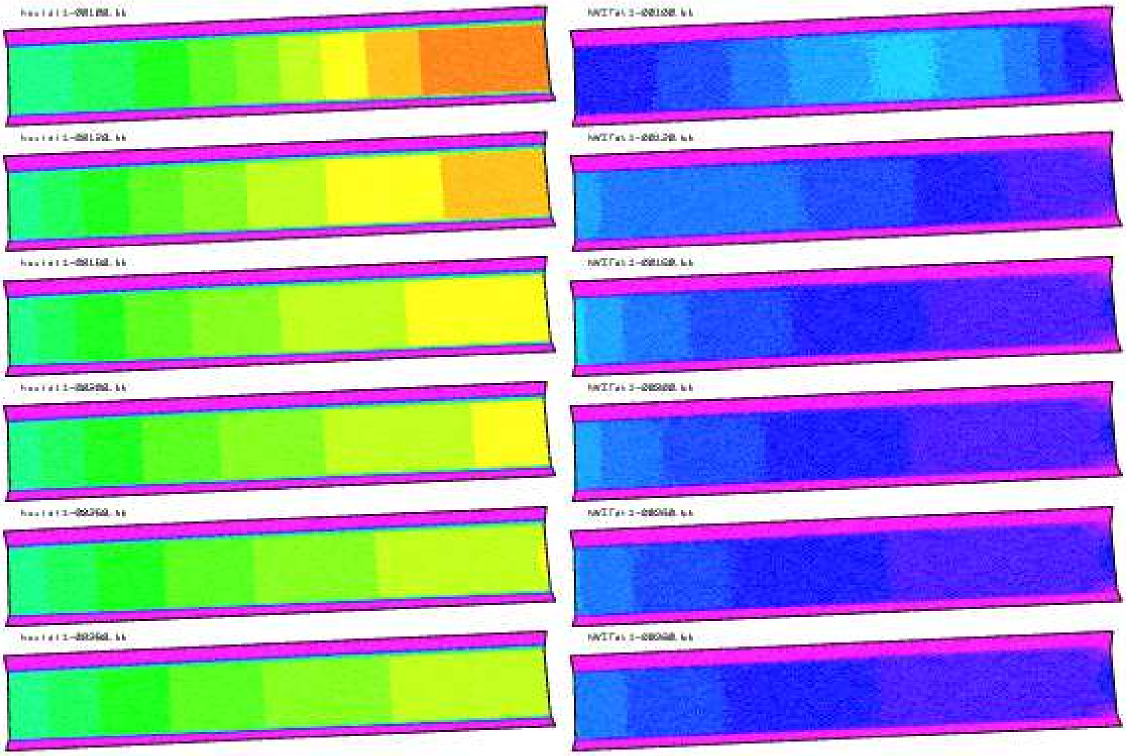

Figure 14. Iso water depth (left) and velocity: t=100,120,160,200,260,280; flux [5-20] m^3/s

6.3.2. Real test case: Foum Tillicht (Morocco)

We present now a real simulation case, treating flood wave propagation in the watershed of Foum Tillicht (Morocco). The section of the river concerned with this study, located just on the outlet side of Foum Tillchit watershed (see figure 15) in the province of Errachidia (Morocco). The triangular finite element mesh presented in figures 16 contains 107968 vertices and 215616 triangles (see [34]).

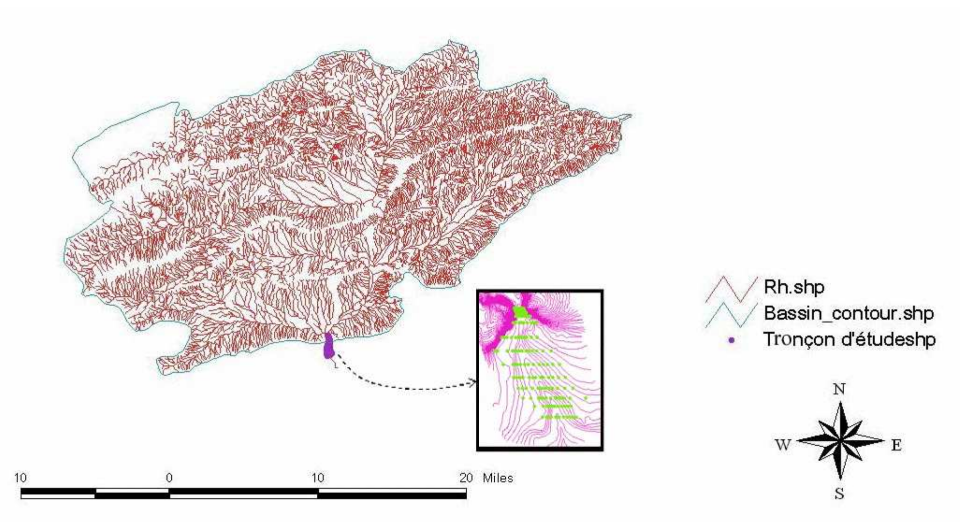

Figure 15. Geographic position of the section with respect to Foum Tillchit watershed.

Figure 16. A view of Foum Tillicht computation mesh

The mesh has been performed under YAMS with the use of variable metric tensor criterion for mesh adaptation. We present two simulation cases (see [34]), corresponding to flood hydrogramms illustrated in figures 17 and 18. On figure 19, we plot the iso-values of the water depth at times t=30min, 2h, 3h, 4h30min, 5h30min, 7h30min, 10h30min, 13h30min, the prescribed inflow flux being the one of the flood of 1986 (Figure 17). Figures 20 and 21 illustrate the time evolution of the water depth on the studied section, in the case of the flood of 1988 (Figure 18) at times t=1h30min, 4h, 5h, 6h, 6h30min, 8h, 11h, 12h30min, 16h, 17h30min, 20h, 23h30min.

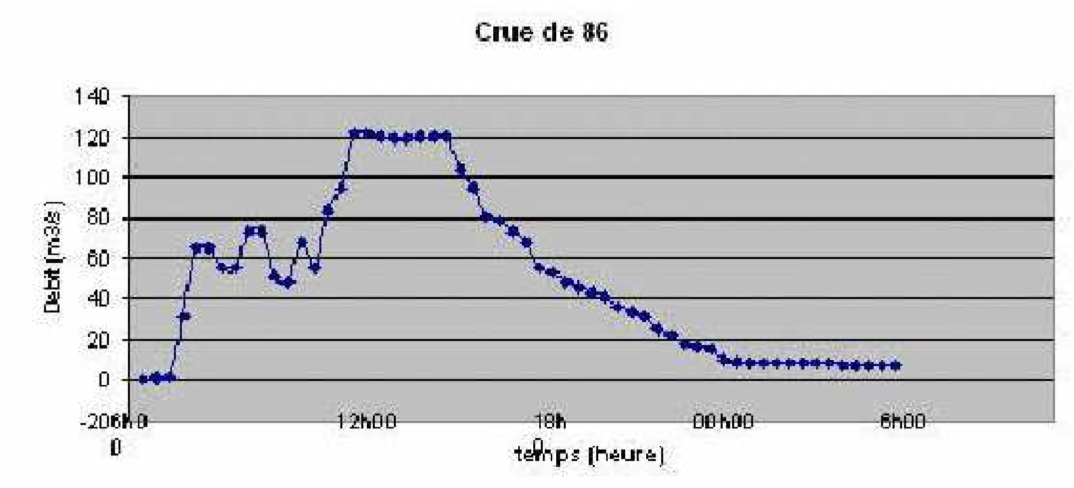

Figure 17. Foum Tillicht flood hydrogram, 1986

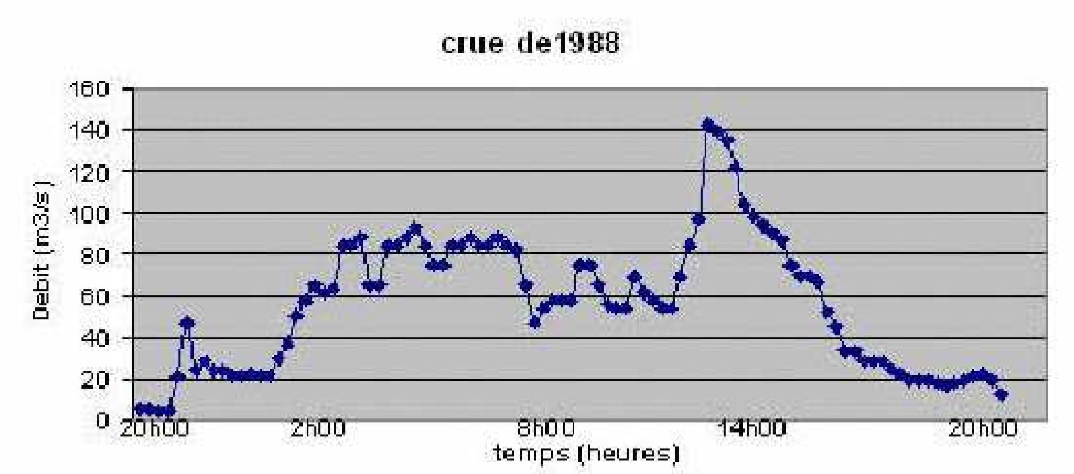

Figure 18. Foum Tillicht flood hydrogram, 1988

6.3.3. Geometric error estimators

On another register, the computation domains meshes having a preponderant role in numerical simulations based on the finite element methods, an automatic technique of mesh adaptation is elaborated and applied for the numerical resolution of the St-Venant equations. The approach is based on a posteriori geometric error estimations, calculated from a bound of the interpolation error, and then on the construction of anisotropic metric tensor for the mesh adaptation (see [32], [31], [42]). This allows at once to reduce notably the mesh

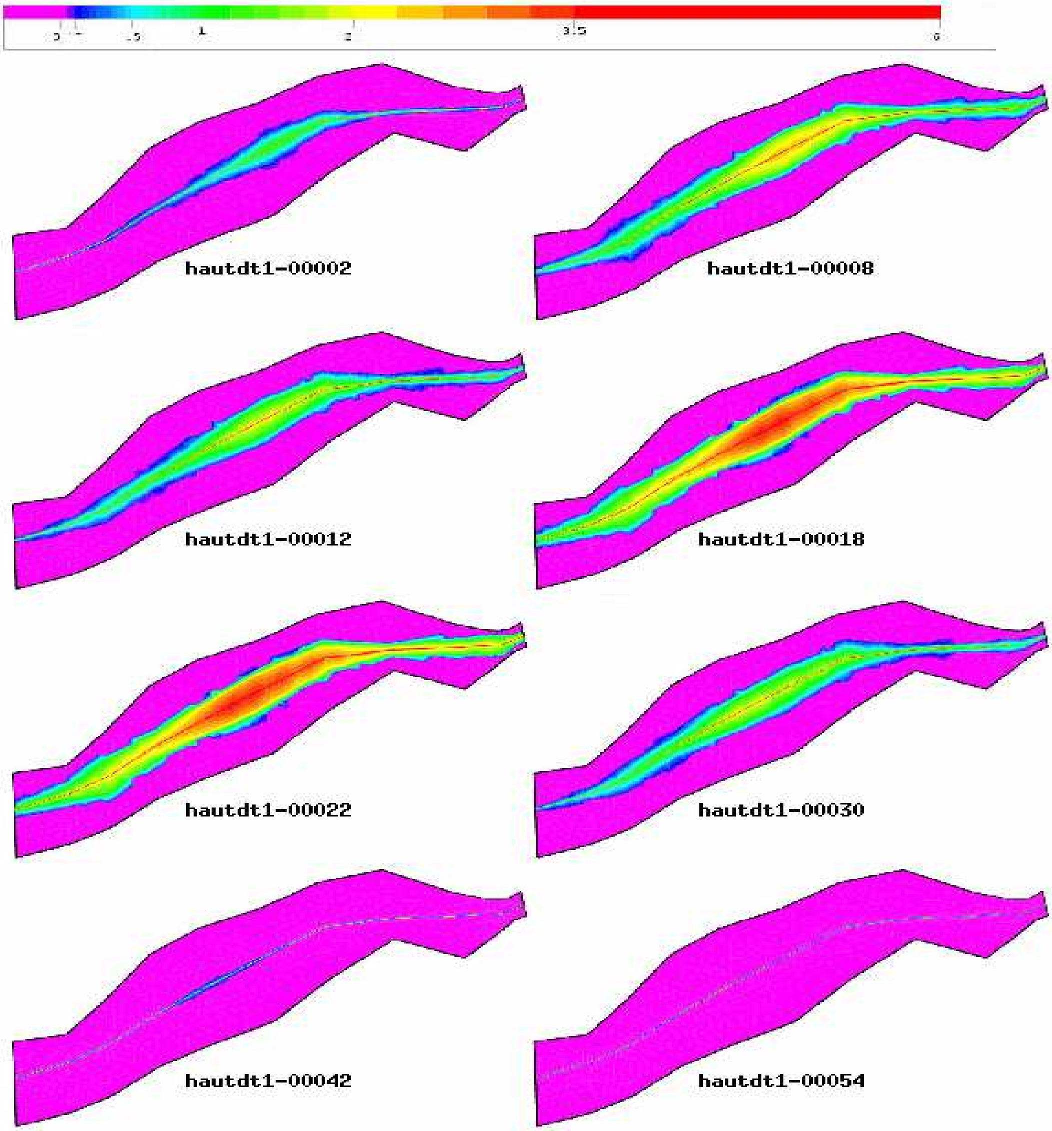

Figure 19. Water depth at t=00h30, 2h00, 3h00, 4h30, 5h30, 7h30, 10h30, 13h30: Flood of 1986.

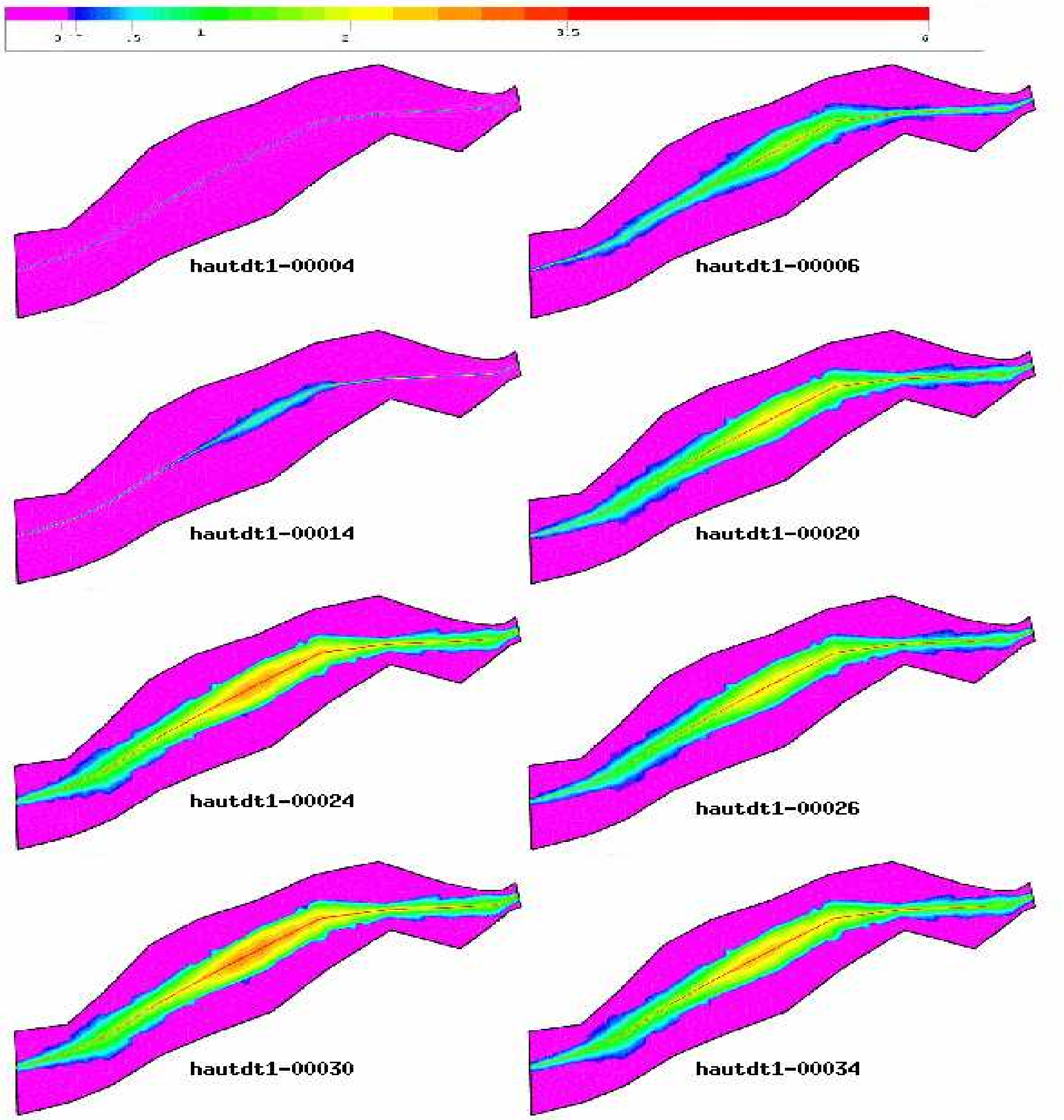

Figure 20. Water depth at t=1h00, 1h30, 3h30, 5h00, 6h00, 6h30, 7h30, 8h30 : Flood of 1988.

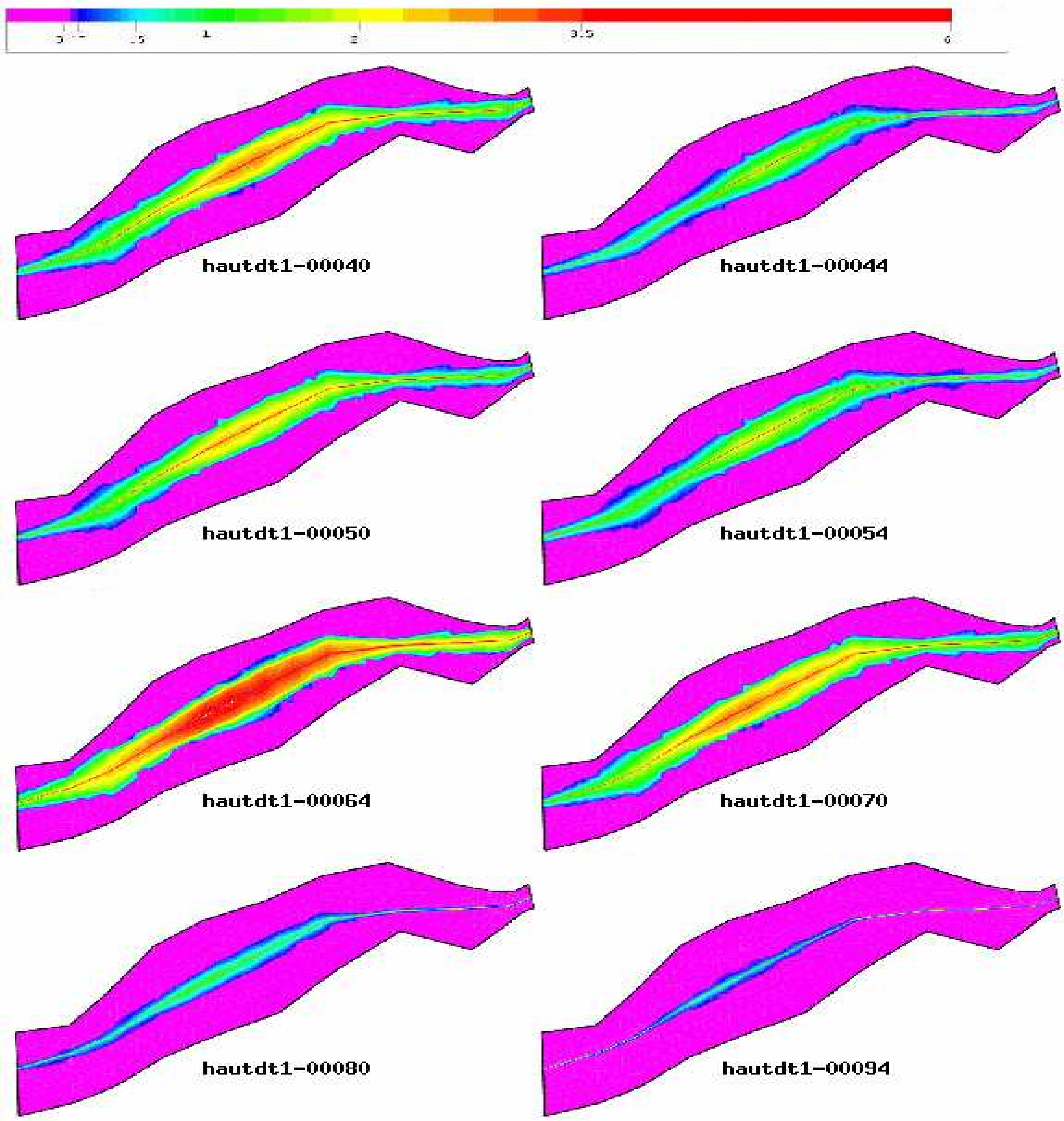

Figure 21. Water depth at t=10h00, 11h00, 12h30, 13h30, 16h00, 17h30, 20h00, 23h30, 20h00, 23h30: Flood of 1988.

size, and therefore to diminish the calculation time of simulations, and to improve the quality of the numerical results. Consequently, jointly with the increase of the HPCN facilities, this technique type authorizes the simulations of real physical phenomena on complex geometries. The idea of the mesh adaptation is to check the generation of a new mesh in an iterative calculation scheme, in such a way that the estimated calculation error on this mesh is limited by a given upper bound and being equi-distributed on the whole mesh. More precisely, from the numerical obtained solution, the approximation error is estimated locally through error indicators. Then, the process consists in modifying (adapting) the mesh in order to satisfy the error estimator, by increasing (resp. diminishing) the mesh density where the error is superior (resp. inferior) to a given upper bound. Once the new mesh constructed, the field of solutions is interpolated on this mesh to continue the calculation (see [33]).

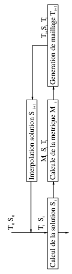

Figure 22. automatic adaptive mesh algorithm

In order to obtain an efficient adaptation algorithm, it is essential to have local estimators that are easily computable and an appropriate stopping criterion. One proposes to find a fixed point for the pair formed by the mesh and the solution. Otherwise, one tries to converge at once towards the solution of the problem and towards the adapted associated mesh. This mesh is such that the interpolation error of the convergent solution be equi-distributed. This yields to an iterative algorithm in which every loop begins from the mesh and the previous step solution. After the computation of the numerical solution, one estimates the error on every element of the mesh, using an suitable a posteriori error estimator. From this error estimation, a metric card serving as criterion to generate an adapted mesh is constructed. This process is iterated until convergence. This scheme is illustrated on figure 22, where one respectively noted T, S and M the mesh, the solution and the metric at each iteration (see [21], [31]).

For validation purposes, we consider a prismatic channel with trapezoidal section. At the beginning, we start from a regular mesh of the channel (figure 23). Calculating the St-Venant solution, we generate error indicators on each element and node, as well as global error indicators, then by applying the proposed algorithm (figure 22), we get a mesh at the second step (figure 24) and so on until the final step (figure 25).

We plot on figure 26 the a posteriori error estimates distribution on the whole mesh at the initial step and second step. In order to validate this approach on a real case, we consider a section of Nahr Soummam river (Algeria). Figures 27 and 28 illustrate the iso-values of the water depth and the velocity at the initial (left) step and final (right) one. We observe that the result-mesh couple is optimized thanks to error indicators calculated on each element, for a required precision.

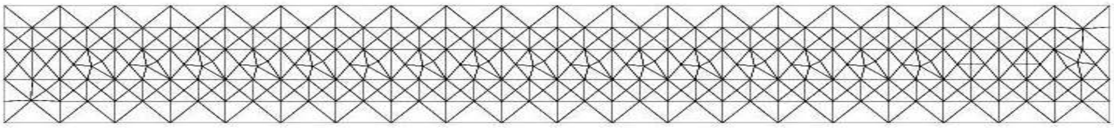

Figure 23. Initial mesh: 634 elements and 1319 P1-P2 nodes; 343 vertices.

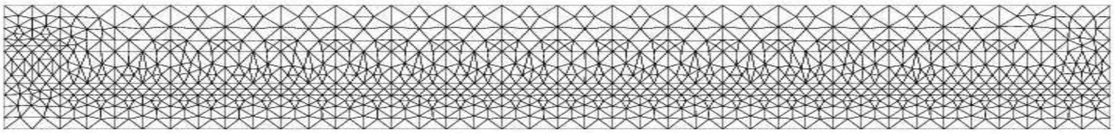

Figure 24. Mesh of step 2: 1992 elements and 4087 P1-P2 nodes; 1048 vertices.

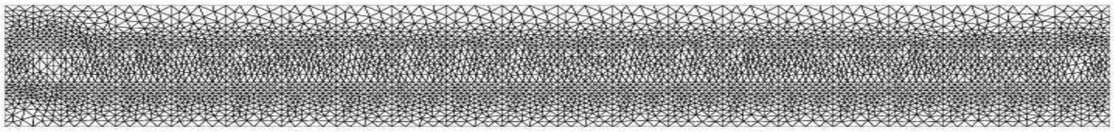

Figure 25. Final mesh: 8690 elements and 17431 P1-P2 nodes; 4411 vertices.

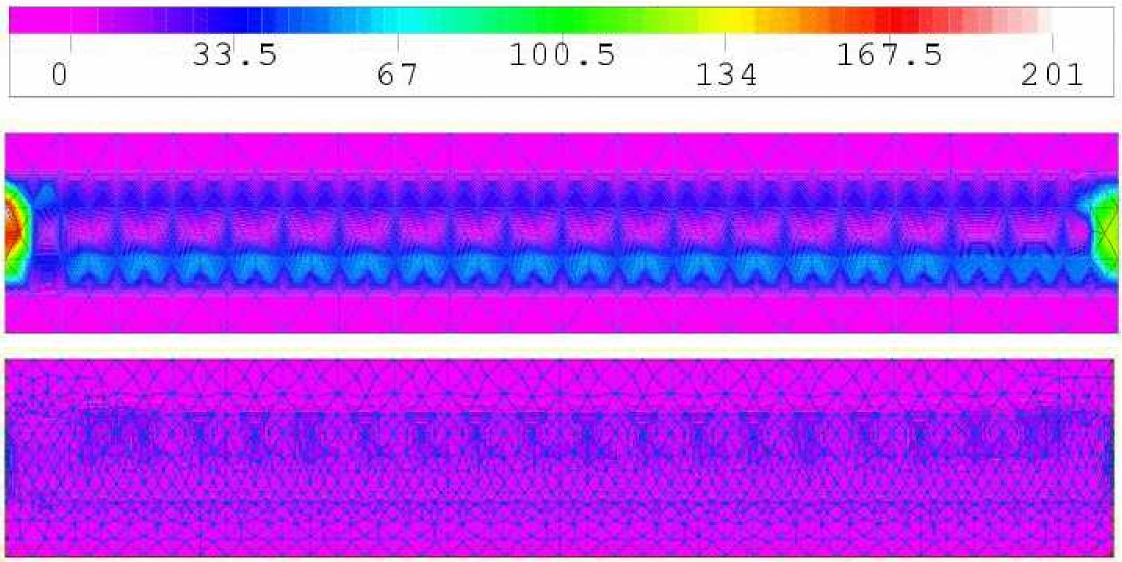

Figure 26. Distribution of the a posteriori error on the initial and the final mesh

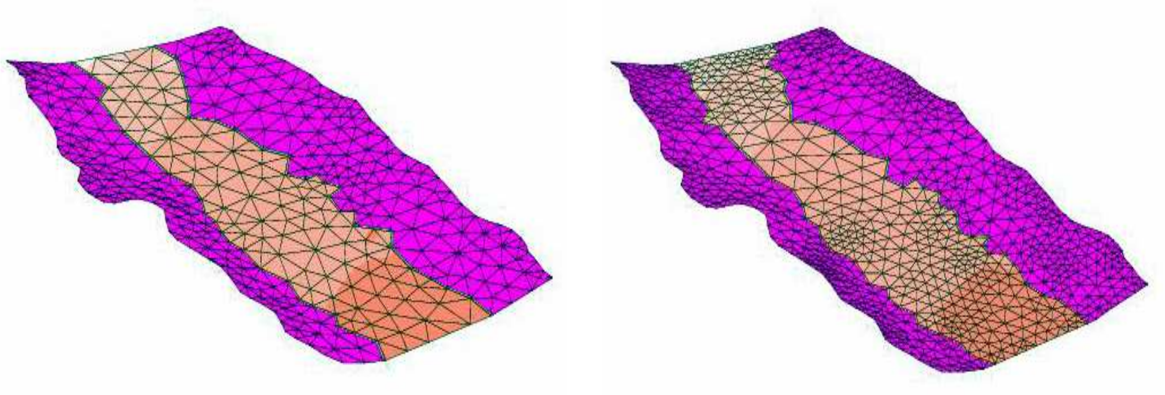

Figure 27. Iso-values of the water depth on the initial (left) and final (right) mesh

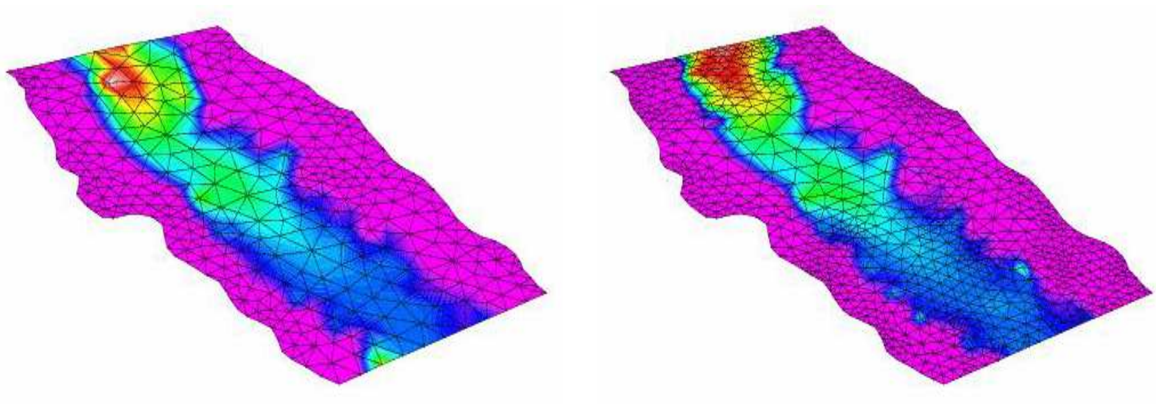

Figure 28. Iso-values of the velocity on the initial (left) and final (right) mesh

6.4. Parallel algorithms and intensive computation

Keywords: *MPI*, *Parallel computation*, *cluster*, *performances*.

Participants: F. El Dabaghi, M. Abdelwahed, B. Nakhle, F. Mezali.

This component concerns the parallel algorithmic of the different solvers already developed or to be implemented within COSIVIE team (see [34], [40], [35]). The goal is to consolidate the application of the intensive distributed calculation technologies (HPCN) in the modelling and numerical simulation of hydro-systems such as sudden floods, their announces, inundation prevention, watershed planning, the impact studies of eventual works on the environment, the quality of drinkable waters, the treatment of the eutrophisation of lakes by mechanical aeration, etc. Noticing the specificity of these problems, notably their big size and the crucial need to reach reasonable compromises between real time responses and computing facilities, it is obvious that the parallel algorithmic of the numerical codes provides efficient solutions. Indeed, for example, the HPCN will allow « quick » simulation of many large scale scenarii, in order to delimit flooding zones by a better restitution of the physical simulated phenomena; the exploitation of these results will permit therefore a bigger reliability in the forecast of floods regarding watershed optimized planning, in the installation of helpful system of announces, as well as in the hierarchisation of alarm levels for prevention measures.
For illustration purposes, we will consider in the following the eutrophication treatement simulation described in 6.1 Despite the various simplifications brought to the various models and the realtive large computing facilities at our disposal, (see [43], [1], [5], [26]), the numerical simulation of the aeration process on a real application case remains always limited even in the 2D cases. Indeed, let us consider for example a real 2D cross section of a lake whose average dimensions are about 500m x 20m, the injector is about 10m with 100 holes about 1 cm diameter for each one. In order to detect the bubbles effect, it is necessary to generate a mesh with elements of about bubbles size which gives a mesh of the order of 10 millions nodes. To shedlight on the difficulty, a simulation using a mesh of 6.10^5 nodes requires approximately 3h30 mn CPU time for an iteration in time on a Risk processor of 650 Mhz clock and 1 Go of memory. For 1 hour of simulation time with a time step of one minute, one needs then 210 hours of calculation (9 days). For more fine meshes, the parallelization of the solver becomes unavoidable.
Within the framework of Mezali and Nakhle thesis, an analysis of various cases tests showed that the part of Conjugate Gradient solver consumes more than $98^o/_o$ of the CPU time. This fact justifies to invest in the parallelization of the preconditioned conjugate gradient constituted of the 3 following principal operations: 2 inner products, 3 linear combinations of two vectors, the product matrix-vector as well as the preconditioning step.
To obtain an efficient parallel solver, we bring some slight modifications in the code structure in order to minimize the number of messages interchanged between the various processes by deriving a maximum of independent tasks. The derivation of such tasks in the first two operations is direct: It is enough to cut the vectors in a number of parts equal to the number of processes. However, for the inner products, a communication will be necessary so that each processor sends to the others its part and receives from each one their part. The derivation of the independent tasks in the third operation (product matrix-vector) is closely dependent on the Morse storage used in the code. This operation is the most important since it consumes about $70^o/_o$ of the total CPU Time. The adopted strategy consists to equi-distribute contiguous lines package of the matrix on the available processors; each one will have the totality of vector X and one lines block A_i of A (see figure 29). Each processor P_i is locally responsible to perform the product of the block A_i by vector X. The result will be a vector $(AX)_i$ of size equal to the number of lines of A_i. One uses a synchronous communication function for the update of the total vector after each product matrix-vector.

For validation purpose, we carried out the parallel code under MPI on a MIMD (HP-V 2250) machine, with 16 processors and 8Go of shared memory in Cross bar architecture. The benchmarks were carried out on 4 space discretizations of the same computation domain as illustrated in Table 4. It is noted that the transition from grid h_i to h_{i+1} requires 4 times more data. For each mesh, execution series with a partition on 2, 3, 4, 6, 8, 10, 12 and 14 processors were done. The results are presented according to two types of curves:

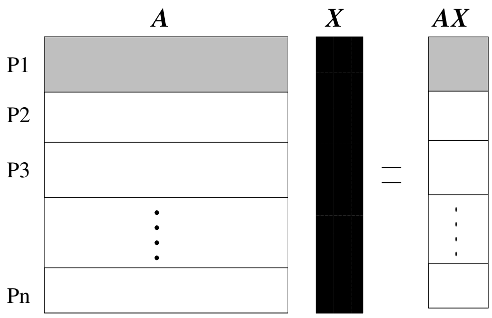

Figure 29. Matrix-vector product

- Curves of CPU time (see figure 30) and Elapsed time (see figure 31) indicating the absolute evolution with respect to the number of processors.
- Curves of Speed-Up CPU (see figure 32) and Elapsed (see figure 33), allowing to evaluate the performance efficiency of the parallel algorithm, the influence of the communication between the processors and the impact of the granularity.

Table 4. Test meshes

Mesh	nodes	unknowns
h_1	1089	3267
h_2	4225	12675
h_3	16641	49923
h_4	66049	198147

6.5. Tools and Data Integration

Keywords: *GIS*, *Integrated information system*, *JAVA*, *Ontology of the field*, *Substitute of document*, *WEB*, *XML*, *client-server application*, *hydrological modelling* , *hydrous resources*, *search and indexing engine*, *thesaurus*, *user profile*.

Participants: F. El Dabaghi, A. Gharbi, N. Souissi, H. Henine, M. Bechchi, K. Ider.

6.5.1. *WIIS:Web Integrated Information System*

- WIIS: Characteristics

The WIIS [36] is an infrastructure of development, perennial, open, modular, robust, effective and convivial offering a complete dynamic and configurable environment. The architecture of this system consists in two levels [25]: the first one contains general modules such as viewers, GIS, grid generators, data warehouse, simulators, etc, and the other one is domain specific and includes all the relevant modules tackling numerical modelling for the water related physical application under study, i.e. hydrology, hydraulics, hydrodynamics floods. This architecture is based on integration principles in terms of software components coupled to heterogeneous data sources [45]. Consequently, this open and modular architecture can serve as a framework for environmental engineering problems in general, and for water resources issues in particular(see [7]). The functional architecture of the WIIS and related components [44] are depicted in Figure 34.

We have observed also that for the hydrous phenomena simulation, we confront an important crossed difficulty: on the one hand, in this field, there remains a considerable need of flexibility, at the same time

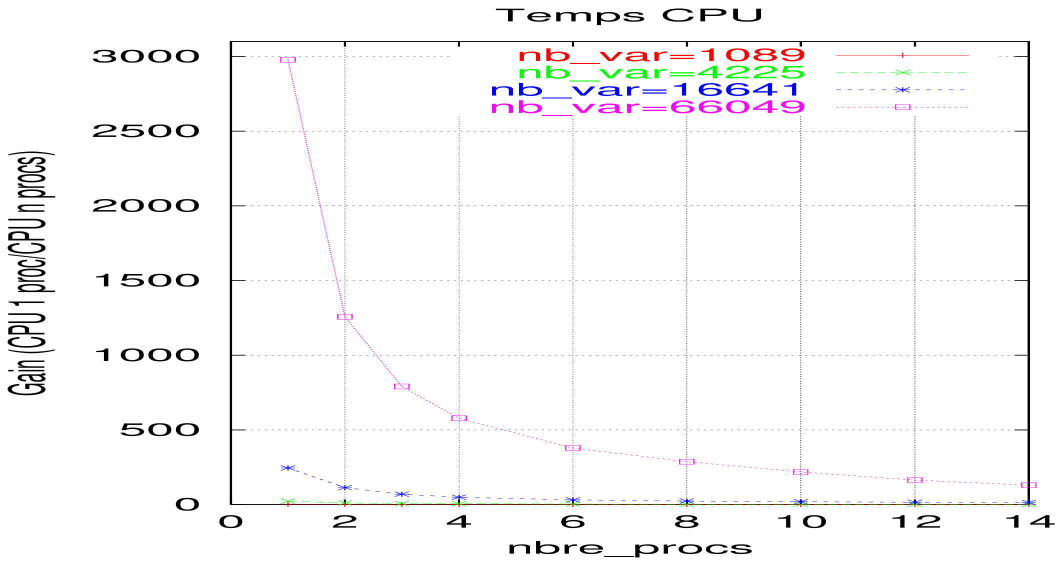

Figure 30. CPU Times curves

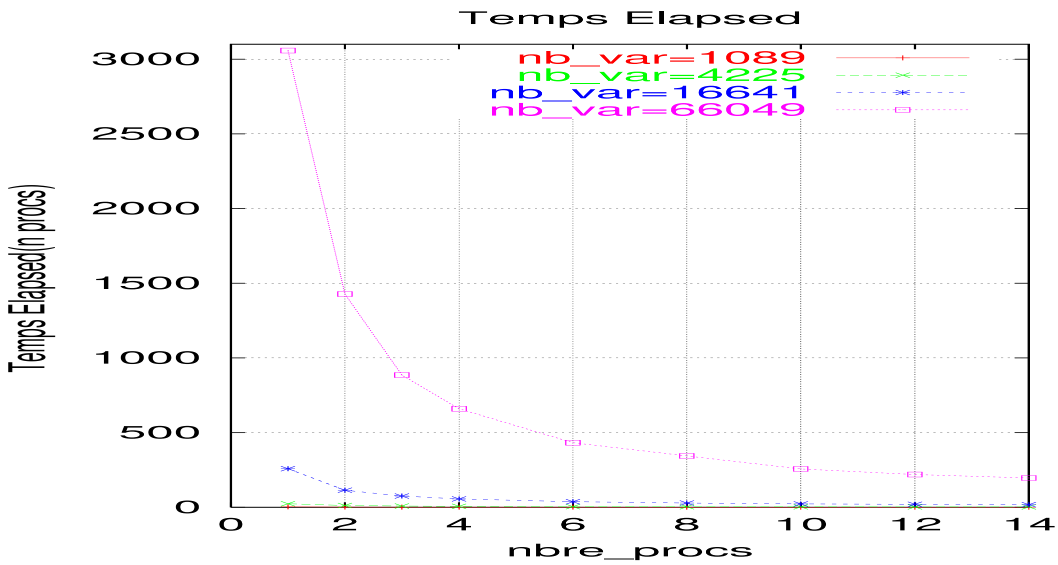

Figure 31. Elapsed times curves

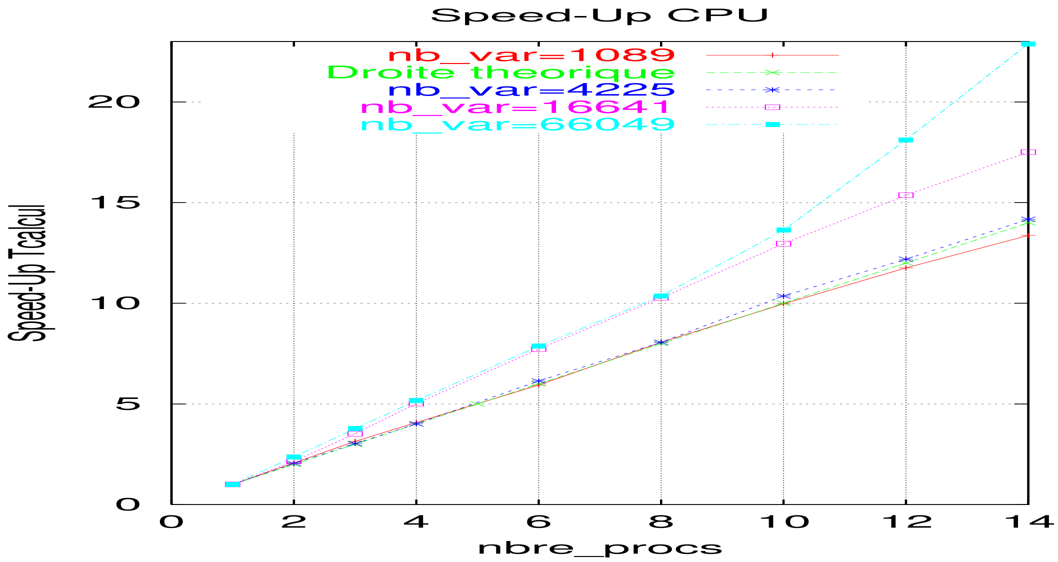

Figure 32. Speed-Up CPU curves

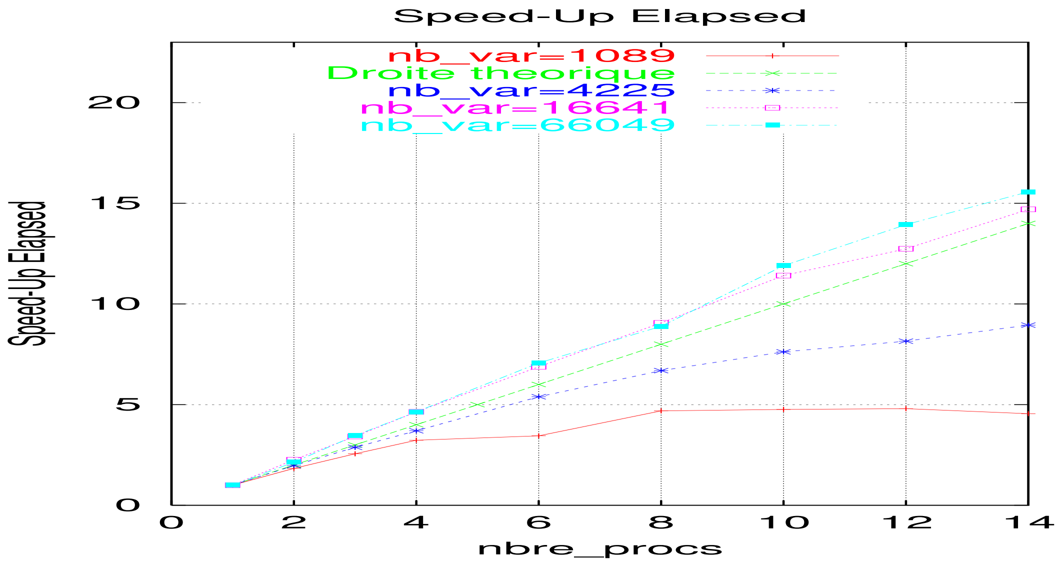

Figure 33. Speed-Up Elapsed curves

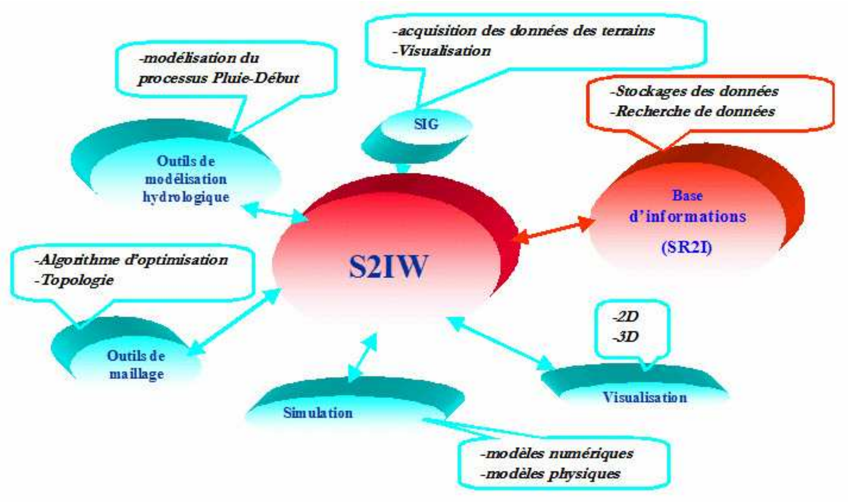

Figure 34. WIIS Software Architecture

in the representation and the handling of the input or output data, which are characterized by the absence of fixed and rigid structure, and on the other hand, these data flow exchanged within the WIIS are a priori not-structured, heterogeneous and distributive which makes them not easily accessible or exploitable. Within this period, the effort was carried out on the definition of a model for the representation and the structuring of the data using XML techniques. In fact, we have led a Pseudo-Xmlisation of the whole data information accessed or exchanged within the WIIS through an Information Indexation and Research System (IIRS) [41]. This IIRS operates on a thesaurus based on substitutes of documents under XML structure of the data warehouse characterized by strongly heterogeneous and distributed contents. More precisely, the WIIS accesses through a pertinent water resources thesaurus to a middleware constituted by the so-called substitutes of document (SD), which means that our database is somehow virtual; each SD contains the essential information and description of the original data as well as a link to its real locality necessary for any specific request [35].

Consequently, the prototype I of WIIS allows on the one hand to extract, prepare, handle, manage and analyse in an automatic way information necessary to the models of simulation and on the other hand to analyse, exploit, interpret, display, manage, communicate, check and calibrate if required in real time the results of these simulations by corroborating them with extracted or identified parameters. This is possible by the use of the integrated numerical models of simulation using the finite element method to resolve the posed water flow problems (see [39]).

- WIIS: Realization and Architecture

All the components of the WIIS [24] are built through Java intelligent interfaces within an appropriate user-friendly framework under a client/server application, portable on both Unix and Win platform, providing coherency in the distribution of data treatments and/or between clients and server stations (Figure 35). The client station prepares and sends requests to the server (currently hydre.inria.fr), a powerful Unix machine in term of memory and input/output capacities and which provides a direct access to a parallel computing machine or HPCN facilities.

This platform allows an inter-application navigation, a co-operation between software and their convivial use on the client and/or server station, a co-operation between programs as an environment of development, and an access to distant materials and software resources (real or virtual parallel machine, data, the call of remote procedures such execution of heavy codes on the UNIX server, storage, etc). Hence, it offers an open

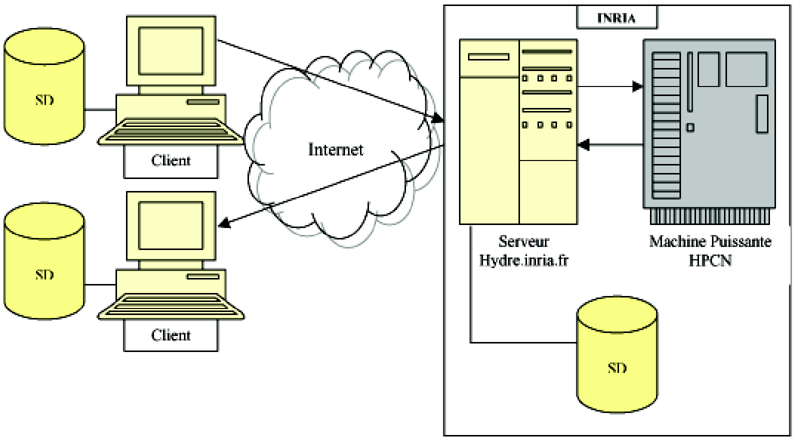

Figure 35. INRIA Client-Server architecture of WADI WIIS

configurable framework which has the ability under some additive specific components to be a kernel of a dicision support system (DSS). Such DSS should permit to the users to carry out an efficient impact assessment analysis for sustainable development taking into account the socio-economic context as well as legal issues and environmental constraints.

The prototype I of the WIIS propose a total sight view that incorporates advanced 2D and 3D hydraulic numerical simulation models. It has been validated and tested on concrete cases as Foum Tillicht (Morocco) and Nahr Beyrouth (Lebanon) for the localization of potential dam sites and the prevision of natural inundation in addition to Oued Soummam (Algeria) [35]. The results are satisfactory and users/developers found in the WIIS a sustainable environment software platform (see [37]).

- AWIIS : Extension of WIIS

Furthermore, we have started within the Bechchi Phd's thesis a preliminary setting up of an Adaptive Web Integrated Information System (AWIIS) ([23], [35] and [22]) continuity of the WIIS, robust and effective in term of integrated tools and data. This AWIIS must provide to the user a convivial, adaptive interface, rich in information, possibly with a total sight or then with various partial views according to its need especially guaranteeing incidents- and faults-tolerance. This customisation is closely depending on the user profile and the use context. Therefore, we suggest to classify each new user according to his profile in one (or several) category. A profile will be given with information obtained by direct questions to user at his first connection to the system which will be able to deduct a number of probable behaviours of the user. The AWIIS will also integrate a PIRS (Personalized Information Research System), generalizing the IIRS, dynamic and evolutionary using the concept of relevance feedback, and whose driving idea is the combination request-result-user. This PIRS operates on dynamic ontologies built around a thesaurus based on substitutes of documents of our data warehouse.

6.5.2. GIS-Hydrological Models

In the practice, numerical simulation of flows described in the above mentioned SWE models leads to many difficulties mainly due to their complexity (non linear terms, scale effects, turbulence aspects, suitable boundary and initial conditions, etc). In order to overcome the boundary and initial conditions input problem, we integrated a conceptual hydrological model based on the HEC-HMS providing a hydrogram of flood, used as input by the numerical models presented above (St-Venant or Flo2DH-FESWMS); the HEC-HMS model computes runoff volume by subtracting the volume of water that is intercepted, infiltrated, stored, evaporated, or transpired from the precipitation in the catchments area. We have used several tools and software (GIS Arcview, Mapinfo, Arcinfo, viewers like EMC2, VISU, MEDIT or SMS, mesh editors like EMC2 or YAMS, etc) for preparation of the data (basin model, weather data, physiographic and computing control parameters, etc.)[11] required for hydrological modelling with HEC-HMS; in this context, we developed an interface under the WIIS, integrating the whole set of utilities necessary to the preparation of these data. The modelling of the precipitation-runoff processes of dendritic watershed under HEC-HMS was divided into three parts:

- Modelling of the basin components using Arcview GIS,
- Modelling of meteorology,
- Particular specifications.

The modelling of the basin components uses a set of procedures, tools, and utilities for processing geospatial data in Arcview GIS. The Arcview GIS allows the preparation of hydrologic modelling inputs to import into HEC-HMS. To create the import file, the user must have an existing digital terrain model (DTM) of the watershed ([12]). The Arcview GIS transforms the drainage paths and watershed boundaries into a hydrologic data structure that represents the watershed response to precipitation. In addition, it offers the development of grid-based data for linear quasi-distributed runoff transformation (ModClark-model), the basin model, physical watershed and stream characteristics, and background map file (see Figure 36) [11].

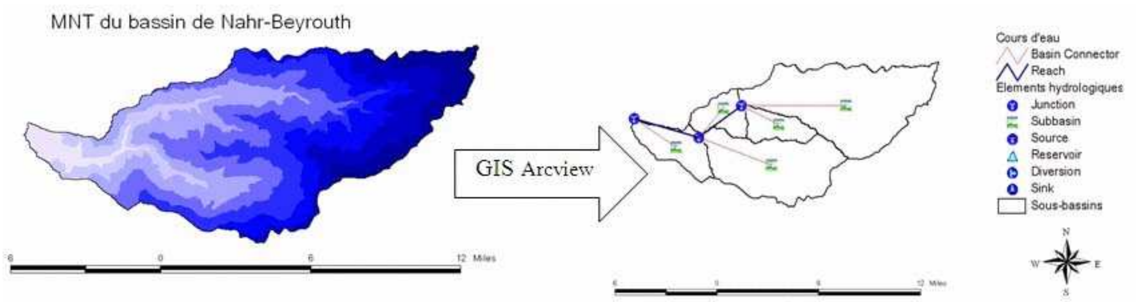

Figure 36. Watershed schematization using the GIS Arcview utilities of the Nahr Beirut Basin

In this context, we have used the HEC-HMS software to simulate the precipitation-runoff processes for large river basin water supply and flood hydrology, and small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems operation. The precipitation simulation with HEC-HMS is represented in (Figure 37), the hydrograph produced in this simulation will be used by the numerical simulation models to reproduce the flooded area [35].

7. Contracts and Grants with Industry

7.1. WADI Action

Participants: F. El Dabaghi, M. Amara, M. Abdelwahed, P. Frey, E. Saltel, N. Guelmi, B. Nakhle, N. Souissi, Ch. Kada Kloucha, A. El Kacimi, K. Ider, S. Benziada, H. Henine, M. Bechchi, A. Gharbi.

Water supply watershed planning and management: an Integrated approach.

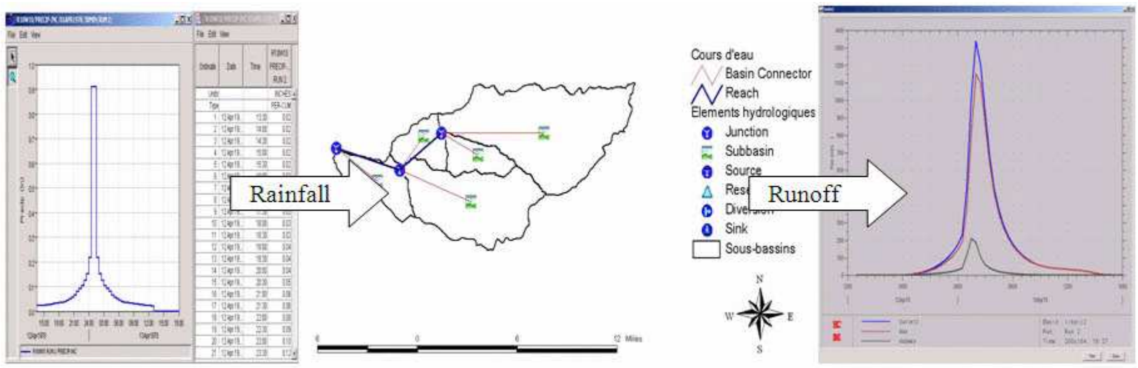

Figure 37. Hydrological simulation of precipitation in Nahr Beirut BasinW

see 8.2.1.

8. Other Grants and Activities

8.1. National Actions

Cosivie team collaborates particularly with:

- Applied Mathematics Laboratory, University of Pau,
- Mechanics Department University of Paris XII,
- PSI Laboratory, INSA - Rouen.

8.2. European Actions

The european collaborations are of two types: a cooperation agreement within the PAI-Platon framework with the IACM-FORTH Greece (project n° 05572UB, title: Prevent-eutrophication) and a European project (IST-INCOII frame) WADI with IACM/FORTH of Heraklion in Crete and the University of Calabria in Italy.

8.2.1. WADI

WADI project (http://www-wadi.inria.fr) coordinated by F.EL Dabaghi, is funded by the EC within the IST program. Its objective is to develop interactive systems of decision-making aid for planning, the execution and the rational management of watersheds characterized by a water shortage and/or a lack of subsoil waters, with an aim of improving the supply water and of helping consequently to satisfy the request of water. The project will evaluate the technical and scientific conditions for the planning and the management of watershed including social and legal aspects, as well as the environmental constraints for a durable development.

With the continual increase of water demand due to socio-economic growth in the Mediterranean regions, among others, water will play a more and more important role in the next millennium. In the next decades, the Mediterranean countries labeled as arid and semi-arid areas, especially the Southern Mediterranean countries will be highly concerned with water scarcity. The project will assess the technical and scientific requirements for watershed planning and management including social and legal aspects, as well as environmental constraints for sustainable development. This matter of fact has been highlighted in several recent studies and analysis reports carried out by independent organizations (ESCWA, World Bank, UNESCO, etc) as well as by the respective national water boards, agencies and offices: the principal recommendation outlines the fact that the main sustainable remedy is in the development of a rational dynamic water planning tool that focuses in priority on how to improve water supply in terms of quantity (optimal dam, water reuse, aquifers, etc) and quality (sediments, pollution, etc).

The WADI project will focus on the development of tools and methodologies that can assist decision making in watershed management boards and water planning authorities having to determine where to locate new dams/reservoirs. The tools and methodologies will address the various elements related to reservoir identification (e.g., geographic location, water volume, infrastructure cost) given the watershed characteristics (water demand requirements, water researches, DEM, etc) in an integrated manner that considers socio-economic issues as well as environmental aspects related to flood and drought risks. In addition, WADI will develop advanced data processing tools for modeling and simulations related to floods, reservoir design, and optimization of the complete planned network of a watershed.

8.3. International Actions

8.3.1. Mediterranean

The relations concern institutions of all principal French-speaking countries of this zone to knowing:

- Algeria, Ecole Nationale Polytechnique d'Alger (ENP),
- Lebanon, Ecole Supérieure d'Ingénieurs de Beyrouth (ESIB),
- Morocco, Ecole Mohammadia d'Ingénieurs (EMI),
- Tunisia, Ecole Nationale d'Ingénieurs de Tunis (ENIT).

These very developed relations (various co-directed theses completed or in progress) have as a framework euro-Mediterranean programs (mentioned before) or bilateral programs engaged since 1996; in the sequel, one will quote the most recent:

- CMEP 01 MDU 529 project with the ENP of Algiers - Algeria, Numerical Modeling of eutrophication treatment via the Distributed Intensive Computing. Jan 2001 - Dec 2004 (per year: 9 months of junior training, 2 months of senior stay, 1 week of coordination stay).
- CMIFM AI. n° MA/01/03 project with EMI, Rabat-Morocco, Distributed Intensive Calculation and aeration of lakes and marine lagoons. Jan 2001 - Dec 2004 (per year: 9 months of junior training, 2 months of senior stay, 1 week of coordination stay).
- PAI-PLATON project n° 05572UB with IACM-FORTH of Crete-Greece (Prevent-Eutrophication), Jan 2003-Dec 2004 (per year: 2 weeks of senior stay).

8.4. Reception of Foreign Researchers

For Oct2003-Sept 2004 period:

- N. Kampanis, IACM/FORTH, Greece (1 week)
- P. Prastacos, IACM/FORTH, Greece (2 X 1 weeks)
- M. Berrah, ENP-Alger, Algeria (2 X 1 weeks)
- S. Benmamar, ENP-Alger, Algeria (1 month)
- M. Abdelwahed, ENIT-Tunis, Tunisia (3 X 2 weeks)
- W. Najem, ESIB-Beyrouth, Lebanon (1 week)

9. Dissemination

9.1. Animation of the Scientific Community

In the framework of dissemination activities, COSIVIE team organized and animated several events related mainly to WADI EC project and to the bilateral cooperation mentioned above:

- 12th ERCIM Meeting, Working Group - Environmental Modelling Workshop, Creete-Greece, May 2004.
- WADI Workshop, WADI Simulation System Hands on Applications, Rabat-Morocco, Jun 2004.
- Workshop sur l'apport des technologies de l'information et du calcul intensif distribué dans la gestion et la modélisation des ressources en eau : Problématique de l'eutrophisation, Algiers-Algeria, Dec 2004.

9.2. Teaching Actions

- Numerical methods for PDE, University of Pau (M. Amara).
- Numerical simulation methods, course of DESS, University of Pau (M. Amara).
- Course of analysis, second preparatory year, IPEIM-Tunisia (Mr. Abdelwahed).
- Analysis and algebra, course of DEUG, University of d'orléans (N. Guelmi).
- WADI WIIS: XML, JAVA and Use of the Client Server WIIS, Course within the framework of WADI Workshop, EMI-Rabat, Morocco (F. Dabaghi, M. Bechchi, H. Henine, B. Nakhle), Jun 2004 ([39]).
- Parallelisation and programming: Use of MPI library, Course within the framework of ENP-INRIA Workshop, ENP-Algiers, Algeria (M. Abdelwahed, B. Nakhle, H. Leroy), Dec 2004.

9.3. Participation in conferences

Team members took part in international and regional conferences and workshop; one will refer to the bibliography to have the complete list of the contributions.

- 12th ERCIM Meetings, Working Group Environmental Modelling Workshop, Creete-Greece, May, 2004.
- International Conference on Thermal Engineering:Theory and Applications, Beyrout-Lebanon, June 2004.
- IASTED International Conference on Applied Simulation and Modelling (ASM 2004), Rhodos-Greece, June 2004.
- WADI Workshop, WADI Simulation System Hands on Applications, EMI-Rabat, Morocco, June 2004.
- ENP-INRIA Workshop sur l'apport des technologies de l'information et du calcul intensif distribué dans la gestion et la modélisation des ressources en eau : Problématique de l'eutrophisation, ENP-Algiers, Algeria, Dec 2004.

9.4. Publications

All the publications are available here.

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