Development of a 1D-2D coupled hydrodynamic model

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Objectives

The objectives of this new software are the development of a coupled river/lake numerical model that can be used for the description of complicated river branch systems and reservoirs. The code will be applied to a system in Turkey where data is available and where the methodology can be tested and validated. It will be also applied to the Venice lagoon, where the channel system of the Venice city offers a perfect test case for the new code.

Work program

The existing modeling framework SHYFEM will be adapted to also describe a 1D river branch system. This will allow describing interaction between 1D rivers and 2D lake systems.

The model will then be tested in a specific part of Turkey where already a catchment modeling system has been applied. This allows the testing and validation of the new model and a first assessment of its capacity. Since data for the Turkish river system was not yet available the code will be first applied to the channel system of Venice, where the channels crossing the city of Venice are coupled to 2D elements of the lagoon. Here data is already available and the new software can be tested in great detail.

The new model has been integrated in the open source code SHYFEM and made available through the ISMAR Internet web site for the scientific community.

Finally it is foreseen that the model will be applied to systems in Italy, like the Po River Delta and the Venice lagoon catchment area.

Project description

The group of Coastal Oceanography, ISMAR-CNR, Venice, has developed a hydrodynamic model of the Venice Lagoon that is applicable also to other water bodies with different physical characteristics. The model has been successfully applied to several lagoons in Italy (Venezia, Cabras, Taranto, Orbetello) and in other parts of the world (Hakata Bay, Japan, Roskilde, Denmark, Nador lagoon, Morocco). The actual hydrodynamic model is a two-dimensional finite element model using the well known vertically integrated shallow water equations in their formulation with levels and transports. Its description is given later. It will be coupled to a 1-dimensional river model that can accurately describe the flow in these segments. This will make it possible to describe complicated river systems together with lakes and reservoirs.

The modeling framework will then also be applied to Italian systems, like the Po Delta or the catchment area of the Venice Lagoon.

Impact

There are very little models available that allow the description of 1D/2D flow systems. The coupling of these systems is of importance when areas of interacting lakes and rivers have to be modeled for their hydrodynamics and for ecological parameters.

Achievements

The following documents the achievements that have been reached during the stay in Istanbul. As it was already clear that the code conversion would not be possible in 3 weeks, here the main points that have been achieved during my stay are listed. It has to be mentioned that the whole code of SHYFEM consists of around 600,000 lines of code. It was therefore impossible to rewrite the complete code, but adaptation of the base code was paramount.

- The code has been thoroughly scanned to find the places where changes have to be practiced in order to allow a nice interplay between the parts treating 2D and 1D elements
- Some modules have been rewritten to allow for an easy integration of the 1D code. These parts are mainly the basin module that provides basic facilities to the whole

model describing interconnectivity of the elements. Also the finite element basic libraries have been updated to deal also with the implementation of finite element gradients inside the elements. To this code the 1D part has been added.

- Utility routines have been written to allow for easier averaging of elements and nodes. All routines dealing with averaging have now been collected into one module, so changes in the code can be handled very easily. Other modules do not implement their averaging routines on their own, but use the general utility routines.
- All places where explicit mention to 2D elements has been made have been changed to more general treatment that will allow the elegant treatment of different dimensionalities.
- Some unused parts have been eliminated in order to get rid of old dead code and make the code base more readable.

Once the code conversion was complete the code has been tested. The tests that have been carried out are the following:

- The code was compiled and simulations have been carried out only for the 2D case. The results were compared to existing test cases with the old code and care has been taken that the results were perfectly identical.
- After it has been made sure that results for the 2D model could be reproduced with the new code bas, tests have started with the combined 1D/2D model.
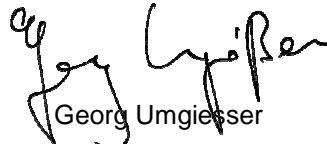
Test case for the 1D/2D case

As already mentioned the test case for the Turkish river system has not been available. There it has been decided to construct a test case for the Venice lagoon, where the 1D structures of the city channel system has been exploited. Below an example of the 1D/2d model grid that has been used for testing the new code. In Fig. 1 the complete grid is shown, whereas in Fig. 2 the detail of the 1D channel system around the city of Venice can be seen

Conclusions

The code conversion is still far from being finished. The 1D code is compiling, but is still not running and producing correct results. Software development is a tedious procedure and it will take some more months before the code is running as anticipated.

Once this has been achieved the new model will be published and will be used in various model applications. It is foreseen that scientific articles will be produced that will cite the short term mobility program of the CNR in the acknowledgements.
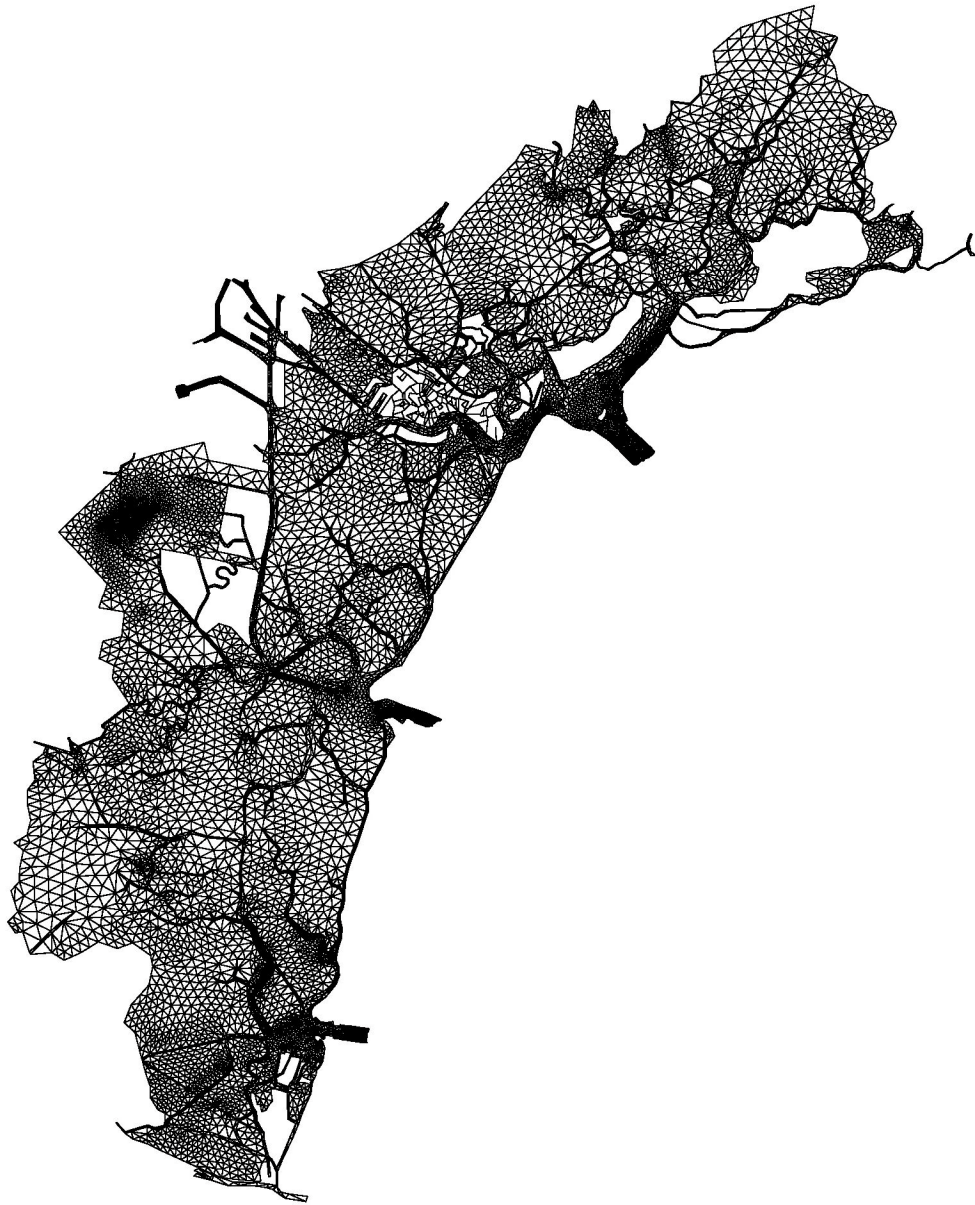
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Fig 1: Plot of the model grid used for testing the coupled 1D/2D model.
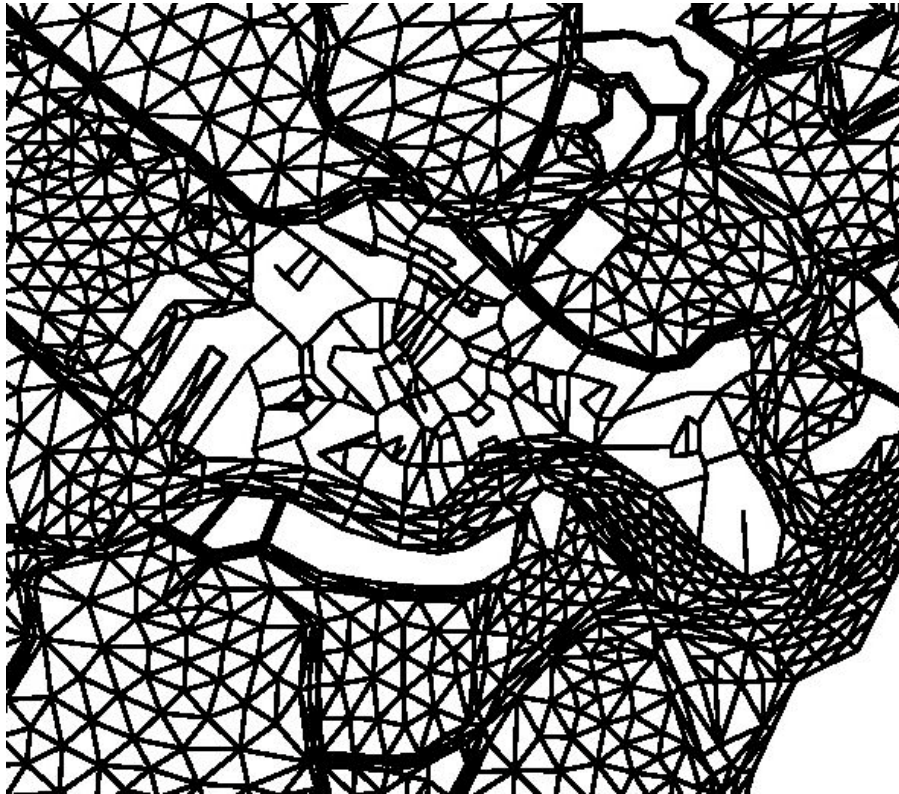
Fig 2: Zoom of the city of Venice where the usage of 1D channel system can be seen.