Data assimilation of image data into a spatialized water and pesticide fluxes model
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The Morcille (Beaujolais Region, France) is a small watershed with high risk of pesticide contamination:
- steep slopes (> 25%), 70% of vineyard
- permeable sandy soils
- continental climate with Mediterranean influence
- research on pesticides since 1985
- River quality and flow monitored between 2006 and 2011.

CATHY Hydrological model
Coupled surface/subsurface flow and transport [1-7]
- Richards eq. for variably saturated porous media:
  \[ S_w \frac{\partial \psi}{\partial t} + \frac{\partial S_w}{\partial t} \nabla [K_t(\psi + \psi_0)] + q_w \]
- 1D diffusive wave equation at surface:
  \[ \frac{\partial Q}{\partial t} + \frac{\partial Q}{\partial x} \frac{\partial Q}{\partial t} = D \frac{\partial^2 Q}{\partial t^2} + C_q \psi (h, \psi) \]
- Advection – dispersion equation
  \[ \frac{\partial C}{\partial t} = \nabla (D \nabla C) - \nabla (v C) + R \]
- Linear adsorption and first order decay
  \[ K_d = \frac{C_0 \psi}{\nabla} \]

First results with reactive solute transport

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( K_s ) (m/s)</td>
<td>5.9x10^{-6}</td>
</tr>
<tr>
<td>( K_c ) (m/s)</td>
<td>3.33x10^{-5}</td>
</tr>
</tbody>
</table>

DA for pesticide transfer modeling

Modeling pesticide transfer in a watershed is particularly complex:
- Very high heterogeneity of the system
- Many processes in interaction
- Few information on physico-chemical interactions of molecules
- Lack of data deep in the soil

\[ \text{research focuses on development of modeling in function of chosen processes to transfer} \]
\[ \text{DA would improve input parameters} \]
\[ \text{characterisation and pesticide transfer understanding.} \]

High spatial heterogeneity

Twin experiments
Simulation of virtual temporal series of surface water images with CATHY

Assimilation of images
- Usually, remote sensing data and sequences are under-used, though their content in information is very high (shapes evolution, correlations, ...)
- HR images would also help to identify the landscape elements (grass strips, hedges, ...)
- Classical approaches: uncorrelated noise, because the proper description and numerical manipulation of non-diagonal error covariance matrices is complex
- How to provide observation error covariance matrices adapted to spatially correlated errors? [2]
- Focusing on the observations operator description, and distances definition in the DA scheme

References:
[2] Pasetto et al. 2015 – assimilation of water content improved the parameter estimation of spatialised \( K_s \)

Which DA method?

Ensemble Kalman filter

\[ \begin{align*}
\frac{\text{state } x_{k-1} - x_k}{\nabla} &= \text{CATHY} \\
\text{obs } y_k - y_{k-1} &= \text{OBS.} \\
\text{or } x_{k-1} - x_k &= \text{MONTE CARLO}
\end{align*} \]

4DVar

In classical approaches: uncorrelated noise, because the proper description and numerical manipulation of non-diagonal error covariance matrices is complex
- would allow testing many more situations to help estimate the input parameters for the hydrological part of CATHY
- would reduce uncertainty for the pesticides transfer part
- no need for expensive Monte Carlo estimation, as long as the adjoint model coded.

Nudging / BFN: to consider?
- the poor man’s data assimilation method", very simple to implement but can be very efficient (Paniconi et al., 2003)
- the weighting functions can incorporate prior knowledge about the spatial and temporal variability

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