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On The External And Iterative Coupling Of Multiple Open Channel Flow Models With OpenMI

Bernhard P.J. Becker

Jan Talsma

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ON THE EXTERNAL AND ITERATIVE COUPLING OF MULTIPLE OPEN CHANNEL FLOW MODELS WITH OPENMI

BERNHARD P. J. BECKER (1), JAN TALSMA (2)
(1): Deltares, PO box 177, 2600 MH Delft, The Netherlands, bernhard.becker@deltares.nl
(2): Deltares, PO box 177, 2600 MH Delft, The Netherlands, jan.talsma@deltares.nl

Introduction

Model coupling makes it possible to analyze multiple models and their interactions in a coherent way. Models that represent different flow processes are often coupled for physical reasons. But administrative or institutional reasons can make it necessary to couple models of the same type. With the help of a simple test case of two open channel flow models based on the flow simulation program Sobek (Stelling and Duinmeijer 2003) we explain technical aspects of different coupling methods. Based on the simulation results we make conclusions on the choice of a coupling method for practical river model applications.

Methods of model coupling

Following Morita & Yen (2000) we distinguish three methods of model coupling:

- simultaneous solution or fully coupled approach
- iterative coupling and
- external coupling.

In Tab. 1, advantages and drawbacks of these coupling methods for models of the same type are given. The table also shows the technical realization of the three methods for this study. For details on the coupling method see Becker & Talsma (2014).

Tab. 1 Summary of advantages and drawbacks for three methods of model coupling and their technical realization for this study

Coupling method according to Morita & Yen (2000)	Technical realization within this study (see Becker & Talsma 2014 for details)	Advantages and drawbacks
Full coupling, simultaneous solution	One Sobek mesh, unification with the import-function of Sobek-Netter (the Sobek graphical user interface)	- Separate models are unified to one model, coupling is not reversible, - probably the most accurate and fastest method in most cases, - the highest level of model coupling from a numerical point of view.
Iterative coupling	Sobek models coupled with OpenMI 1.4 via the iteration controller	- Models remain separate, - accurate, but computationally expensive.
External coupling	Sobek models coupled with OpenMI 1.4	- Models remain separate, - mass balance error, - comparatively fast, - the simplest way of model coupling during runtime.

Simulation results

The functional principle of the three different coupling methods is explained with the help of a simple one-channel test case. Fig. 1 shows the schematization: the channel contains the two reaches “east channel” and “west channel”. The downstream boundary condition is a water level time series that represents a simplified tidal pattern. The upstream boundary condition is given by a discharge hydrograph that forms an idealized flood wave.

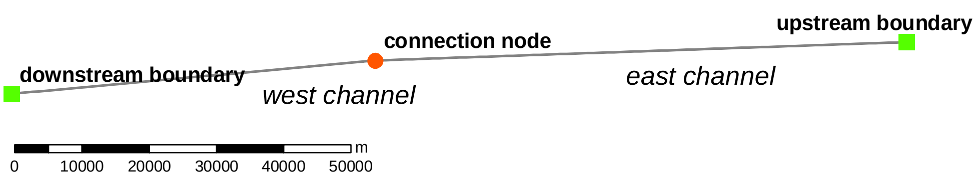

Fig. 1: Schematisation of the test channel

In Fig. 2 the computed water levels from simulation runs with different coupling methods are compared. Tests have been performed with coupling time step of 10 and 30 minutes for the external coupling and 10, 30 and 60 minutes for the iterative one. The water level curves from all the externally coupled simulation runs and the iteratively coupled simulation runs are similar, but they differ both from the result from the fully coupled solution: the water level from the fully coupled simulation is slightly higher than the other solutions. The fully coupled simulation is considered to be the most exact because here the data exchange between the two reaches East and West in principle is active for each time step including internal time steps. A difference in water level or discharge at the connection node is not existent, because the location is represented only once (one model).

The comparison of discharge values (Fig. 3) shows that iterations do not improve the simulation results significantly: with the same coupling time step the externally coupled solution is as close to the simultaneous solution as the iteratively coupled one, although, the latter method should basically be more accurate. However, the larger the coupling time step size, the higher is the difference of externally/iteratively coupled simulations and the reference case, the fully coupled solution. In the current case the tidal effects from the downstream boundary condition at the model Sobek West result in a dynamically change of the water level at the coupling point. If large coupling time steps are chosen, dynamical effects get lost.

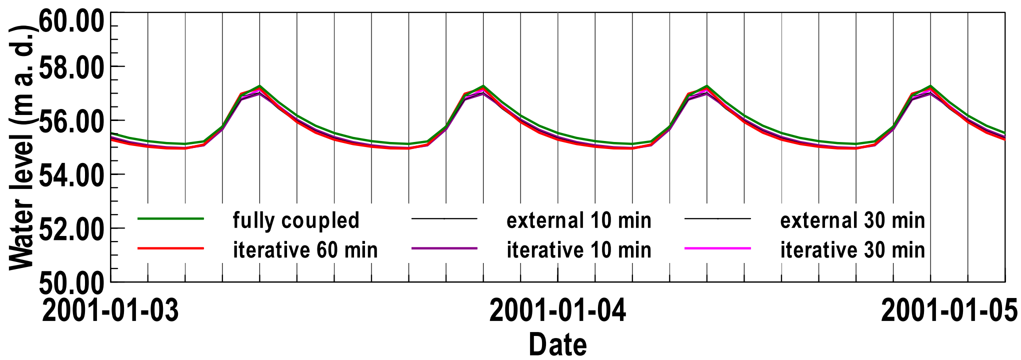

Fig. 2: *Computed water level over time at the connection point from different coupling methods. Coupling time steps are reported in the legend in min.*

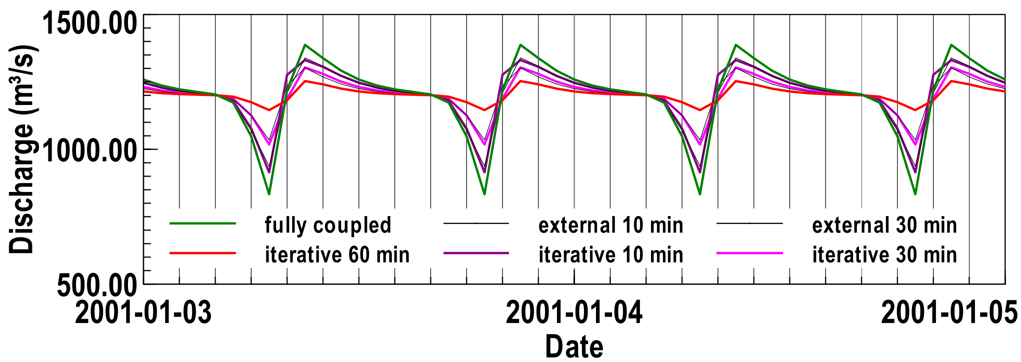

Fig. 3: *Computed discharge over time at the connection point from different coupling methods. Coupling time steps are reported in the legend in min.*

Conclusions

The advantages and drawbacks of the three coupling methods are summarized as follows:

- The unification of the meshes (fully coupled approach) is the most accurate way of model coupling and at the same time the least computational expensive. Sobek facilitates the unification of sub-models to a large model as a programme feature. However, this process is basically not reversible. If both the sub-models and the unified model are needed, model-related work (actualization of data, calibration, implementation of model features) has to be done twice.
- Iterative and external coupling according to the OpenMI standard are thus an interesting option if the sub-models are owned and maintained by different institutions and if both in a coupled model composition and the sub-models as standalone versions shall be used. Calibration, model update and maintenance can be carried out for each sub-model independently.

- The external coupling method is easier to implement, is basically faster, but is less accurate than an iterative coupling. To reach a sufficient match of simulation results at the shared boundary nodes small coupling time steps must be chosen for externally coupled models.
- Because the simulation is repeated for each time step, with an iterative coupling larger coupling time steps can be chosen. This can potentially reduce the computing time. However, the larger the coupling time step size, the larger is the loss of “dynamic information” at the coupling points. Large coupling time step sizes are appropriate only for flow patterns with moderate variation over time.
- The simulations indicate that an external coupling will be sufficient for many practical applications. An iterative coupling does not necessarily provide an added value in terms of accuracy.

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