Linked Hydraulic and Impact models in the DRIHM project

J. Lhomme, P. Cleverley, D. Kelly, M. Wetton, M. Panzeri, Q. Harpham (HR Wallingford)

Abstract

The Distributed Research Infrastructure in Hydro-Meteorology (DRIHM) project is developing a prototype e-Science environment to facilitate the collaboration between meteorologists, hydrologists, and Earth science experts. The environment aims to promote accelerated scientific advances in hydrometeorological research (HMR) through the provision of end-to-end HMR services (models, datasets and post-processing tools) at the European level, with the ability to expand to global scale.

What the DRIHM e-infrastructure will allow is a connection of all the components in a transparent way for the end-users, thus pooling the dispersed expertise by fostering cross-disciplinary work. In addition, the DRIHM infrastructure will offer a unique framework for accelerating the development of ensemble forecasting strategies. The many components of the forecasting chain suffer from uncertainties which need to be accounted for in order to properly determine the hydrometeorological risk. By providing a quick and easy way of running various combinations of different meteorological and hydrological and hydraulic models, the DRIHM infrastructure will facilitate the production of probabilistic forecasts and will thus lead to an improvement in their skill.

To demonstrate the e-infrastructure, the DRIHM project is developing a number of Experiment Suites which combine data and models from across the expertise of Europe to exhibit how these components can be combined in an integrated modelling chain to better improve our predictions of extreme events. Certain components, in particular those at the hydraulic and impact level, are integrated using the Open Modelling Interface (OpenMI) version 2 standard.

HR Wallingford are developing a chain of linked Hydraulic and Impact models for an Experiment Suite to simulate the extreme hydro-meteorological event that occurred in Liguria, Northern Italy in November 2011. Genoa, the capital city of Liguria was hit by severe flash floods on 4th November 2011. About 500 millimetres of rain, a third of the average annual rainfall, fell in six hours. Six people were killed. The torrential rainfall inflicted the worst disaster Genoa has experienced since the flash flood of 1970, when a similar event killed 25 people.

This chain of models consists of

- A 1 dimensional (1D) hydraulic model for representing flow in rivers and channels
- A 2 dimensional (2D) hydraulic model for representing inundation flow in the floodplain
- An impact model to calculate potential damage and loss-of-life caused by the flood waters

Each model is made OpenMI compliant in a first stage. This task is facilitated by using the FluidEarth Software Development Kit (SDK). Then the "OpenMI wrapped" models are linked together in what is called a composition using the user-friendly Pipistrelle software, part of the Open-Source FluidEarth tools.

The data fed into the 1D hydraulic model is coming from a hydrological model or a river flow database. Its format in the DRIHM project is WaterML (OGC standard).

The 1D open channel hydraulic model is the MASCARET software, historically developed by EDF (Goutal and Maurel 2002, Goutal et al 2012) and now an open-source software managed by the TELEMAC-MASCARET consortium. For MASCARET, the OpenMI wrapping has been facilitated by an existing API previously created by EDF to link MASCARET to other EDF software using their own protocol.

An OpenMI data adapter has been created to convert the WaterML input data into the format read by the MASCARET engine.

The 2D hydraulic model is the Rapid Flood Spreading Model (RFSM) developed by HR Wallingford, more specifically the EDA variant (Explicit Diffusion wave with Acceleration terms) (Jamieson et al 2012a&b). In the RFSM approach, the topography is pre-processed to identify the key features and the 2D mesh is built around these features. The computational elements are irregular polygons associated with a volume-level curve and a level-width curve describing respectively the storage capacity and interface conveyance properties. This allows the use of large computational elements with a minimal loss of accuracy in the description of the topography, which is not possible with a conventional mesh using one ground elevation per element. Therefore the total number of computational elements can be kept to a relatively low value, enabling fast simulations.

An adapter is also needed to convert the river levels from MASCARET into a suitable format to be read by the RFSM-EDA engine.

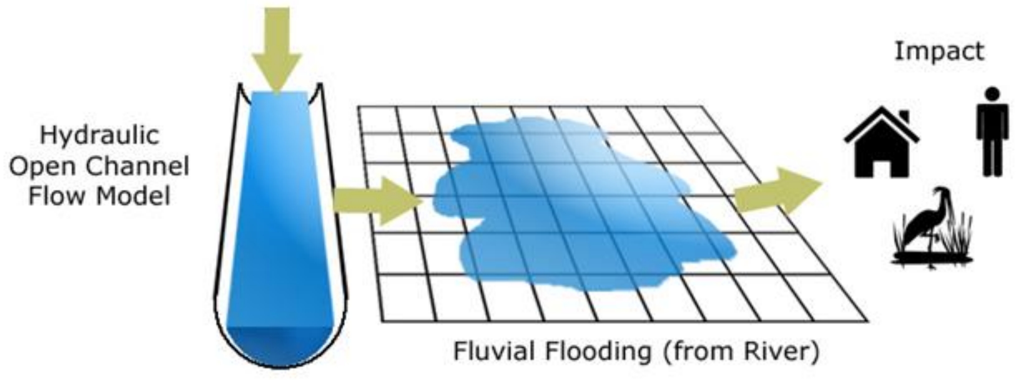
MASCARET and RFSM-EDA are linked dynamically to represent complex interactions between the river and the floodplain. When the water level in the river exceeds the crest level of the banks or embankments, there is an inflow into the floodplain. Conversely, when the floodwaters accumulate at a location in the floodplain, there is flow back into the river if the floodplain water level exceeds the river level.

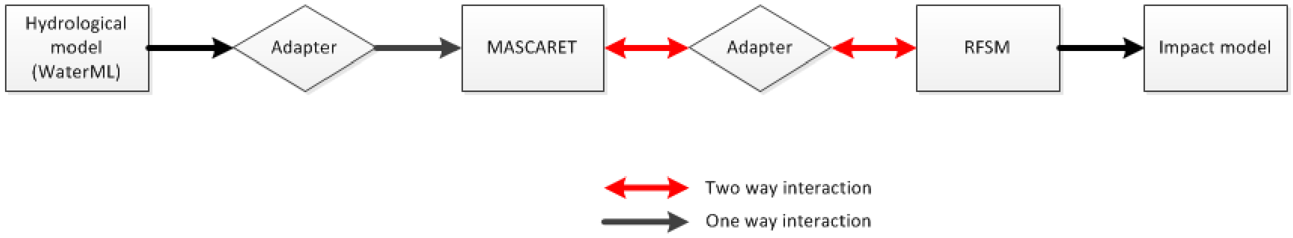
By developing the model composition in an OpenMI compliant way, it is trivial to replace components in the chain with alternatives, for example the 2D hydraulic model can also be TELEMAC 2D.

The Impact model is an “OpenMI wrapped” version of a tool that forms part of the Flood Risk Estimator (FRE) system developed by HR Wallingford. A grid of maximum inundation depth and velocity values are used to calculate:

- The damages to buildings, infrastructures and crops using a method developed by the Flood Hazard Research Centre (UK), commonly referred to as the Multi-Coloured Manual. Different damage functions are associated to different land uses and property types
- The risk to life, using a simple approach developed in the UK (“Flood Risk to People”, Environment Agency 2003), accounting for the nature of the flooded area, the speed of onset of the flood, any flood warning, the vulnerability of people.

One of the main hurdles when wrapping models and setting up a composition is to properly manage the exchange of boundary conditions between models. Usually in a standalone run, a model reads the boundary condition file during the initialisation phase as those are known beforehand. However in the context of a multi-model composition, all models need to be initialised at the start of the run and the boundary conditions to each model are not known at this stage. Here MASCARET and RFSM-EDA are both initialised, then MASCARET reads the boundary conditions passed by the hydrological model. During the run, the conditions at the boundary between MASCARET and RFSM-EDA are exchanged (laterally) and the discharge recalculated at each timestep.




Hydrological model (WaterML)
Adapter
MASCARET
Adapter
RFSM
Impact model
Two way interaction
One way interaction