Implementing and evaluating a surface-subsurface flow and reactive solute transport model at the hillslope scale.

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Pesticide use in agricultural watersheds leads to an important surface and subsurface water contamination in France. Awaiting a deep evolution of agricultural practices and a sustained decrease in pesticide use, it is of interest to limit transfers form agricultural fields to rivers. A deepen knowledge of processes at stake and their potential interactions is made possible with large field databases, or with physically-based modeling. Physically-based models are built on mechanistic equations and are able to represent the processes and the physics observed on the field if the system is well described. Integrated surface and subsurface hydrologic models (ISSHM) are complex models taking into account the major water pathways and their interctions. Two ISSMH intercomparison studies from Maxwell et al. (2014) and Kollet et al. (2017) show that models such as CATHY (Camporese et al., 2010), HydroGeo-Sphere (Brunner et al., 2012), and Parflow (Kollet 2006) share many common features. Their behaviours in simulation on virtual and real hillslope are coherent. However, they de not use the same surface-subsurface coupling strategies and include solute transport with various complexity levels. The coupling strategy of CATHY is based on the switching boundary conditions regarding to the situation of each surface cell at each time step. It has been proved to be very efficient and able to correctly represent water flow interactions between surface and subsurface (Sulis et al., 2010 ans Guay et al., 2013).

Recently, reactive solute transport has been implemented in the CATHY model (Weill et al., 2011 and Gatel et al., 2017 *submitted*). In the present work, the surface-subsurface switching procedure for solutes is improved in order to achieve a better mass conservation, and a mixing module is implemented to represent the solute mobilisation from the top soil to surface runoff. The new coupled model named CATHY-Pesticide is evaluated for an intense rain event on an experimental vineyard hillslope. The hillslope is characterized by important surface-subsurface interactions (see Figure (a)). The hillslope is composed of a 125 m long vineyard and downslope, a 25 m long bufferstrip. Four transerval ditches on the fields collect and redirect surface runoff to the buffer strip.

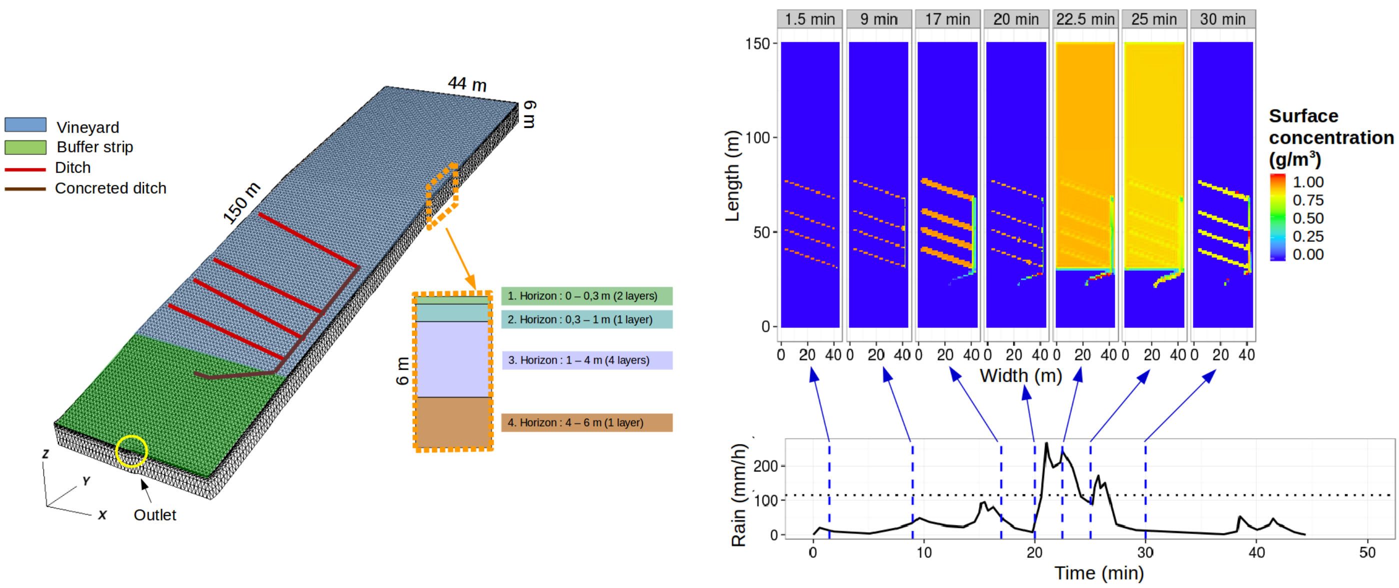

__Figure__ : (a) Model setup of the experimental hillslope. (b) Concentration in surface runoff of tebuconazole during a rainfall event (right).

Simulation was performed with two pesticides with various adsorption coefficient, tebuconazole (Kd : 109.8) and diuron (Kd : 8.6), according to the field study of Randriambololohasinirina, 2012. Figure (b) shows the evolution of tebuconazole concentration in the surface-subsurface model. The influence of the new implemented mixing module can be observed : at initial conditions, some solutes are only present in the subsurface and solute transport via surface runoff occurs during the event due to remobilisation from subsurface to surface and to surface adsorption. During the intensity peak of this short rain event, the vineyard soil fail to infiltrate all water and the whole vineyard area produces runoff (t = 22.5 min and t = 25 min). Results analyses on surface runoff and subsurface solute transfer behaviour show a good match with field data and the mass conservation is very accurate despite the complexity of the processes.

As a second step, a global uncertainty and sensitivity analysis is conducted on a simplified version of the hillslope (without the ditches representation). The uncertainty effect of input parameters on the mass balance and the variation of subsurface mass solute and water volume is evaluated on a large Monte-Carlo sampling. The sensitivity analysis performed with the Sobol method (Sobol, 1993 and Saltelli et al., 2008) allows to quantify the effect of each factor on surface and subsurface transfers (from vineyard to the bufferstrip and at the outlet) and on the mass balance. The analyses of 17000 simulation results highlights the significant influence of saturated conductivity, porosity, and the *n* parameter of the retention curve.

CATHY-Pesticide has been evaluated with various methods, the model is a robust and able to reproduce observed data. Even if some complementary processes such as subsurface preferential transfers and surface sedimentary transport are still missing in the model, CATHY-Pesticide is able to properly represent coupled surface and subsurface transfer ways at the hillslope scale.

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