Modularity in integrated catchment modeling covering different time-scales

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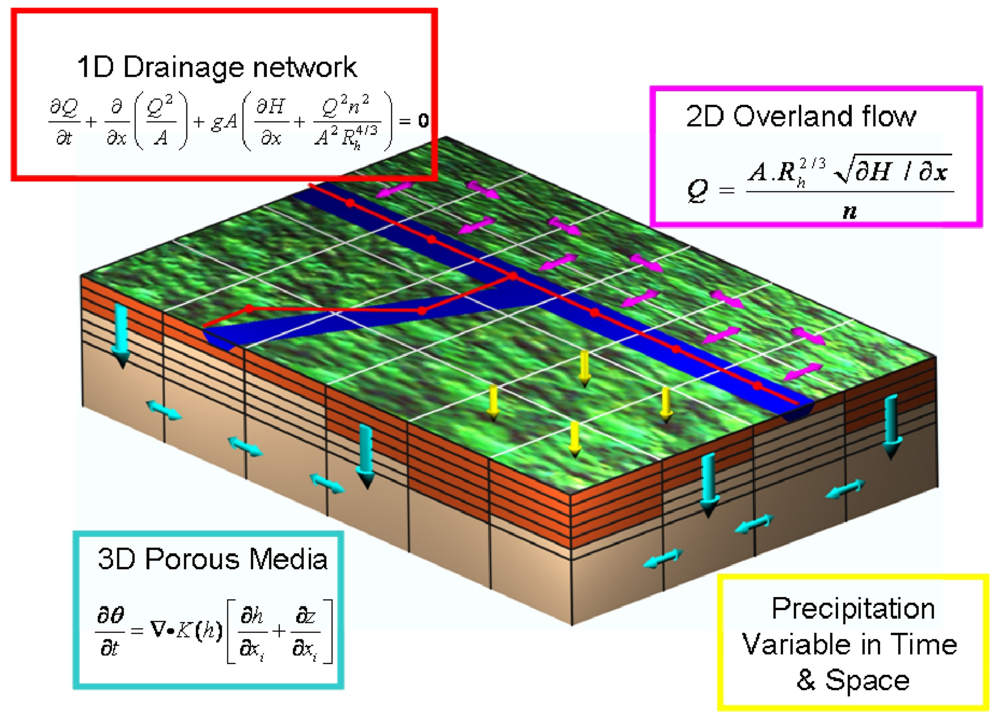
INTRODUCTION

The majority of existing catchments models are either designed to be used as basin management tools or as event based models. Models of the first type usually use lumped approaches to characterize the processes occurring in catchments and work over hydrological response units or similar structures. Models of the second type are called physical based distributed models (PBDM). Due to limitation of available computer power and due to internal time stepping PBDM are usually not suitable to be used for long term simulations.

Mediterranean catchments provide further challenges in terms of simulations:
? long dry periods without runoff;
? extreme first-flush events;
? formation of pools and flow interruption;
? water quality and sediment quality processes influenced by expansion and contraction dynamics in the channel bed.

This poster describes the methodology adopted in the development of the integrated catchment model MOHID Land, integrated into the Water Modeling System MOHID (WMS - MOHID), allong with some ongoing aplications.



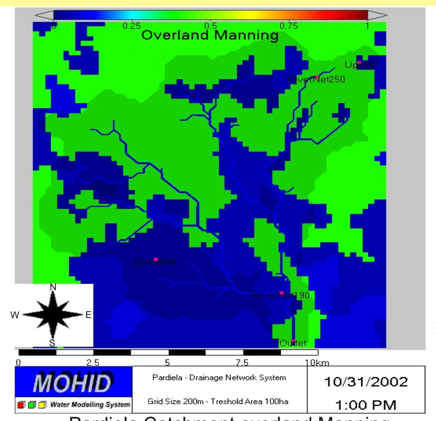
In order to solve all the above mentioned challenges and keep at the same time the model suitable to carry out long term simulations the model must be able to solve efficiently events of short duration and long periods where the system is rather "un-dynamic". For this MOHID Land uses a dynamic time stepping.

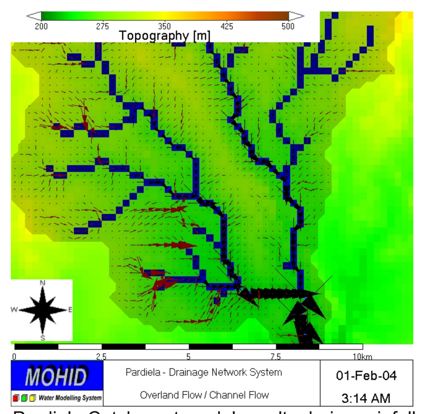
MOHID Land computes water, sediments and properties transport in a watershed, using finite volumes. The core modules of MOHID Land which simulate the hydrological cycle are:
(i) a module for 2D overland flow,
(ii) a module for 1D river flow (kinematic wave, or the complete St. Venant equation),
(iii) a module for 3D unsaturated flow by solving Richards equation and
(iv) a module for 2D saturated flow.

Evapotranspiration is considered in the model as a dynamic boundary condition and is computed as a function of the potential evapotranspiration.

The in stream water quality can be simulated using different water quality modules: (i) a WASP like module, (ii) the CE-QUAL-W2 module or (iii) a module based on the model ERSEM.
Current applications include four different catchments in the scope of three European projects, TempQSim, ICReW and Ecoriver.

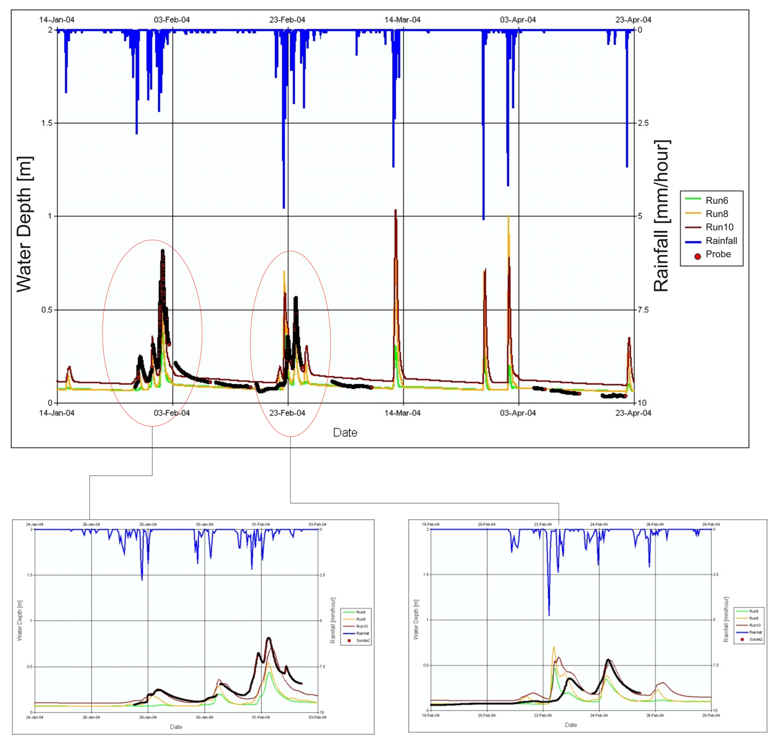
TempQsim http://www.tempqsim.net/


Pardiela Catchment overland Manning Parametrization


Pardiela Catchment model results during rainfall event (overland and channel flow)

The in-stream part of MOHID Land (Module Drainage Network) is developed within the TempQsim project.
Goals of TempQsim are the evaluation and improvement of water quality models for application to temporary waters in Southern European catchments.

To achieve these goals, module Drainage Network contains the following temporary waters specific feature:
(i) Formation of pools,
(ii) Wetting and drying of channels,
(iii) Contraction and expansion dynamics and
(Iv) Transmission losses.
Graphics show the model output against stream gage measurements with different parameterizations for the channels Manning roughness factor.
These measures are from the pardiela catchment (90 km2) located at the south of Portugal, one of TempQsim study sites
Module drainage network was also coupled to SWAT model.
This coupling allowed Drainage Network with run-off and underground discharges (and associated nutrient concentrations) obtained from Swat.



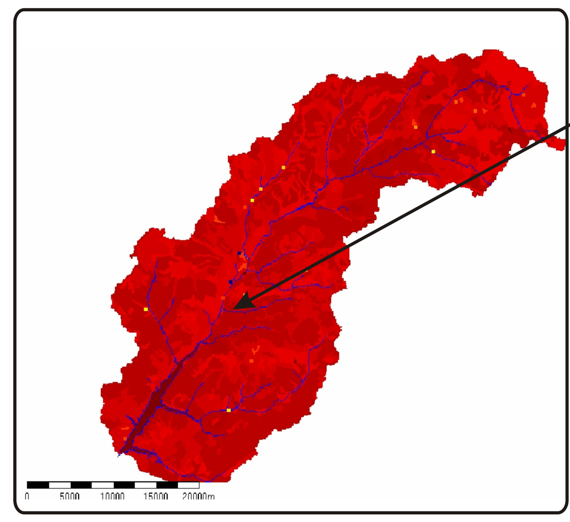
Run 06 – Manning Channels = 0.03, Rain Constant in Space
Run 08 – Manning Channels = 0.03, Rain Variable in Space
Run 10 – Manning Channels = 0.06, Rain Variable in Space

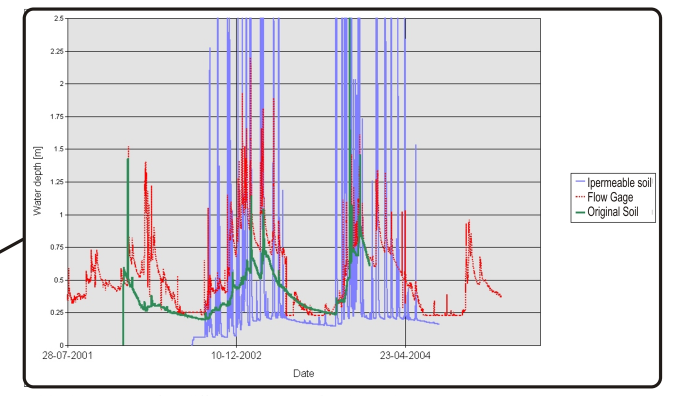
ICReW http://www.icrew.info

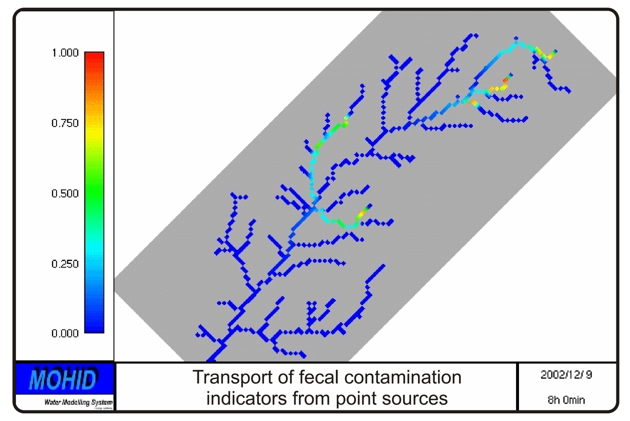
ICReW is an Interreg IIIB funded projects aiming to improve recreational waters, and help deliver the new bathing water directive.

MOHID Land is used in this project has a delivery model for both Portuguese study sites (a reservoir with bathing potential and a small beach). The reservoir is situated close to Montargil in the center of Portugal and is supplied by a watershed with an area of 1180 km2.
Both water routing and bacterial indicator transport is done with MOHID Land.
Modeling of the reservoir is done with MOHID water coupled to CEQUALW2 water quality model. Basin loads of nutrients are obtained coupling SWAT model to Mohid Water.

These graphics represent the model sensitivity to soil types, varying from a situation with practically no base flow to a situation where the base flow is very similar to what was recorded by an automatic flow gage station located at the entry of the reservoir.

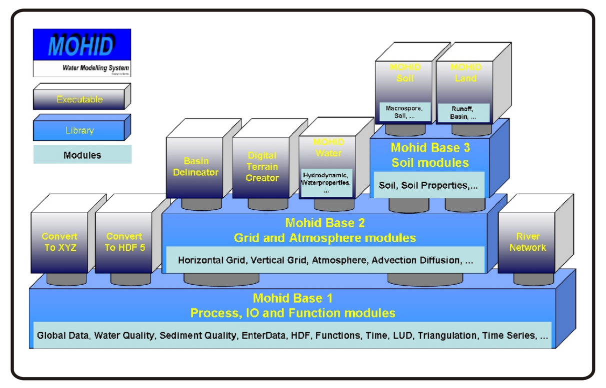

Watershed configuration, highlighting the reservoir, land use and point sources

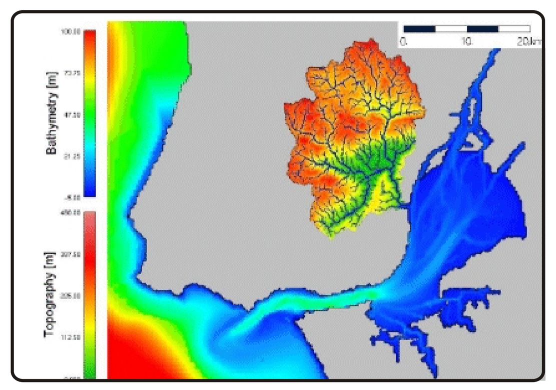

Model results for different types of soil against stream gage measurements


Transport of fecal contamination indicators from point sources

Numerical Tools Overview

MOHID is a water modeling system, developed by MARETEC (Marine and Environmental Technology Research Center) at Instituto Superior Técnico (IST) - Technical University of Lisbon.
Initially the MOHID modeling system was composed only by MOHID water, a three-dimensional numerical program to simulate surface water bodies (oceans, estuaries, reservoirs).
Recently MOHID Land, a watershed modeling program was developed.
The layered, object oriented structure of the code allows the adoption of an integrated modelling philosophy.
The integration of MOHID different tools, (MOHID Water, MOHID Land) can be used to study the water cycle in an integrated approach.

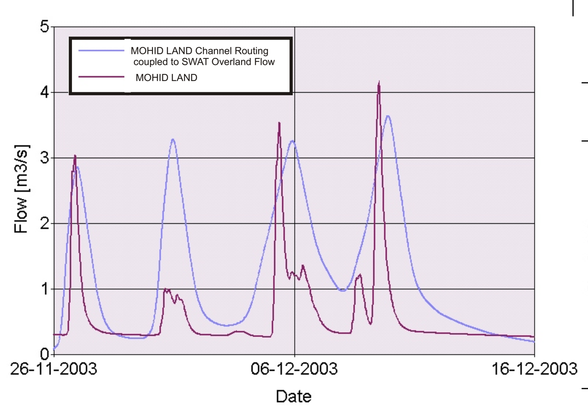

MOHID Framework Structure

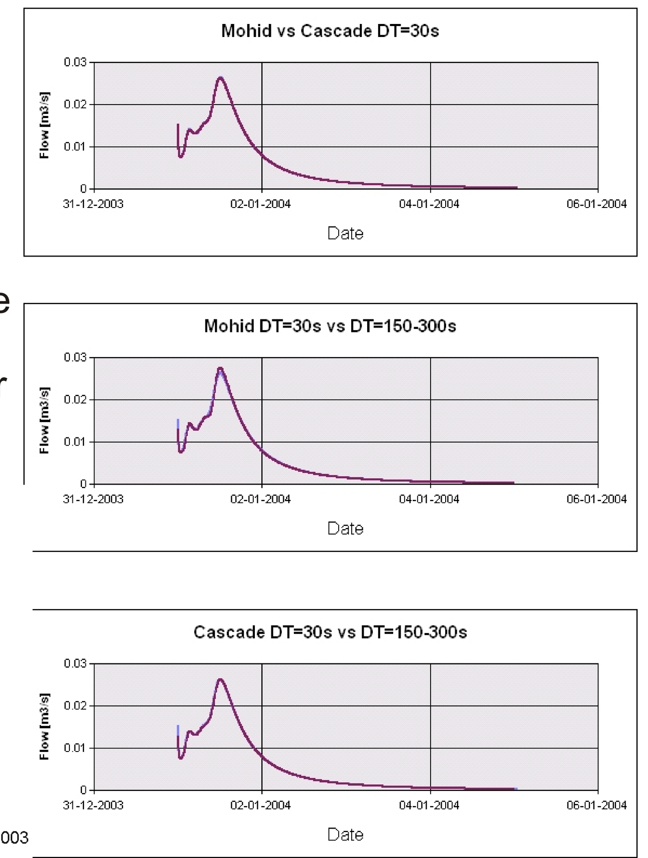

Integrated Trancao Basin / Tagus Estuary System

Overland flow and Routing

MOHID Land solves river flow with the complete St. Vernant Equation (needed if back-water effects are to be consiered) or with the kinematic wave simplification.
Initially an upwind - explicit algorithm was implemented for the kinematic wave simplification.
During the TempQsim project the Cascade model algorithm (four point implicit) was also coupled to MOHID Land. The graphics on the rigth show results with both methods for diferent time steps.
For overland flow the diffuse wave equation is solved to obtain water exchange between surface cells according to slope and a resistance factor (overland Manning).

The graphic below compares flow results using this aproach withSWAT model outputs.
Both flows where suplied to MOHID Land stream network for routing.

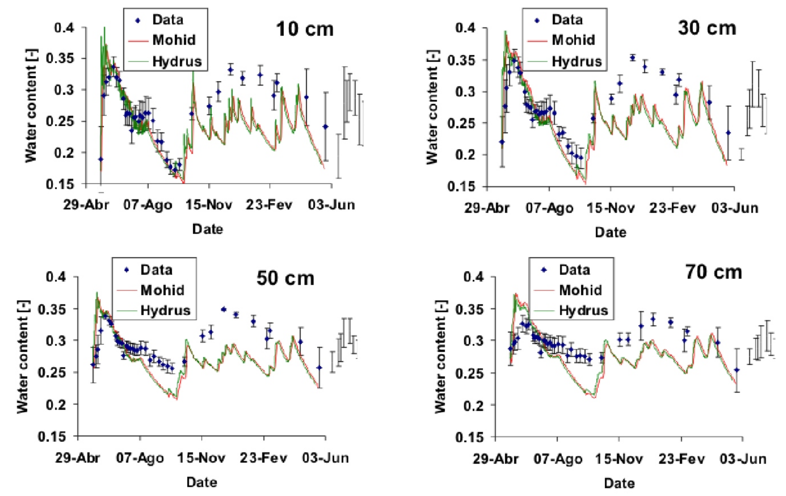




Subsurface Processes

MOHID Land solves Richards equations to obtain infiltration and redistributions of water. Water in the vadose zone is exchanged with streams and the aquifer.
These graphs show the results of a field experiment where the water content, at several depths, of variably saturated soil blocks where monitored with TDR probes.

Water variations in the vadose zone where modeled with both MOHID Land vadose zone model and Hydrus. It is possible to see that both Mohid and Hydrus models give the same results. Differences between modeled results and measures are related with experimental difficulties in controlling weed development in monoliths.
More recent results allowed calibration and validation of models for this experimental site.



TDR PROBES

Conclusions & future work

MOHID Land implementation of the hydrologic cycle is complete and is currently being applied and calibrated in catchments that range from 90 km2 to 1180 km2 with promising results. The modular object oriented structure of MOHID framework has proven successful in integrating different time scales and processes.

Future work will include overland and subsurface production and transport of nutrients. This will allow MOHID Land to produce dynamic loading for instream water quality models already coupled to MOHID. Currently these loading can be suplied using the swat model. This formulation in currently being used on both TempQsim and ICReW projects.