FINAL REPORT PROGRAM LEFE

Program LEFE/ MANU	ADIMAP = Assimilation of remote sensing images and in situ data in a pesticide transfer model	Years 2015 – 2016

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Context: pesticide transfer issues and challenges

Controlling and reducing surface water contamination by pesticides is a major issue for the protection of surface and groundwater resources and of aquatic flora, fauna, and biodiversity. To achieve the ”good status” of rivers in Europe required by the Water Framework Directive, modeling tools are necessary to help in the management of pesticides applied in agricultural watersheds. Pesticide transfer can be accelerated or slowed down depending on landscape features, distribution of plots, and spatial and temporal distribution of pesticide applications. Since pesticides interact strongly and nonlinearly with the environment, it is essential to understand the flow paths in the surface and subsurface domains. Modeling should thus take into account all watershed characteristics, in particular soil properties, to help describe properly the risk of contamination of surface water.

Physically spatialized models that solve the surface and subsurface flow and transport equations make it possible to represent in fine detail water and pesticide fluxes at any point within the spatial discretization of the system. However, these distributed models depend on a large amount of spatialized parameters that render their practical application difficult. The different processes related to hydrology and pesticides interact in the surface and subsurface and are highly non-linear. Input parameter setting is a complex step and difficult at that scale, due to the high heterogeneity of the system (saturated hydraulic conductivity, humidity, rugosity, etc.) and the uncertainty on many parameters. For example, physico-chemical properties of molecules (adsorption, degradation, etc.) play a key role in their transfer pathways, but they are poorly known in the field and very difficult to measure. The process-based, hydrologic model of coupled surface-subsurface flow CATHY (CATchment Hydrology, Camporese et al., 2010) was recently extended to reactive solute transport and evaluated in detail through a global sensitivity analysis (Gatel et al., 2017).

Data assimilation in the CATHY-pesticides model

To help parameterize this type of model, data assimilation methods that combine all of the available information (physical model, data, associated errors) to estimate the input parameters and correct the model can be used. Data assimilation techniques have only very recently been applied in detailed process-based hydrological modeling and even more rarely for pesticide transfer. In this study, we develop a Kalman Ensemble data assimilation scheme in order to estimate spatialized model parameters and to evaluate the impact that a more detailed parameterization has on pesticide transfer.

The data assimilation scheme should pay a special attention to the spatial properties of remote sensing images. Indeed, satellite imagery can potentially be very useful to help overcome the lack of spatial information for the model, due to the highly detailed spatio-temporal information they provide, but they are most often under-exploited by considering pixels as single data [6]. For example, classical DA approaches don’t consider correlated noise on observations, defining the observation error covariance matrix as diagonal. This simplified representation makes the numerical resolution easier and can be valid for independent sensors, but images from a same satellite sensor are necessarily affected by spatially correlated errors. This study is a first step to prepare for a larger project that aims at developing coupled DA into pesticide transfer modeling, providing observation error covariance matrices adapted to spatially correlated errors, focusing on the observations operator description, and the definition of distances in the data assimilation scheme. The methodological development for pesticide modeling is tested on virtual data using twin experiments on a hillslope. The CATHY-Pesticide model setup will be based, however, on a real field experiment in the Beaujolais vineyard region, including a vineyard plot and a vegetative filter strip, in order to stay close to well-known conditions.

Main results:

On Figure 1 we can see concentration of a pesticide (tebuconazole) applied on the whole plot at different times of a short event. The product is first routed along preferential pathways through ditches that collect and drain water and sediments into a concreted pipe (on the right of the plot) out of the steep vineyard plot (25% slope), which is a typical practice in Beaujolais. These surface drains are then oriented to the vegetative filter strip that slows down the surface runoff and thus the pesticide fluxes and increase water infiltration and pesticides degradation. On this experiment, runoff pathway through the ditches and the concreted pipe is well represented. We observe that when the rain intensity exceeds the vineyard hydraulic conductivity, the whole vineyard surface generates runoff. The short event simulated on the hillslope reproduced quite well the observed dynamics of pesticide concentration at surface of the hillslope, but with significant delay. This first step of the project helped to build the twin experiments but also assessed the need to reduce uncertainty and to better estimate CATHY input parameters.

The second step of the project was to identify the most sensitive parameters of CATHY-pesticide to estimate with DA. A global uncertainty and sensitivity analysis was conducted on a simplified version of the hillslope (Figure 2). The uncertainty effect of input parameters on the mass balance and the variation of subsurface mass solute and water volume was first evaluated on a large Monte-Carlo sampling and showed the robustness of the model on input variations. The sensitivity analysis performed with the Sobol method (Sobol, 1993 and Saltelli et al., 2008) allowed 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 highlighted the significant influence of saturated conductivity, porosity, and the n parameter of the retention curve.

The GSA showed that first order influences spread between all parameters, but also a lot of interactions and large uncertainties associated to the total indices. CATHY-pesticide is definitely not an additive model. The complexity of the model is due to the complexity of the physics occurring (hydrology, surface, subsurface interactions and solute reactions). The most sensitive input parameters on pesticide fluxes are spatialized hydrodynamic characteristics and chemical properties and the DA scheme was implemented to estimate them on these twin experiments. First results of the DA scheme with Ensemble Kalman Filter were not satisfactory, due to the bad representation of spatial characteristics of observations error. However, this project allowed to prepare a very good basis for now developing the coupled DA scheme including image properties and a proper description of errors in the DA scheme. It shows that the complexity of real field conditions and of interactive processes such as surface/subsurface hydrology and pesticide transfer definitely needs sophisticated DA including spatial properties.

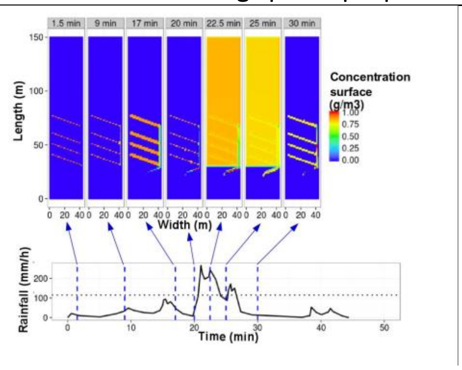

Fig. 1. Runoff dynamics over the hillslope: aerial view of tebuconazole concentration in the surface runoff during a short event

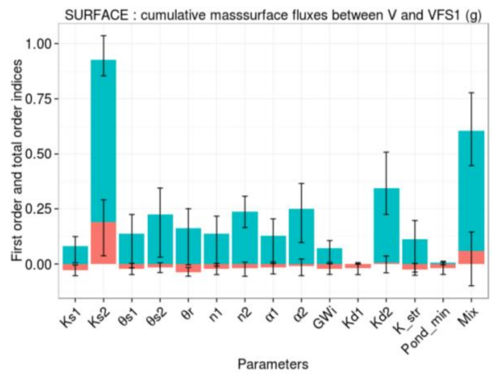

Fig. 2. Sobol Sensitivity Analysis of CATHY-Pesticide: first (red) and total (blue) indices on surface pesticide fluxes

Future of the project: CATHY-Pesticide has been evaluated with various methods, the model is robust and able to reproduce dynamics of 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. However, the need for a better description of observation error should help to better estimate the input parameters in the close future.

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