Modeling interactions between surface water and the unsaturated/saturated zone

Iacopo Borsi (*), **Rudy Rossetto** (**) and **Claudio Schifani** (***)

(*) University of Firenze, Dept. of Mathematics, Viale Morgagni 67/A, 50134 Firenze, Italy (borsi@math.unifi.it)

(**) Scuola Superiore Sant'Anna, Land Lab, Via S. Cecilia 3, 56127 Pisa, Italy (r.rossetto@sssup.it)

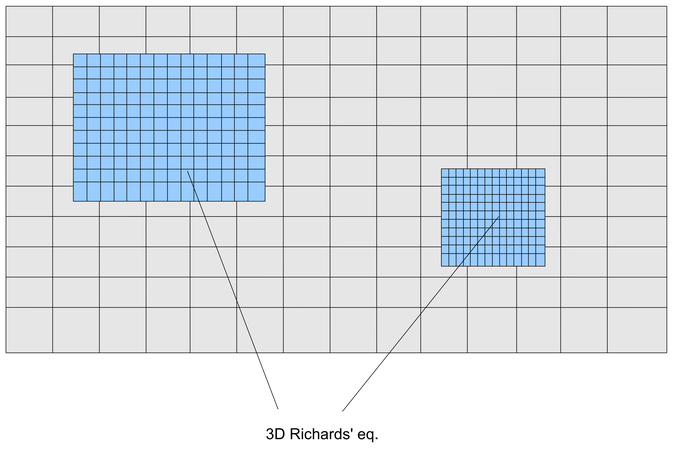
(***) Istituto ISTI – CNR, Via G. Moruzzi 1, 56124 Pisa, Italy (claudio.schifani@isti.cnr.it)

REGIONE TOSCANA — UNIONE EUROPEA Fondo sociale europeo — MINISTERO DEL LAVORO E DELLA PREVIDENZA SOCIALE Direzione Generale per le Politiche per l'Orientamento e la Formazione — POR FSE 2007-2013

The research project **SID&GRID (Simulation and hydroinformatics systems for water resources management)**, started April 2010 and financed by Regione Toscana (Italy) under the POR FSE 2007-2013 programme, will develop a watershed-scale model able to simulate surface and subsurface flow in a three-dimensional domain based on open source and public domain solutions (Rossetto et al., 2010). The model will be structured by integrating **MODFLOW2005-LGR** (Mehl and Hill, 2005) with a new version of **MODFLOW2000-VSF** (Thoms et al., 2006). While the first one allows for local refinement of the grid, the latter allows 3D simulation of the unsaturated zone using Richards' equation. Considering a large scale model will then be possible to define sub-models (*child models*) linked to the parent one by rewriting the boundary conditions: this will allow the level of detail required to simulate 3D unsaturated flow at scale up to 25-50 km^2. In larger areas, the unsaturated zone will be solved using the simplified 1D approach based on the kinematic wave approximation by means of the UZF package (Niswonger et al., 2006). Within the framework of the above-mentioned codes, modules have been developed or modified to attain simulation of all the main processes of the hydrological cycle. Current research activities focus on defining groundwater recharge to the aquifers by simulating canopy interception, evapotranspiration, ponding, surface runoff, interflow, and surface-/ground-water interactions.

Local Grid Refinement to solve 3D Richards' equation

We extended the *Local Grid Refinement* capability of MODLFOW-2005 to the VSF Package (Variable Saturated Flow), available only for MODFLOW-2000. It allows to solve the complete 3D Richards' equation only on particular zones of the domain, guaranteeing both the good accuracy of the solution and a realiable simulation time. In the coarse problem, the unsaturated zone is considered by solving the 1D Richards' equation (i.e. only vertical coordinate is accounted for) making use of the kinematic wave approximation (package UZF in MODFLOW-2005, Niswonger et al., 2006).

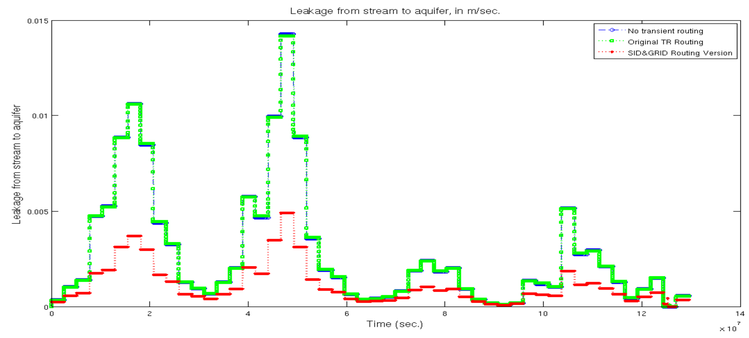


Net rainfall rate

New subroutines have been developed to account for **canopy interception**: this will be divided in wet **canopy evaporation** and cumulate throughfall and stemflow rates. In each time step, these quantities will be computed to get net rainfall rates reaching the soil surface.

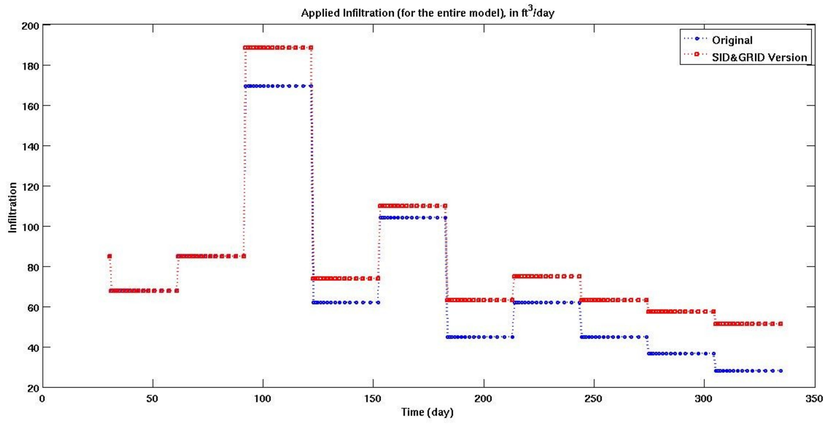
Surface-/ground-water interactions

A new algorithm was developed to compute ***stream flow routing*** in open channel and, in turn, to estimate the ***leakage flow*** between stream beds and aquifers. The new module is based on the numerical solution of the 1D Saint-Venant equation, in which the leakage flow is considered as a source term for the equation itself. Such procedure (widely used in other codes, like PARFLOW-CLM, Maxwell and Miller, 2005) has been implemented in a new version of the MODFLOW SFR2 package (Niswonger and Prudic, 2005).
The preliminary tests show a coherent behaviour of the solution.



Cascading flow

Cascading flow process has been upgraded, both in UZF and in VSF packages, by means of a new algorithm to compute at each time step the redistribution of the excess flow for each cell of the model in condition of soil saturation, considering cell slope and its exposure.



REFERENCES

• Mehl S.W. and Hill M.C., 2005. MODFLOW-2005, The U.S. Geological Survey modular ground-water model—Documentation of shared node Local Grid Refinement (LGR) and the Boundary Flow and Head (BFH) package: U.S. Geological Survey Techniques and Methods 6-A12, 78 p.
• Maxwell R. M. and Miller N. L., 2005. Development of a coupled land surface and groundwater model, J. Hydrometeorol., 6(3), 233 – 247
• Niswonger R.G. and Prudic D.E., 2005. Documentation of the Streamflow-Routing (SFR2) Package to include unsaturated flow beneath streams—A modification to SFR1: U.S. Geological Survey Techniques and Methods 6-A13, 50 p.
• Niswonger R.G., Prudic D.E. and Regan, R.S., 2006. Documentation of the Unsaturated-Zone Flow (UZF1) Package for modeling unsaturated flow between the land surface and the water table with MODFLOW-2005: U.S. Geological Survey Techniques and Methods 6-A19, 62 p.
• Rossetto R., Borsi I., Schifani C., Bonari E., Mogorovic P., Primicerio M., 2010. SID&GRID: hydroinformatics system for the management of the wateresource. Società Geologica Italiana 85° Congresso Nazionale, Bonaccorsi E., Carmina B., Marchetti D. and Pappalardo M. (Eds.), Rendiconti Online Società Geologica Italiana. Vol.11/2010, n. 1.
• Thoms R.B., Johnson R.L. and Healy R.W., 2006. User's guide to the Variably Saturated Flow (VSF) Process for MODFLOW: U.S. Geological Survey Techniques and Methods 6–A18, 58 p.

Please, follow our work at the website **http://sidgrid.isti.cnr.it**

European Geosciences Union
General Assembly 2011
Vienna | Austria | 03 – 08 April 2011