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Combining water and pesticide data with coupled surface/subsurface hydrological modeling to reduce its uncertainty

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ISSHMs, uncertainty and data

ISSHMs, such as CATHY [1,2,3,4] simulate interactions between surface and subsurface hydrology and reactive solute transport. BUT:

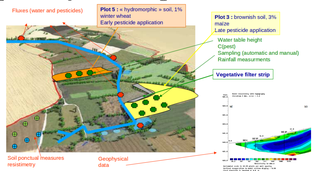
- based on non linear equations
- a large set of spatialized parameters
- many processes affecting pesticide transfer not (well) represented

⇝ **need for uncertainty quantification and reduction**

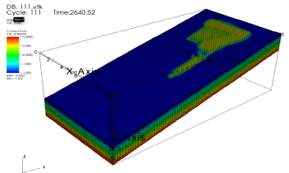
- in situ data on pesticides in a catchment are rare and heterogenous
- satellite images well describe data in space, but only water related

⇝ **very difficult to get the pesticides dynamics in situ**

Spatially heterogeneous data...



...and spatialized modeling



Coupled Data Assimilation techniques to:
- improve pesticide fluxes simulation
- estimate hydrological parameters
- reduce the uncertainty (interactions, lack of knowledge, ...)

The ISSHM: CATHY with pesticide transfer

- Richards eq. for variably saturated porous media :

$$S_w S_s \frac{\partial \psi}{\partial t} + \phi \frac{\partial S_w}{\partial t} = \nabla[K_s K_r (\nabla \psi + \eta_z)] + q_{ss}$$

- 1D diffusive wave equation at surface:

$$\frac{\partial Q}{\partial t} + c_k \frac{\partial Q}{\partial s} = D_h \frac{\partial^2 Q}{\partial s^2} + c_k q_s(h, \psi)$$

- Advection – dispersion equation

$$\frac{\partial C}{\partial t} = \nabla(D \nabla c) - \nabla(\vec{v} c) + R$$

- Linear adsorption and first order decay

$K_d = \frac{C_S}{C_W}$ $\frac{\partial C}{\partial t} = -\lambda C$

References

[1] Camporese, M. et al., 2010. 10.1029/2008WR007536 [2] Weill, S. et al., 2011. 10.1016/j.advwatres.2010.10.001 [3] Gatel, L. et al., 2019. 10.3390/w12010121 [4] Gatel, L. et al., 2019b. 10.1016/j.envsoft.2018.12.006 [5] Rouzies et al., 2019. 10.1016/j.scitotenv.2019.03.060 [6] Rouzies et al., 2022. 10.5194/egusphere-egu22-10384 [6] Emerick & Reynolds, 2013. 10.1016/j.cageo.2012.03.011

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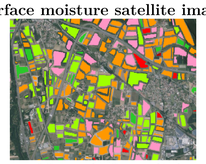
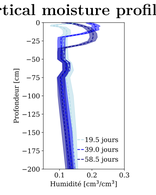
Multisource data on the Morcille catchment

Surface moisture satellite images



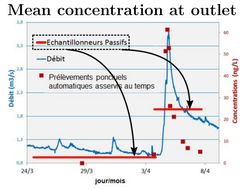
✓ Inversion of Sentinel1/Sentinel2 data (El Hajj et al., 2017)
✓ One value per plot
✓ Freq. = 6 days

Vertical moisture profiles



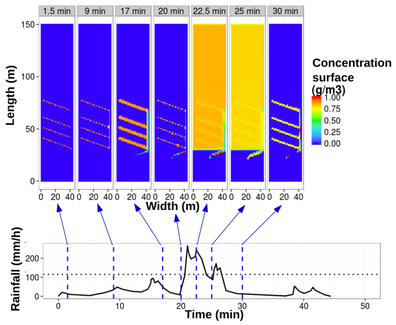
✓ TDR probe or ERT measures
✓ Ponctual (time and space)

Mean concentration at outlet



✓ Passive samplers for example
✓ Variable period of integration

Prior results with CATHY on a hillslope



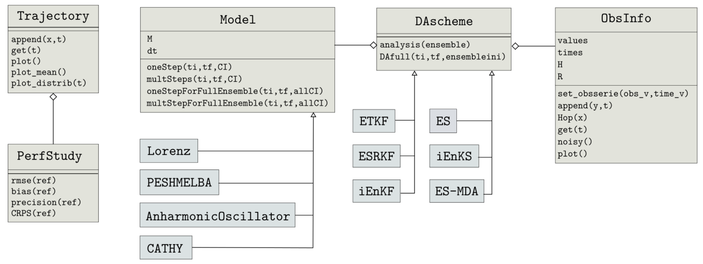
- Dynamics are reproduced, but significant delay
- Sensitivity Analysis showed high influence of hydrodynamic char. on solute transfer outputs [3,4]

⇝ Need to reduce uncertainty

⇝ Need to calibrate the spatialized hydr. characteristics

Tools for the DA methods

Implementation with the Python package PASHA



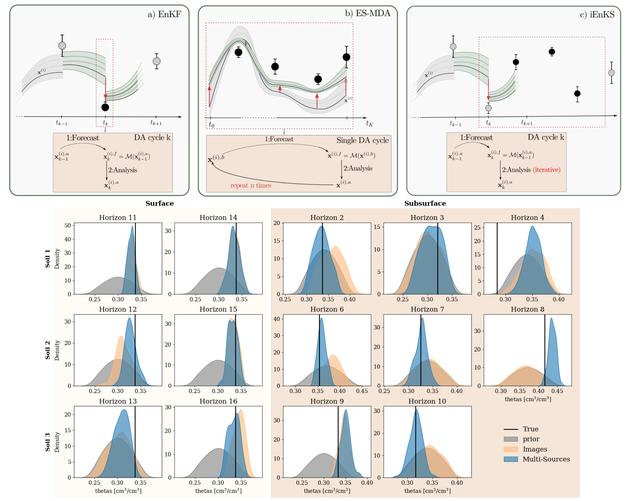
PASHA = PedAgogic StocHastic data Assimilation

`https://forgemia.inra.fr/emilie.rouzies/pasha/`

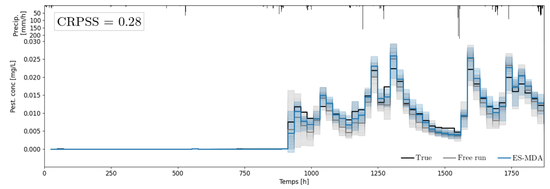
Results: First DA tests with a simpler model

The framework was tested on the PESHMELBA model, a modular, semi-conceptual model of hydrology and pesticide transfers at the catchment scale [4], on many DA methods [5].

⇝ **The most performant *in this context* is ES-MDA [6]**



- DA of **satellite surface moisture images** gives good correction of surface variables and parameters, but with a limited impact (or even negative) in the subsurface
- Adding **subsurface observations** improves moisture estimates at all depths on all plots of the same type
- Significant impact of assimilating **integrated concentration of pesticides** if data at high frequency (< 5 days) and accurate



⇝ **Strongy-coupled DA assimilation efficiently corrects pesticide concentration**

Conclusion

- Multisource DA with a simpler model proves the relevance on pesticide transfer
- Twin experiments provide answers to what can be estimated from which data, the sensitivity to obs. accuracy and frequency
- Next step : set the DA framework on CATHY : many challenges ! (setup CATHY on the whole catchment, handle high computation cost, etc.)