



An advanced modelling tool for simulating complex river systems

Ana Rosa Trancoso ^{a,*}, Frank Braunschweig ^b, Pedro Chambel Leitão ^a, Matthias Obermann ^c, Ramiro Neves ^a

^a MARETEC, Technical Superior Institute, Lisbon Technical University-Av. Rovisco Pais 1049-001 Lisboa, Portugal

^b Action Modulers, Rua Cidade de Frehel, Bloco B, n.º 12, 2640-469 Mafra, Portugal

^c Division of Water Resources Management, Institute for Water Quality and Waste Management (ISAH), Leibniz Universität Hannover, Am kleinen Felde 30, 30167 Hannover, Germany

ARTICLE INFO

Article history:

Received 30 June 2008

Received in revised form 31 December 2008

Accepted 6 January 2009

Available online 12 February 2009

Keywords:

Modelling

River network

Water quality

Object oriented programming

ABSTRACT

The present paper describes MOHID River Network (MRN), a 1D hydrodynamic model for river networks as part of MOHID Water Modelling System, which is a modular system for the simulation of water bodies (hydrodynamics and water constituents). MRN is capable of simulating water quality in the aquatic and benthic phase and its development was especially focused on the reproduction of processes occurring in temporary river networks (flush events, pools formation, and transmission losses). Further, unlike many other models, it allows the quantification of settled materials at the channel bed also over periods when the river falls dry. These features are very important to secure mass conservation in highly varying flows of temporary rivers. The water quality models existing in MOHID are based on well-known ecological models, such as WASP and ERSEM, the latter allowing explicit parameterization of C, N, P, Si, and O cycles. MRN can be coupled to the basin model, MOHID Land, with computes runoff and porous media transport, allowing for the dynamic exchange of water and materials between the river and surroundings, or it can be used as a standalone model, receiving discharges at any specified nodes (ASCII files of time series with arbitrary time step). These features account for spatial gradients in precipitation which can be significant in Mediterranean-like basins. An interface has been already developed for SWAT basin model.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Modelling of water flow and transport processes are, nowadays, common tasks for research, planning and monitoring activities. The research and management advantages of a model increase with interdisciplinary integration. MOHID is an integrated modelling system maintained and developed by the MARETEC (Marine and Environmental Technology Research Centre) group of Technical Superior Institute at the Technical University of Lisbon (www.mohid.com). Its range of applicability has been continuously widened. It was initially developed to simulate the flow in estuarine and coastal waters (Neves, 1985) and then extended to include water quality and sediment transport processes. In 2000, the system was reorganised to be able to simulate the flow using general coordinates (Martins et al., 2001) and in any type of environment, such as groundwater, basins and river networks, due to its modularity and object oriented structure (Miranda et al., 2000; Braunschweig et al., 2004). Since then, it has been constantly enhanced by additional features and modules. Currently, MOHID is a water modelling system that can simulate 1D river networks to 2D basins and 3D estuarine and coastal waters and soil processes.

MOHID has been used in several Portuguese estuaries to simulate transport processes, sediment dynamics and water quality (Cancino and Neves, 1999b; Pina et al., 2003; Trancoso et al., 2005; Saraiva et al., 2007). It has also been applied to ocean circulation (Santos et al., 2002; Coelho and Santos, 2003) and to oil spill modelling (Montero et al., 2003).

The present paper describes MOHID River Network (MRN), which arose from the necessity of having improved inland boundary conditions for the estuary and coastal waters models, and to help manage environmental problems posed by interior waters. From its earlier development stages, MRN took into consideration the need to simulate basins which can be classified as semi-arid, and are characterised by:

- long periods with a partial or complete dry river network,
- pools formation in river transects where water remains even after surface flow has ceased,
- intense flush events resulting from typical Mediterranean storms, and
- transmission losses due to permeable river beds and soils (infiltration) and high temperatures in summer (evaporation).

Modelling these semi-arid basins and, more generally, temporary waters, poses a numerical challenge due to the high spatial and temporal gradients and proximity of zero value. These conditions are not well handled or not simulated at all in most of the currently

* Corresponding author. Tel.: +351 218 419 440; fax: +351 218 417 365.
E-mail address: arosa@ist.utl.pt (A.R. Trancoso).

available watershed models, as reviewed in, for example, Borah and Bera (2004) or Kalin and Hantush (2006). The widely-used SWAT model (Arnold et al., 1998) allows the user to include pools. Transmission losses are also accommodated, but since SWAT uses a daily and monthly time step, it is not suitable to simulate the extreme flush events of interest in temporary waters. HSPF (Bicknell et al., 1993) uses a coarse routing approach and does not allow time steps shorter than 1 hour. It also does not allow pools and transmission losses to be simulated. All models classified by Borah and Bera (2004) as “Single Event”, such as MIKE SHE (Refsgaard and Storm, 1995), have a time step controlled by numerical stability, making them suitable for describing flush events. Of these models, only KINEROS (Woolhiser et al., 1990) allows the inclusion of pools. These examples demonstrate some of the limitations of existing models.

MOHID River Network (MRN) is a hydrodynamic model that considers a network of tributaries and allows for dynamic time step. It can also compute properties transport, such as nutrients and sediments. Being part of the general MOHID framework, it can use the 0D water quality models included in MOHID. MRN can compute water storage in pools, transmission losses and evaporation fluxes with the fine spatial and temporal discretisation required by temporary waters.

It was developed as a companion module of the basin model MOHID Land (Braunschweig et al., 2004) in order to allow dynamic exchange of water and material carried between the river and the river banks. In normal conditions runoff carries material (i.e. water, sediment, nutrients etc) to the river and during floods the river exports material across the river bank onto adjacent floodplain areas when the level of the water inside the river channels exceeds full bank storage. MRN can however be used independently of MOHID Land, as a standalone model. In that case this module imports results of the basin as point sources in the format of time series.

In MOHID Land, different processes occurring in a basin are programmed in different modules, allowing simulation of the desired ones only. The processes simulated, depicted in Fig. 1, can be 2D overland flow, 1D drainage network transport, and 3D infiltration and saturated and unsaturated porous media transport.

Due to this structure, MRN can be used as a standalone model, importing basin material as point sources in the format of time series, or integrated into MOHID Land where the interactions between the different processes (e.g. water exchange between aquifer and MRN) are calculated dynamically by the model, using hydraulic gradients. In this case, each node in the drainage network corresponds to a cell in the grid used by the other compartments, where there is flow exchange.

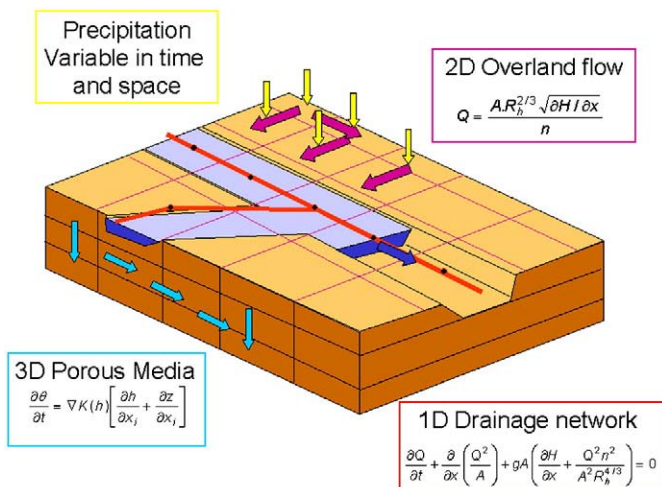


Fig. 1. Schematic representation of MOHID Land modules for hydrodynamic calculus.

MOHID Land was developed within three EU projects: EcoRiver, TempQsim and ICRew for the simulation of water flow in watersheds with pathways for river and groundwater flow. Porous media module was developed in close collaboration with soil scientists from EAN-INIA (Portuguese National Agronomic Station).

This paper begins with a description of MRN model (Section 2) presenting its main equations (Section 2.1) and how they are handled by the model (Sections 2.2 and 2.3), specific processes formulation, such as water quality, sediment dynamics, pools and transmission losses along river channels, and coupling to run-off models (Sections 2.4 to 2.7). Next, verification examples are presented in a schematic river and in a real long term simulation of the Trancão basin (Section 3), followed by the main conclusions (Section 4).

2. MRN model description

2.1. General description of MOHID

The MOHID Water Modelling System (www.mohid.com) has been constructed using an object oriented approach to facilitate integration of new processes and models. The numerical algorithms are based on the finite volume approach, a flux-driven strategy that facilitates the coupling of different processes and allows conservation of mass and momentum.

MOHID is programmed in ANSI FORTRAN 95, a language where object creation is not achieved by class instantiation but through module instantiation (Braunschweig et al., 2004). Since the start of MOHID, more than 72 modules with over 300 k codes lines have been written. Further developments can take advantage of these existing modules, limiting the requirements for new coding. The hierarchical structure of the MOHID framework is presented in Fig. 2. The lower level models (Base 1) are grid independent (i.e., 0D or 1D) and produce the MRN and Water Quality models (executables in the figure). The Base 2 modules are grid dependent and produce among others, MOHID Surface water model, which can be 2D or 3D, and MOHID Land, which is 2D for runoff and 3D for porous media processes.

MOHID I/O formats are in the form of time series at a given point (ASCII files) and/or matrix data in HDF5 binary format. There are several tools to produce, convert to and from, and to visualize these files, such as MOHID GIS and MOHID GUI (Braunschweig et al., 2005). These interfaces can use the Triangulation, TidePreview and Digital-TerrainCreator executables in Fig. 2.

In the case of MRN, the model needs an ASCII file of the drainage network, time series of arbitrary time step of solar radiation, air temperature, cloud cover, relative humidity and wind speed for the run period. The drainage network consists of nodes and reaches and can be constructed from the digital elevation model with MOHID GIS. Point discharges, pools and time series outputs can be specified along the network. For every point discharge, flow, temperature or constituents can be either constant or given as external time series. Variables initialization and needed parameters (e.g., growth rates, half saturation constants) for the sub models can be either specified in ASCII files by keyword/value pairs or left to the default value preset in the model.

The next sections describe the equations solved by the MRN to model fluid flow (continuity and momentum) and the fate of water constituents, by means of transport, reactions with other constituents (water quality processes), erosion and deposition to river beds and accumulation in pools.

2.2. Governing equations of MRN

Fluid flow is governed by conservation equations for mass, momentum, energy and any additional constituents. The numerical algorithm is based on the finite volume approach and for that reason equations are presented in their integral form. Following this strategy

Download English Version:

<https://daneshyari.com/en/article/4431988>

Download Persian Version:

<https://daneshyari.com/article/4431988>

[Daneshyari.com](https://daneshyari.com)